MICROSILICA MODIFIED CONCRETE FOR BRIDGE DECK OVERLAYS

Construction Report

FHWA Experimental Features
OR 89-03A, OR 89-03B, and OR 89-03C

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ABSTRACT

The objective of this study is to see if microsilica concrete (MC) is a viable alternative to the latex modified concrete (LMC) usually used on bridge deck overlays in Oregon. This study addresses five MC overlays placed in 1989 on Portland cement concrete (PCC) bridge decks at three sites.

At each site the first MC pours had the most problems, as the contractors had no experience with the product. Most of the later pours went smoothly.

On most of the problem pours, the mixes were either too stiff as delivered or they started to lose slump too early in the placement and finishing process. Consequently, the MC was hard to finish and a poor quality overlay resulted. Solutions to this problem were: using mixes with higher slumps, delivery of consistent mix to the jobsite, adding most of the superplasticizer at the jobsite rather than at the batch plant, and streamlining jobsite testing and mix adjustment.

If the mix was workable, the overlay could be mechanically finished. Otherwise, it was hand finished. Fogging was always needed.

Delamination and/or cracking was seen on some decks after several months of traffic. The cause of this distress is not known.

In conclusion:

1) Although the long-term durability of MC deck overlays in Oregon is not presently known, MC overlays were constructed in this study that had adequate strength, a smooth uncracked surface, and minimal delamination, the same as LMC. Many of the problems observed in this study may be prevented by using the February 1990 or later specifications. Consequently, further use of MC is recommended as an alternative to LMC.

2) Unlike LMC that requires mobile mixers at the jobsite and priming of the old deck; MC can be produced in an off-site batch plant, placed, and finished with tools and procedures normally used for conventional PCC. In some cases this may be an advantage over LMC.

3) The combined cost of furnishing and placing MC and LMC are similar, based on experience with the overlays in this study. The lower cost of furnishing MC is offset by higher construction costs.

4) MC overlays have higher initial skid resistances than typical LMC surfaces.

ACKNOWLEDGEMENTS

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DISCLAIMER

This report reflects the view of the author who is responsible for the facts and accuracy of the data. The contents do not necessarily reflect the official views or policies of the Oregon State Highway Division or the Federal Highway Administration at the time of publication.

The brand names in this report are essential to its content. This report is not a standard, specification, or regulation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 Background

Latex modified concrete (LMC) bridge deck overlays are used by the Oregon State Highway Division (OSHD) to add structural strength, provide a smooth and durable wearing surface, and seal the deck from the intrusion of de-icing agent chlorides.

Manufacturers of microsilica admixtures claim that microsilica concrete (MC) can be used as an alternative to LMC in deck overlays. In addition, suppliers state that MC can be mixed in batch plants, like Portland cement concrete (PCC). Batching LMC requires the use and added expense of mobile mixing plants at the jobsite. Furthermore, it is claimed that MC can be placed and finished in a manner similar to PCC.

1.2 Objectives and Scope

The objective of this study is to see if MC is a suitable alternative to LMC for structural deck overlays. The study covers the construction and short term performance of overlays on five bridges using MC containing Force 10,000^R microsilica slurry made by W.R. Grace, Inc.

This report covers the placement, finishing, and curing of the overlays. Also included are the post-construction evaluations of the following: resistance to shrinkage cracking, strength of the overlay-deck bond, skid resistance, and resistance to delamination. Available construction costs are also included.

Interim reports will be issued after the first and second year inspections, and a final report will be published after the fourth year inspection. These reports will address the overlay's maintenance needs and costs, skid resistance, and resistance to cracking, delamination, and rutting.

The sealing properties of MC are proven and are not evaluated in this study [1].

2.0 LOCATION AND MATERIALS

2.1 Overlay Location and Layout

The overlays are listed in Table 2.1, their locations throughout the state are shown in Figure 2.1, and the location of the pours on the bridge decks are shown in Figure 2.2.

Table 2.1: Overlay Listing

OSHD Bridge Number	Bridge Name	Dates of Pours	Highway	Milepoint	Number of Pours
9260B	Colestin Road Overcrossing Bridge	4/27/89 8/31/89 9/6/89	Pacific (OR #1 or US #I-5)	4.61	3
9184A	Neil Creek Road Overcrossing Bridge	5/11/89 9/14/89	"	10.34	2
7036	Holladay Street Ramp Bridge	4/29/89 5/6/89	Columbia River (OR #2 or US #I-84)	1.32	2
7040AA	Grand Avenue Ramp Bridge	9/9/89	"	.52	1
8498W	Westbound Meacham Overcrossing Bridge	8/3/89 8/9/89 8/10/89	Old Oregon Trail (OR #6 or US #I-84)	237.95	3

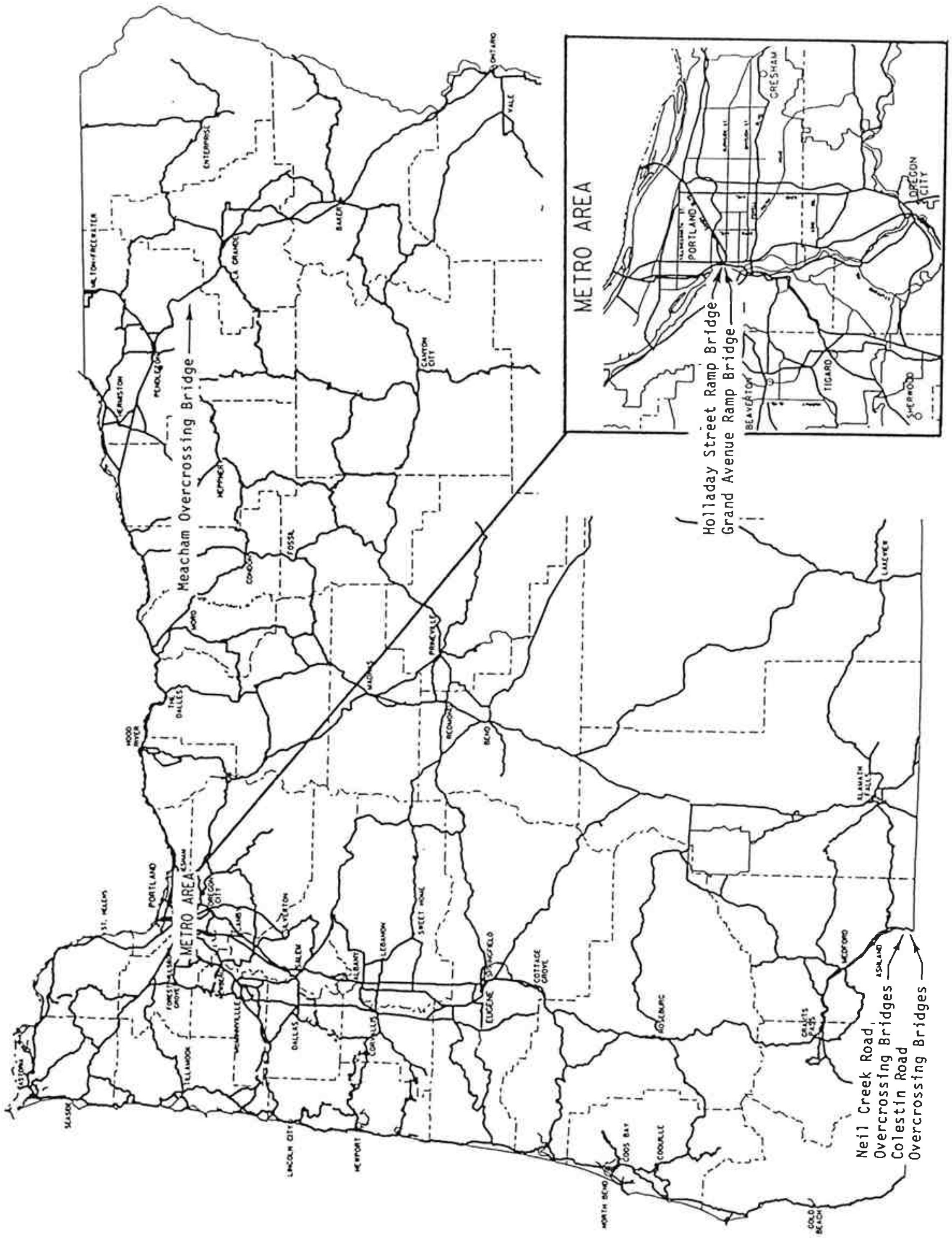

Figure 2.1: Overlay Locations

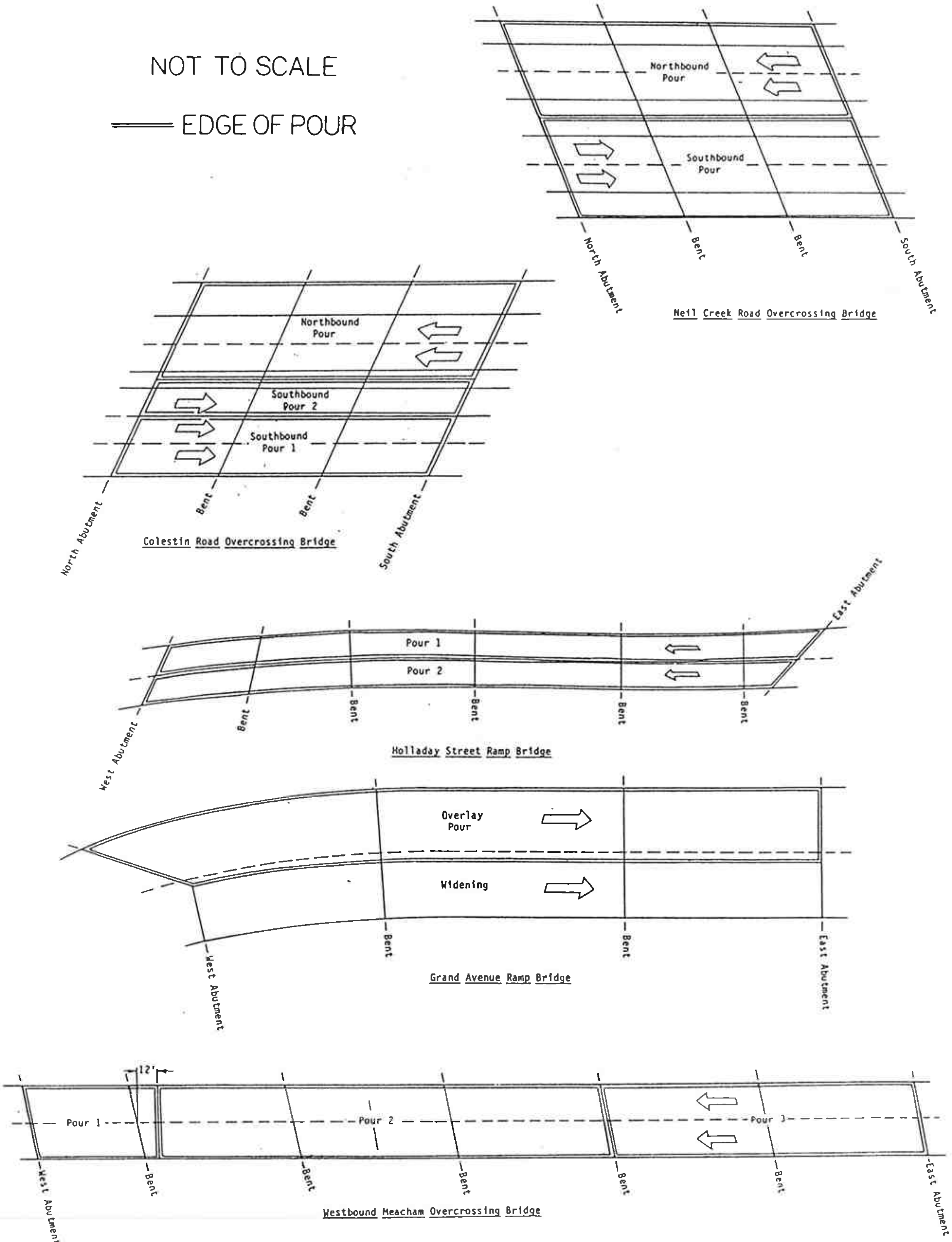

Figure 2.2: Pour Locations

2.2 Environment and Traffic

Climate and traffic data are summarized in Table 2.2 [2], [3].

Table 2.2: Environment and Traffic

	Colestin Road Bridge	Neil Creek Bridge	Holladay Street Ramp Bridge	Grand Avenue Ramp Bridge	Westbound Meacham Overcrossing Bridge
Elevation (feet)	4,275	2,565	125	65	3,740
Average Daily Temperature of Coldest Month (°F) (January)	30	32	41	41	28
Mean Daily Temperature Swing in January (°F)	14	14	11	11	14
Average Daily Temperature of Hottest Month (°F) (July)	63	64	66	66	63
Mean Daily Temperature Swing in July (°F)	31	32	23	23	32
Average Annual Precipitation (inches)	39	39	39	39	30
1988 Average Daily Two-Way Traffic (vehicles/day)	11,900	12,350	-	-	4,400[a]
Heavy Trucks (% of ADT)	32	32	-	-	39

[a]This bridge carried the full two-way traffic load during the first year after the overlay, as all eastbound traffic was detoured onto the structure. Normally, this bridge would have been under a one-way traffic loading of 2,200 ADT.

2.3 Materials

The microsilica slurry added to the concrete on this project was:

Force 10,000^{R} by
Construction Products Division of W.R. Grace & Co.
62 Whittemore Avenue
Cambridge, Massachusetts 02140
(617) 876-1400

The primary ingredient in this water-based slurry was finely powdered microsilica produced as a by-product from the manufacture of metallic silicon. The slurry was delivered to the batch plants in tanker trucks.

Other materials are listed in Appendix A.

3.0 CONSTRUCTION

Mix designs, construction quality control test results, and construction data are presented in Appendix A.

3.1 Deck Preparation

Colestin Road Overcrossing Bridge -
Neil Creek Road Overcrossing Bridge -

The decks of **all structures** were prepared for the overlay the day before the pour. A chain drag survey was made to detect delaminations. Using a rotomill, 1/4 to 1/2 inches of PCC was ground from the entire surface of each deck. Each deck was surveyed a second time for delamination. All distressed or delaminated concrete was removed using jackhammers. If reinforcing steel was exposed, 3/4 inches of concrete was chipped out around the bar. All concrete was chipped away from rusty reinforcement and the oxidized steel was sandblasted. Chipped areas were vacuumed and the decks were washed with water, covered with plastic sheeting, and kept wet until the pour.

Shallow delaminations were detected within the deck of **all structures** after rotomilling. This distress was not present before milling. Construction personnel suspect that rotomilling caused the delaminations.

The **Colestin** decks were the most distressed. Approximately 22% of the northbound deck and 15% of the southbound deck needed more extensive repair than rotomilling. One distressed area about two feet in diameter and extending completely through the deck was removed from the southbound span. This hole was patched with conventional PCC prior to the overlay. Otherwise, none of the additional chipping extended below one-half of the deck thickness.

The **Neil Creek** decks needed very little repair other than milling.

Holladay Street Ramp Bridge -
Grand Avenue Ramp Bridge -

On **all decks**, a 1/4 to 1/2-inch thick layer of the PCC was milled out of the entire surface. The decks were chipped by hand along the curbs where the rotomill could not reach. Chain drag surveys were made to detect delamination and none was found. The decks were cleaned with a high pressure water-sand slurry, washed with water, covered with plastic sheeting, and kept wet until the pour.

The entire **Holladay** deck was prepared the day before the north side was poured. This deck had the most cracking. The **Grand** deck was prepared a few days before the pour. This deck was slightly cracked and repairs were made on a small area of the span that was damaged when the deck was widened.

Westbound Meacham Overcrossing Bridge -

A 1/4 to 1/2-inch thick layer of PCC was milled out of the entire deck several days before the pour. Some deeper chipping was needed near the joints between the deck slabs. The surface was sandblasted clean and excess sand was blown off with compressed air. Next, the deck was washed with water, covered with plastic sheeting, and kept wet until the pour.

3.2 Pouring, Finishing, and Curing

Colestin Road Overcrossing Bridge -
Neil Creek Road Overcrossing Bridge -

The MC was batched by the Ashland, Oregon, plant of LTM Inc. of Medford, Oregon, and placed by the subcontractor, D.W. Thompson of North Bend, Oregon. The prime contractor was Ball, Ball, and Brosamer of Danville, California.

All overlays were placed by a Gomaco C450 paver using steel rails for grade control and a drag plate for leveling. The 1-1/4 to 2-inch deep overlays were placed directly by the paver. The deeper chipped areas were filled with microsilica concrete and vibrated by hand immediately before they were covered by the machine. The overlays were hand finished, hand tined, covered with curing compound, and kept wet throughout the seven day cure. The curing blanket was wet burlap covered by plastic sheeting which was held down by wooden boards.

The **Colestin N.B.** overlay was poured on April 27, 1989. The concrete was very stiff and sticky. Consequently, the mix tended to stick to tools, tear, and push during finishing. In addition, the finishers were inexperienced with this material and they could not keep up with the paver. The spray bar on the paver was used for fogging during the later stages of the pour. This fogging was stopped, as the spray bar applied too much water to the surface. Subsequently, water was fogged onto drier areas using a hose-end mister. This localized fogging worked well and was used on subsequent pours.

The **Neil Creek N.B.** overlay was poured on May 11. The overlay was fogged as needed to help finishing. The finishers were able to keep up with the paver.

During the **Colestin N.B.** and **Neil Creek N.B.** pours, it was noted that the microsilica concrete would lose slump and workability much more rapidly than conventional Portland cement concrete. This slump loss usually occurred about 80 to 90 minutes after batching. In some cases, the mix would lose about an inch of slump in the 15-minute period between the testing after the final additive additions and the pour. In order to retain the workability of the mix throughout the placement process, three changes were made when the southbound overlays were poured.

First, the maximum allowable water/cement ratio, air content, and slump was increased from .35 to .37, 7.0 to 8.0 %, and 7.0 to 8.0 inches, respectively [Table 3.1]. It was felt that these changes would allow for a more fluid and workable mix without sacrificing quality.

Second, only a small amount superplasticizer was added at the batch plant, and the bulk of this additive was added at the jobsite. On the previous pours, half of this additive was added at the batch plant. It was felt that the late addition of this material would help the mix retain its slump during placement.

Third, two, rather than one, quality control technicians made samples and tested the mix at the jobsite.

As in the previous pours, all of the set retarder and the bulk of the air entrainment agent was added at the batch plant.

The **Colestin S.B.** overlay was poured on August 31 and September 6, 1989, and the **Neil Creek S.B.** overlay was poured on September 14. Compared to the northbound overlays, the average microsilica concrete temperature of these later southbound pours was higher and the average time between mixing and placement was longer. However, the mixes were fluid and workable during pouring and finishing. The changes to the original mix design worked. A comparison between the northbound and southbound pour's water/cement ratio, air content, slump, concrete temperature, and mixing to placement time are summarized in Table 3.1.

Table 3.1: Differences in Mix Consistency, Temperature, and Placement Time Between Northbound and Southbound Pours
Colestin Road Overcrossing Bridge
Neil Creek Road Overcrossing Bridge

Test	Decks	Average Test Result	Limits Min.	Limits Max.
Water/Cement Ratio	Northbound	.34		.35
	Southbound	.34		.37
Air Content (%)	Northbound	5.1	4.0	7.0
	Southbound	5.7	"	8.0
Slump (in)	Northbound	5.9	4.0	7.0
	Southbound	7.0	"	8.0
Microsilica Concrete Temperature (^oF)	Northbound	67	50	80
	Southbound	76	"	"
Time: Batch to Discharge (min)	Northbound	66		90
	Southbound	75		"

Holladay Street Ramp Bridge -
Grand Avenue Ramp Bridge -

The MC was batched by Ross Island Sand and Gravel Co. and placed by the subcontractor, Aztech Industries, Inc. Both companies are based in Portland, Oregon. The prime contractor was Weaver Construction Co. of La Grande, Oregon.

All overlays were placed by a double roll Bid-Well paver using steel rails for grade control and a pan vibrator between the auger and the finish rollers. Just prior to the placement of the mix, compressed air was used to remove excess water from the deck surface. All of the Type A water reducer and one-half of both the superplasticizer and air entrainment agent were added at the batch plant. Drier sections of the overlays were fogged using a hand held hose-end mister to ease finishing, and an oversized pan was dragged behind the rollers to seal the surface. After finishing, the overlays were hand tined, covered with wet burlap and sheets of plastic, and kept wet throughout the cure.

Pour 1 of the Holladay deck was a 2 to 5-inch deep overlay of the north side placed on April 29, 1989. Attaining the proper slump was critical. If the slump was less than 6 inches, the mix piled up in front of the sealing pan. If the slump was greater than 7 inches, the mix tended to sag, as this deck has approximately 4% grade.

It was difficult to get the correct mix consistency, as the MC arrived at the jobsite far out of specifications in both air content and slump. Field adjustments were time consuming, as the concrete was very sensitive to the addition of superplasticizer. These delays caused concrete to be poured near the 90 minute batch to discharge time limit in the specifications.

Much of this mix lost slump too soon and was hard to finish. On this and the later pours, the mix stuck to the sealing pan unless the surface was fogged. This sticking caused a ridge to form near the edge of the panel where the pan reversed directions. In addition, large hand tools such as grout rods and long straightedges were hard to use, as the mix adhered to them.

Near the end of the pour, gusts of wind blew onto the fresh concrete. Although the front of the pour was quickly shielded with plastic sheeting, there were several small cracks where the wind blew across the fresh mix. These cracks were sealed with mix and they did not reappear after the cure. This 50yd^3 pour took about 9 hours.

The surface was covered with wet burlap and plastic sheeting that were held down by concrete reinforcing bar supports. These supports were removed after they started to sink into the pour. Thereafter, wooden boards were used.

Pour 2 of the **Holladay** deck was a 2 to 3-inch thick overlay of the south side placed on May 6, 1989. The **Grand** pour on September 9 covered the entire deck with a 2 to 3-1/2-inch thick overlay. Both of these pours went much faster, as two changes were made. First, the supplier used more experienced people in the batch plant, and the mix was more consistent when it arrived at the jobsite. As a result, fewer time consuming mix adjustments were needed in the field, and the finishing process was completed before the mix set. Second, after the mechanical finishing, the entire surface was bullfloated with smaller hand tools that are usually used on sidewalks. **Pour 2** of the **Holladay** deck was fogged constantly during finishing, whereas the **Grand** deck was fogged as needed. These two later pours went much smoother than **Pour 1** of the **Holladay** deck. The 40 yd^3 **Pour 2** of the **Holladay** deck took 3-1/2 hours, and the 23yd^3 of the **Grand** deck took 3 hours.

Westbound Meacham Overcrossing Bridge -

On this project, the maximum allowable water/cement ratio was increased from .35 to .37 by a change order before the overlay was poured. Experiences on earlier overlays indicated that a higher water content might make a more workable mix.

The MC mix was placed by the subcontractor, D.W. Thompson of North Bend, Oregon. The prime contractor was Acme Materials and Construction of Spokane, Washington. For **all pours**, the aggregate, sand, and water were batched at Collman Redi-Mix in La Grande and transported to Acme's batch plant in Meacham, where the cement and admixtures were added.

The 1-3/4 to 2-inch thick overlays were placed by a Gomaco C450 paver using steel rails for grade control. All of the Type A water reducer and the bulk of the air entrainment agent and superplasticizer were added at the batch plant. Final adjustments of these last two additives were made in the field. Two technicians were used for testing and W.R. Grace personnel added the additives.

The mechanical finishing used a pan dragged behind the finish rollers. Hand finishing was used to form the gutters along the pour edges and smooth over blemishes. Tining was done by hand and curing compound was used. The decks were kept wet for the seven day cure by burlap covered with plastic sheeting and held down by wooden boards and loose bridge railing. A hose-end mister was used to fog the surface during finishing, before the curing compound was applied, and before the wet burlap was spread.

Pour 1 was started at the north end of the bridge on August 3, 1989. The first four loads were rejected for being out of specifications. Set retarder was mistakenly added to the mix rather than superplasticizer. Loads five through seven were accepted. After load eight was rejected for high temperature, the pour was stopped and a night joint was made about 12 feet beyond the end of the first span.

A second pour was attempted on August 8. This pour was stopped after the first truck was rejected due to excessively high mix temperatures.

Pour 2 and **Pour** 3 were done on August 9 and 10, respectively. A complete substitution of ice for water at the batch plant kept mix temperatures down. A rain squall delayed finishing on the second pour, as the freshly finished surface was too wet to be tined or support the curing blanket without deforming. After this interruption, the covering process could not catch up to the laydown operation. On **Pour** 3, the last panel was not covered with curing compound due to equipment trouble. Otherwise, these pours went smoothly.

3.2.1 Compressive Strength vs Cure Duration

Six inch diameter concrete test cylinders of job mix were fabricated and tested under AASHTO T23-80 and AASHTO T22-82 guidelines. On the **Colestin N.B.** pour and **Pour** 1 of the **Holladay** deck, cylinders were tested after various cure lengths [Figure 2.3 and Appendix A]. Test results from both of these pours easily exceeded the OSHD strength requirements of 3,300 psi after a seven day cure.

3.3 Post-Construction Inspections and Repairs

Colestin Road Overcrossing Bridge -
Neil Creek Road Overcrossing Bridge -

All overlays were uncovered after curing and checked for delamination using chain drag surveys. Cores were drilled and bond tests were made. The concrete over the delaminations was chipped out and both these cavities and the core holes were filled with microsilica concrete. Cracks were sealed with Concresive 2075 methacrylate sealer.

After the **Colestin N.B.** overlay was uncovered, several isolated cracks were sealed and delaminated areas were repaired. All of these delaminations were between the old deck and the overlay. The cause of these unbonded areas could not be found. All bond tests were satisfactory.

After traffic was allowed on the structure for a few months, there was extensive map cracking over most of the deck. Most of the cracking was over areas that were not fogged during finishing. In

Axial Compression of 6-inch Diameter Cast MC Cylinders

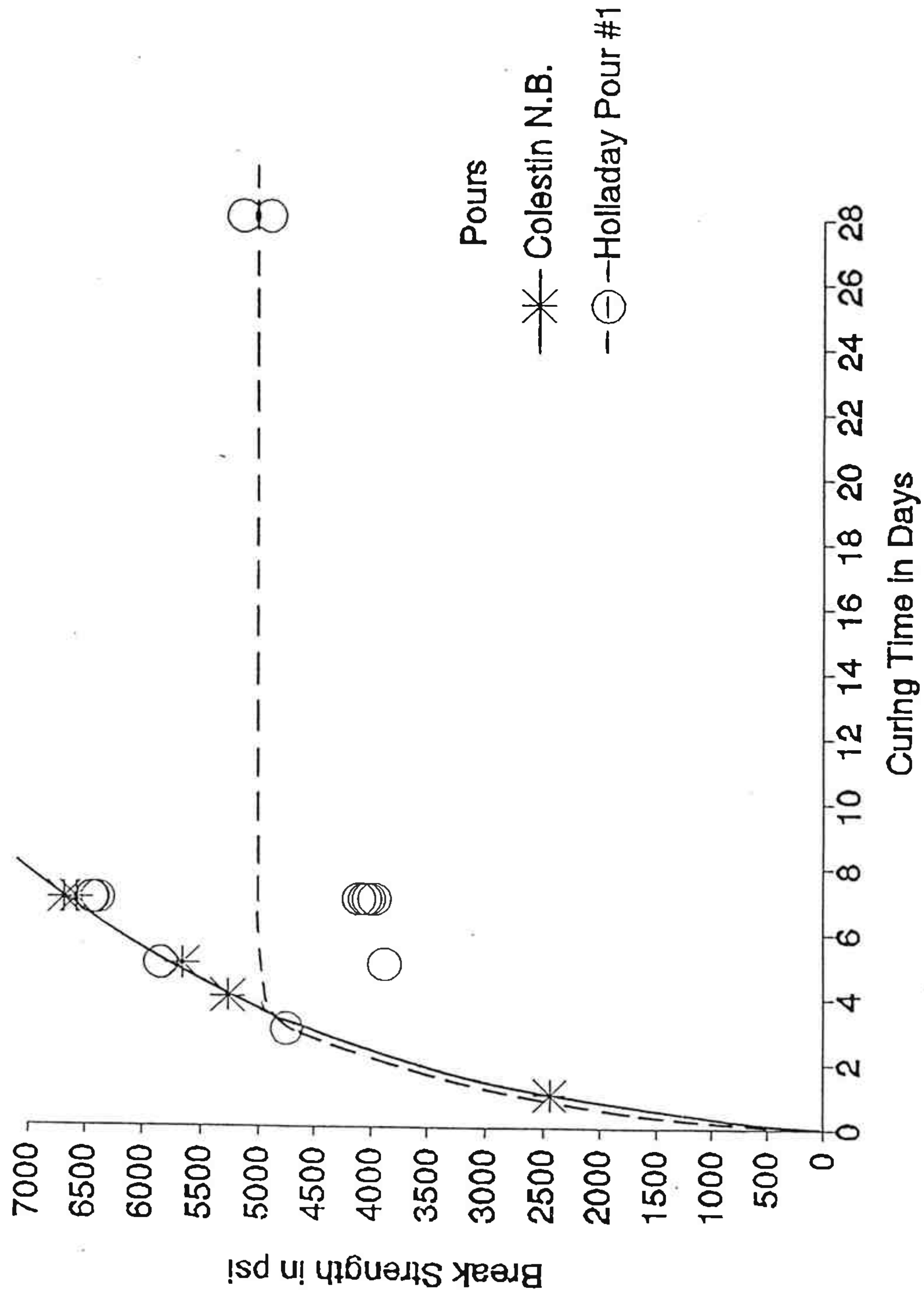

Figure 2.3: Compressive Strength vs Cure Duration

addition, 34 new delaminations covering 1.9% of the deck area were mapped. The entire deck was flooded with methacrylate sealer and covered with #30 grit sand.

Three cores were drilled to find the cause of the delaminations. The first core was drilled out of a known delaminated area. The overlay was not bonded to the old deck. The second core was drilled out of a solid area near a delamination. The overlay and old deck were bonded. The third core was drilled out of a known delamination. The overlay and the old deck were bonded, and the delamination was within the old deck.

The **Neil Creek N.B.** overlay was not cracked when it was uncovered. A few delaminated areas on the median side of the pour were detected and repaired. All bond tests were satisfactory.

After traffic used the deck for several months, the overlay remained uncracked. However, 20 new delaminations were mapped, including a long transverse delamination at the leading edge of the overlay. All of these delaminations covered 1.4% of the deck area and were not repaired.

The **Colestin S.B.** overlay was not cracked or delaminated when it was uncovered. All bond tests were satisfactory. About 30 delaminations were mapped after traffic had used the bridge for one winter. All of these delaminations were adjacent to either the seam where the first and second pour abutted or the joints at the ends of the decks. None of this distress was repaired.

The **Neil Creek S.B.** overlay had no delaminations or cracking when it was uncovered. All bond tests were satisfactory. After one winter's use, there was no delamination.

Holladay Street Ramp Bridge -
Grand Avenue Ramp Bridge -

All overlays were uncovered after the cure and inspected for delamination. Cracks were sealed with methacrylate and traffic was allowed on the structures. Rough spots were ground smooth after traffic had used the decks for a few weeks. Later, bond tests were made and the resulting holes were sealed with microsilica concrete.

Pour 1 of the Holladay deck was uncovered after a 5-1/2 day cure. The surface was rough and four 1-inch long shrinkage cracks were found on the entire pour. There was no delamination. Three longitudinal cracks appeared on the 5-inch deep section on the west end of the bridge after the curing blankets had been off for 24 hours. These cracks disappeared as the thickness of the overlay decreased. The cracks were sealed and the rough surface was smoothed by a diamond grinder. One bond test was performed and the results passed specifications.

The **south side** of the **Holladay** and **Grand** pours were uncracked, smooth, and had no delaminations when they were uncovered after their seven day cures. A small amount of grinding was needed on a high spot on the **Grand** overlay. The **south side** of the **Holladay** pour passed two of four bond tests, and the **Grand** pour passed both of its bond tests.

Westbound Meacham Overcrossing Bridge -

A chain drag survey and bond tests were made before traffic was allowed on the bridge. All bond tests passed. A total of 16 delaminations were found on **all pours**, and every one was chipped out and repaired with MC. Some delaminations were between the overlay and the existing deck and the others were within the old deck.

Pour 1 had .3% of its surface area delaminated. The largest delamination was at the edge of the pour near the west abutment. Three cracks 1 to 1-1/2 feet long were found and sealed. Construction personnel feel these cracks may be tears from the tining.

Both **Pour 2** and **Pour 3** had .1% of their surfaces delaminated and no cracks. Almost all of the delamination on **Pour 2** was in both lanes on the west edge of the pour adjacent to the night joint. Almost all of **Pour 3**'s delamination was on the west edge of the pour on the south side of the deck.

3.3.1 Skid Resistance

The skid resistances of two of the five bridges were tested just after construction. The friction numbers of 47 and 52 for the **Colestin S.B.** and **Holladay** decks, respectively, were higher than the FHWA recommended minimum of 45 for both structures [4]. In contrast, freshly constructed LMC overlays often have friction numbers in the high 20s to mid 40s [5].

3.4 Specifications

The current OSHD specifications for MC (February 1990) are in Appendix B. They were developed using experience gained from constructing the overlays that are the subject of this report. The main differences between these new specifications and the ones used for the decks in this study are:

1) **New Spec** - maximum allowable air content is 8.0%.

   Old Spec - maximum air content was 7.0%.

2) **New Spec** - maximum allowable slump is 8.0 inches.

   Old Spec - maximum slump was 7.0 inches.

3) **New Spec** - diamond grinding and water blasting are permitted for deck preparation.

   Old Spec - mechanical scarifiers and scabblers, as well as diamond grinding and water blasting were allowed.

4) **New Spec** - surface evaporation, air and deck temperature, and wind speed limits are included in construction specifications.

   Old Spec - air and deck temperature, wind speed, and seasonal limitations were included.

5) **New Spec** - surface must be hand floated to a tight and uniform texture, in addition to mechanical finishing. Water misting

is required during floating.

Old Spec - mechanical finishing was required.

6) **New Spec** - grooving may be done by saw, finned float, or hand tining.

Old Spec - hand tining was allowed.

4.0 COSTS

The use of microsilica slurry increased the mix cost approximately \$50/yd^3 over PCC on these decks, according to W.R. Grace representatives. This added expense included: the microsilica slurry; additives such as set retarder, superplasticizer, and air entrainment agent; and a company representative at each project. These costs may be lower on larger pours, as personnel costs can be amortized over larger volumes of mix, according to the supplier.

There was little or no cost savings by using MC, as compared to LMC, on the bridges in this study. Based on information from the contractors, it cost:

\$300 to \$400/yd^3 to furnish MC.

\$16 to \$25/yd^2 to construct MC.

Based on unit prices for the eight LMC bridge deck overlays built for the OSHD in 1989, the average low bid prices were:

\$406/yd^3 to furnish LMC.

\$8/yd^2 to construct LMC.

Comments from the contractors:

On the **Colestin** and **Neil Creek** bridges the contractor bid \$400/yd^3 and \$18/yd^2 for furnishing and placing LMC, respectively. The contractor was allowed to switch to MC for no additional cost after the bid was accepted. The subcontractor, Dan Thompson, feels that LMC bid item prices were adequate for MC.

On the **Holladay** and **Grand** bridges, the contractor could use either MC or LMC. According to Rick Shaw of Aztech, the contractor's bid price of \$300/yd^3 and \$25/yd^2 for furnishing and placing concrete were for either option. Shaw felt that the bid prices covered the actual costs of the MC overlay.

On the **Westbound Meacham** bridge, the contractor bid \$247.25/yd^3 and \$16/yd^2 for furnishing and placing MC. The subcontractor, Dan Thompson, feels that this bid was low. He feels that a bid price of \$350-\$400/yd^3 for furnishing the mix would have been more appropriate, as the MC was more troublesome than expected.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

MC overlays can be built that have adequate strength, smooth uncracked surfaces, and minimal delamination, the same as LMC. In addition, the MC overlays have higher initial skid resistances than typical LMC decks.

MC can be produced in an off-site batch plant, placed, and finished with tools and procedures normally used for conventional PCC. This may be an advantage over LMC in some cases.

Many problems with MC are due to insufficient slump during finishing. These decks are hard to finish, and they may have excessive cracking and/or delamination.

If the mix is workable, the overlay can be mechanically finished. Fogging should be used.

As with PCC mixes, heavy objects used to hold down the curing blanket can leave dents in the overlay. Lighter objects, such as boards will not settle into the mix.

Delamination and cracking was seen on some decks after they were under traffic for several months. Similar problems have been noted on LMC overlays. The cause is not known.

There is little or no cost savings when MC is used, as the lower price of furnishing the mix is offset by higher construction costs. On projects in this study, the cost of furnishing MC varied between \$300 and \$400/yd^3. This was less than the average 1989 LMC low bid price of \$406/yd^3. The cost of constructing the MC overlays, between \$16 and \$25/yd^2, was higher than the 1989 LMC average low bid construction cost of \$8/yd^3.

5.2 Recommendations

Further use of MC is recommended as an alternative to LMC. Many of the problems observed in this study may be prevented by using the February 1990 or later specifications.

In addition to meeting the latest specifications, the following may aid in solving problems associated with an MC mix:

- Use mixes with slumps between 7 and 8 inches.
- Shorten mix testing and adjustment time at the jobsite by delivering consistent mix and having adequate quality control personnel.
- When the time period between batching and pouring is near the upper limit of 90 minutes, add most of the superplasticizer at the jobsite.

6.0 REFERENCES

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5. Geraldine Pierce, memorandum to author, July 9, 1990.

APPENDIX A: MATERIALS AND CONSTRUCTION DATA

Table A-1: Materials and Construction Data
Colestin Road Overcrossing Bridge
Neil Creek Road Overcrossing Bridge

Materials -

Cement:	Type II Portland cement by Calaveras.
Aggregate:	3/4 - 0 inch crushed river gravel from Kendall Bar on the Rogue River.
Additives:	"Force 10,000" microsilica, "WRDA 19" high range water reducer (superplasticizer), "Daratard 17" set retarder, and "Daravair" air entrainment agent. All additives were made by W.R. Grace.

Mix Design Batch Quantities (lbs/yd^3) -		Specification Limits Min.	Specification Limits Max.
Cement	660	660	
Coarse Aggregate (SSD)	1588		
Fine Aggregate (SSD)	1475		
Microsilica in Microsilica Slurry	52	52	
Water	164		
Water in Microsilica Slurry	55		
High Range Water Reducer	11		
Set Retarder	3		
Air Entrainment Agent	1		
Other Mix Design Properties -			
Fine Aggregate (% of Aggregate Weight)	48	45	55
Water/Cement Ratio	.35		.37[a]

Construction Quality Control Test Results, Post Construction Test Results, and Construction Data -

Test	Test Method	Deck	Average Test Result	Specification Limits Min.	Specification Limits Max.
Water/Cement Ratio	OSHD TM729-86	Colestin N.B.	.33		.35
		Neil Creek N.B.	.34		"
		Colestin S.B.	.38 [.32]		.37
		Neil Creek S.B.	.33		"
Air Content (%)	AASHTO T152-82	Colestin N.B.	5.2	4.0	7.0
		Neil Creek N.B.	5.0	"	"
		Colestin S.B.	5.0 [5.8]	"	8.0
		Neil Creek S.B.	6.2	"	"
Slump (in)	AASHTO T119-82	Colestin N.B.	5.8	4.0	7.0
		Neil Creek N.B.	5.9	"	"
		Colestin S.B.	7.3 [6.8]	"	8.0
		Neil Creek S.B.	7.0	"	"
Unit Weight (lbs/ft^3)	AASHTO T121-82	Colestin N.B.	147		
		Neil Creek N.B.	148		
		Colestin S.B.	147 [143]		
		Neil Creek S.B.	146		
Microsilica Concrete Temperature (^oF)[b]	ASTM C1064	Colestin N.B.	65-70	50	80
		Neil Creek N.B.	63-70	"	"
		Colestin S.B.	71-80 [72-76]	"	"
		Neil Creek S.B.	76-81	"	"

[a]Water/Cement Ratio upper limit was .35 for Northbound decks.
[b]Minimum and maximum during pour.

Table A-1: Materials and Construction Data, Contd.
Colestin Road Overcrossing Bridge
Neil Creek Road Overcrossing Bridge

Construction Quality Control Test Results, Post Construction Test Results, and Construction Data -
Construct

Test	Test Method	Deck	Average Test Result	Specification Limits Min.	Specification Limits Max.
Air Temperature (°F)		Colestin N.B.		35	
		Neil Creek N.B.	55[b]	"	
		Colestin S.B.	48-72[a] [45][c]	"	
		Neil Creek S.B.	39[d]	"	
Deck Surface Temperature (°F)		Colestin N.B.		45	80
		Neil Creek N.B.		"	"
		Colestin S.B.	45[e] [45][e]	"	"
		Neil Creek S.B.	45[d]	"	"
Humidity (%)		Colestin N.B.			
		Neil Creek N.B.	85[e]		
		Colestin S.B.			
		Neil Creek S.B.			
Wind Speed (mph)		Colestin N.B.			15
		Neil Creek N.B.	4[e]		"
		Colestin S.B.	11-14[a]		"
		Neil Creek S.B.			"
Time: Batch to Discharge (min)		Colestin N.B.	80		90
		Neil Creek N.B.	51		"
		Colestin S.B.	93 [72]		"
		Neil Creek S.B.	60		"
7-day Compressive Strength (psi)	AASHTO T22-82	Colestin N.B.	6650	3300	
		Neil Creek N.B.	5833	"	
		Colestin S.B.	6467 [6340]	"	
		Neil Creek S.B.	7087	"	
Bond Test Break Strength (psi)		Colestin N.B.	184	100	
		Neil Creek N.B.	185	"	
		Colestin S.B.	250 [170]	"	
		Neil Creek S.B.	243	"	
Delamination (% Deck Area)		Colestin N.B.	1.9		
		Neil Creek N.B.	1.4		
		Colestin S.B.			
		Neil Creek S.B.			
Friction Test (Friction Number)	AASHTO T242-84	Colestin N.B.		37	
		Neil Creek N.B.		"	
		Colestin S.B.	47	"	
		Neil Creek S.B.		"	

[a]Minimum and maximum during pour.
[b]9:55 AM: near midpoint of pour.
[c]9:13 AM: near end of pour.
[d]6:30 AM: near start of pour.
[e]Spot check. Full range of values unknown.
Figures in brackets are for the second Colestin S.B. pour.

Table A-1: Materials and Construction Data, Contd.
Holladay Street Ramp Bridge
Grand Avenue Ramp Bridge

Materials -

Cement: Type I Portland cement by Ashgrove.

Aggregate: 3/4 - 0 inch crushed river gravel dredged from the Willamette River near Ross Island.

Additives: "Force 10,000" microsilica, "WRDA 19" high range water reducer (superplasticizer), "WRDA 79" Type A water reducer, and "Darox" air entrainment agent. All additives were made by W.R. Grace.

Mix Design Batch Quantities (lbs/yd^3) -		Specification Limits Min.	Max.
Cement	660	660	
Coarse Aggregate (SSD)	1588		
Fine Aggregate (SSD)	1475		
Microsilica in Microsilica Slurry	52	52	
Water	164		
Water in Microsilica Slurry	55		
High Range Water Reducer	10		
Type A Water Reducer	3		
Air Entrainment Agent	As needed for 4-7% air.		
Other Mix Design Properties -			
Fine Aggregate (% of Aggregate Weight)	49	45	55
Water/Cement Ratio	.35		.35

Construction Quality Control Test Results, Post Construction Test Results, and Construction Data -

Test	Test Method	Bridge	Average Test Result	Specification Limits Min.	Max.
Water/Cement Ratio	OSHD TM729-86	Holladay	.27 [.35]		.35
		Grand	.37		"
Air Content (%)	AASHTO T152-82	Holladay	5.3 [5.5]	4.0	7.0
		Grand	4.6	"	"
Slump (in)	AASHTO T119-82	Holladay	6.1 [5.1]	4.0	7.0
		Grand	7.5	"	"
Unit Weight (lbs/ft^3)	AASHTO T121-82	Holladay	144 [145]		
		Grand	147		
Microsilica Concrete Temperature (°F)[a]	ASTM C1064	Holladay	68-75 [71-80]	50	80
		Grand	77-79	"	"
Air Temperature (°F)		Holladay	49-78[a] [66][b]	45	
		Grand	70	"	

[a] Minimum and maximum during pour.
[b] 8:33 AM: near midpoint of pour.
Figures in brackets are for the second Holladay Ramp Bridge pour.

Table A-1: Materials and Construction Data, Contd.
Holladay Street Ramp Bridge
Grand Avenue Ramp Bridge

Construction Quality Control Test Results, Post Construction Test Results, and Construction Data -

Test	Test Method	Bridge	Average Test Result	Specification Limits Min.	Specification Limits Max.
Deck Surface Temperature (°F)[a]		Holladay	47-60	45	80
		Grand		"	"
Humidity (%)[a]		Holladay	60-80		
		Grand			
Wind Speed (mph)[a]		Holladay	0-30		15
		Grand			"
Time: Batch to Discharge (min)		Holladay	[63]		90
		Grand			"
7-day Compressive Strength (psi)	AASHTO T22-82	Holladay	5064 [6660]	3300	
		Grand	6277	"	
Bond Test Break Strength (psi)		Holladay	149 [90+]	100	
		Grand	220	"	
Friction Test (Friction Number)	AASHTO T242-84	Holladay	52	37	
		Grand		"	
Delamination (%[b] Deck Area)		Holladay	0 [0]		
		Grand	0		

[a]Minimum and maximum during pour.
[b]Before traffic used structure.
Figures in brackets are for the second Holladay Ramp Bridge pour.

Table A-1: Materials and Construction Data, Contd.
Westbound Meacham Overcrossing Bridge

Materials -

Cement:	Type I Portland cement by Ashgrove.
Aggregate:	3/4 - 0 inch crushed river gravel from the R. D. Mac pit on the Grand Ronde River near Island City.
Additives:	"Force 10,000" microsilica, "WRDA 19" high range water reducer (superplasticizer), "WRDA 79" Type A water reducer, and "Daravair" air entrainment agent. All additives were made by W.R. Grace.

		Specification Limits	
		Min.	Max.
Mix Design Batch Quantities (lbs/yd^3) -			
Cement	660	660	
Coarse Aggregate (SSD)	1604		
Fine Aggregate (SSD)	1375		
Microsilica in Microsilica Slurry	52	52	
Water	154		
Water in Microsilica Slurry	54		
High Range Water Reducer	14		
Type A Water Reducer	3		
Air Entrainment Agent	1		
Other Mix Design Properties -			
Fine Aggregate (% of Aggregate Weight)	46	45	55
Water/Cement Ratio	.34		.37

Construction Quality Control Test Results, Post Construction Test Results, and Construction Data -

Test	Test Method	Bridge	Average Test Result	Specification Limits Min.	Specification Limits Max.
Water/Cement Ratio	OSHD TM729-86	Meacham W.B.	.35 (.34) [.35]		.37 "
Air Content (%)	AASHTO T152-82	Meacham W.B.	5.6 (5.6) [6.6]	4.0 "	7.0 "
Slump (in)	AASHTO T119-82	Meacham W.B.	6.5 (6.6) [6.3]	4.0 "	7.0 "
Unit Weight (lbs/ft^3)	AASHTO T121-82	Meacham W.B.	141 (137) [138]		
Microsilica Concrete Temperature (°F)[a]	ASTM C1064	Meacham W.B.	71-79 (68-80) [60-64]	50 "	80 "
Air Temperature (°F.)[a]		Meacham W.B.	48-66 (58-67) [40-64]	35 "	
Deck Surface Temperature (°F)[a]		Meacham W.B.	52-78 (60-68) [49-51]	45 "	80 "

[a]Maximum and minimum during pour.

Table A-1: Materials and Construction Data, Contd.
Meacham Bridge, W.B.

Construction Quality Control Test Results, Post Construction Test Results, and Construction Data -

Test	Test Method	Bridge	Average Test Result	Specification Limits Min.	Specification Limits Max.
Wind Speed (mph)[a]		Meacham W.B.	6-10 (0-6) [0]		15 "
Time: Batch to Discharge (min)		Meacham W.B.	42 (50) [50]		90 "
7-day Compressive Strength (psi)	AASHTO T22-82	Meacham W.B.	6000 (5310) [5100]	3300 "	
Bond Test Break Strength (psi)		Meacham W.B.	193 (230) [185]	100 "	
Delamination[b] (% Deck Area)		Meacham W.B.	.3 (.1) [.1]		

[a]Maximum and minimum during pour.
[b]1-1/2 months after pour.
Figures in parenthesis and brackets are for the second and third pours, respectively.

APPENDIX B: SPECIFICATIONS

(Contractor-designed mix and Contractor process control. Requires SSS106.18 and SP701.)

SECTION 509 - PORTLAND CEMENT CONCRETE RESURFACING OF BRIDGE DECKS

Delete Section 509 of the 1984 Standard Specifications and substitute the following:

SECTION 509 - MICROSILICA CONCRETE RESURFACING OF BRIDGE DECKS AND PAVEMENT

Description

509.00 Scope - This work shall consist of preparing and resurfacing bridge decks and portland cement concrete pavement with Microsilica Concrete (MC).

509.01 Abbreviations and Definitions:

ACI - American Concrete Institute
CCT - Concrete Control Technician
MC - Microsilica Concrete
MMTR - Microsilica Manufacturer's Technical Representative
PCC - Portland Cement Concrete
QCT - Quality Control Technician
QPL - Qualified Products Listing

509.02 Microsilica Manufacturer's Technical Representative - The Contractor shall have the microsilica manufacturer provide technical representatives to:

- Guide development of the microsilica mix design and be present during preparation of the trial batch submitted for review as required in 509.13.

- Be at both preplacement conferences.

- Be at the batching plant throughout all batching to control addition of microsilica and chemical admixtures as required in 509.15(c-1).

- Be at the placement site throughout all placement to evaluate each batch delivered and control addition of chemical admixtures as required in 509.15(c-1).

509.04 Preplacement Conference - Supervisory personnel of the Contractor and any subcontractors or suppliers who are to be involved in the MC work and a technical representative from the microsilica manufacturer shall meet with the Engineer for a preplacement conference at a time mutually agreed upon. At this conference, the Contractor shall present and discuss methods of accomplishing all phases of the MC work.

A second preplacement conference shall be held at the job-site one-half hour before the first placement begins to discuss placement duties and procedures. It will be attended by the Engineer, the MMTR and the Contractor's entire placement crew.

Materials

509.11 General - Materials shall meet the requirements of the following Part 700 subsections of the Standard Specifications as well as modifications and/or additions given in this subsection and Section 701 of these special provisions:

Air Entraining and other Chemical Admixtures	701.03
Coarse Aggregate	703.02
Curing Materials	701.05
Epoxy Cement	701.06
Fine Aggregate	703.01
Fly Ash	701.07
Microsilica	701.12
Portland Cement	701.01
Poured Filler	705.03
Preformed Elastomeric Joint Seals	705.02
Preformed Expansion Joint Fillers	705.01
Proprietary Epoxy and Nonepoxy Bonding Agents	701.10
Water	701.02

701.01 Portland Cement - The portland cement shall be Type I or II.

703.01 Fine Aggregates for Portland Cement Concrete - Delete 703.01(b) and substitute the following:

(b) General requirements - Fine aggregates shall consist of natural sand having hard, strong, durable particles. A 100 pound sample of fine aggregate shall be submitted to the Engineer at least 14 calendar days prior to intended use for qualification testing at the beginning of production unless the fine aggregate source has been qualified within the past 12 months.

Fine aggregates furnished during the progress of the work which show a variation greater than 0.20 from the fineness modulus of the fine aggregate used in the Contractor's mix design may be rejected or, at the option of the Engineer, may be accepted subject to such changes in concrete proportions as may be necessary by reason of such variation. The FINENESS MODULUS of the fine aggregate shall be determined according to OSHD TM 771.

In 703.01(c) change the limit for friable particles from 3 percent to 1.50 percent maximum.

In 703.01(f) add a No. 8 sieve between No. 4 and No. 16 for determination of the fineness modulus only.

In 703.01(g) change the sand equivalent for fine aggregate from not less than 68 to not less than 75.

(Require crushed aggregates on steep gradients with Bridge Section concurrence.)

703.02 Coarse Aggregates for Portland Cement Concrete - Delete 703.02(b) and substitute the following:

(b) General requirements - Coarse aggregates shall consist of uncrushed, clean gravel having hard, strong, durable particles free from adherent coatings.

A 100 pound sample of coarse aggregate shall be submitted to the Engineer at least 14 calendar days prior to intended use for qualification testing at the beginning of production unless the coarse aggregate source has been qualified within the past 12 months.

In 703.02(c) change the limit for friable particles from 2.00 percent to 1.00 percent maximum.

In 703.02(f-2) delete the table of "Grading Requirements" and substitute the following:

Sieve Size	Percent Passing (by weight) Min.	Max.
3/4"	100	
1/2"	85	100
3/8"	20	50
No. 4	0	10
No. 200	0	1.5

3/26

In 703.02(f-2) add the following to the last paragraph:

Elongated pieces in the coarse aggregate will be determined as described in OSHD Test Method 229N, with the proportional caliper device set at a ratio of 4:1, and shall not exceed 10 percent by weight of the material retained on the No. 4 sieve.

509.13 MC Mix Design and Review - The Contractor shall be responsible for developing a MC mix design under the guidance of the MMTR as required in 509.02 and submitting it to the Engineer for review. If the Engineer determines that the design complies with specifications the mix design will be accepted for use on the project.

(a) Proportioning of the mix - The mix proportions shall be determined by a CCT (See 509.15(a)). The mix shall be designed by the volumetric method as outlined in ACI 211.1 or OSHD TM 718 and shall meet the limits in 509.14. The mix shall include a high range water reducing admixture meeting the requirements of AASHTO M 194, Type F.

(b) Microsilica - The microsilica slurry shall be added to the concrete mix such that the amount of dry microsilica added meets the requirement of 509.14. This shall be based on the manufacturer's certification of the weight of dry microsilica per volume of slurry. The liquid in the microsilica shall be considered mixing water and included in water-cement ratio calculations.

Equipment provided for the addition of microsilica slurry shall insure that the slurry is well agitated and accurately dispensed into the mixture.

(c) Chemical admixtures - All chemical admixtures to be used must be on the Division's QPL. The quantity of each chemical admixture to be used in the MC mix shall be determined by trial batches prior to its use in MC produced for incorporation into the project. However, this quantity may have to be adjusted by actual field use to obtain the properties specified in 509.14. Each chemical admixture shall be added to the MC mix according to the manufacturer's recommendations.

(d) Trial batch - The CCT shall make at least one trial batch of 2 cubic yards minimum mixed in a truck mixer with the proposed mix design to verify that the mix will produce MC in compliance with these specifications. Preparation and testing of the trial batch and molding, curing and strength testing of the cylinders shall be done by the Contractor and will be witnessed by the Engineer.

(d-1) Plastic MC - The Contractor shall test the slump, air content and unit weight and shall calculate the water-cement ratio for each trial batch. Slump, air content and water-cement ratio must be within the specification limits for the trial batch to be valid.

(d-2) Strength tests - At least five 6"x12" test cylinders shall be cast for each mix design and tested at 7 days. The cylinders shall be cast in single-use plastic molds. All strength specimens shall be cast and cured in accordance with AASHTO T 23 or T 126. The cylinders shall be tested in accordance with AASHTO T 22.

(d-3) Required strength - The average 7-day compressive strength of the trial batch cylinders must exceed the specified compressive strength by at least 1000 psi.

(e) Mix design review - Each mix design proposed for use shall be identified by a unique mix design number and submitted to the Engineer for review. The Contractor shall not proceed with concrete placement using the mix design until the Engineer has determined that all materials and the mix design are in compliance with specifications. Review of concrete mixes, materials, and production procedures by the Engineer will not relieve the Contractor of responsibility to provide concrete conforming to the specifications. The Contractor shall submit all the following data and the samples requested in 509.15(b) to the Engineer at least 14 calendar days prior to intended use:

(e-1) Mix design proportions - Provide the weight per cubic yard and absolute volume of cement, microsilica, each size of aggregate, water and mineral admixtures. Indicate dosage rates of chemical admixtures.

(e-2) Materials identification - Identify type and brand of cement, microsilica and admixtures to be used. Identify the source of the aggregates by OSHD source number.

(e-3) Reports on plastic concrete - Report on slump, air content, unit weight, water-cement ratio and calculated cement content of trial batch(es).

(e-4) Compressive strength results - Report on 7-day compressive strength tests from the trial batch(es).

(e-5) Test reports on aggregate - See 509.15(b).

(e-6) Test report on water - See 701.02.

(f) Changing mix proportions - Once a mix design has been reviewed and accepted by the Engineer no changes in proportions shall be made by the Contractor without written concurrence of the Engineer. If the Contractor proposes adjustments considered by the Engineer to be significant, the Contractor shall submit a new mix design proposal to the Engineer with verification of strength by trial batch.

(g) Contractor costs - All materials, equipment and work required for designing the mixes, testing materials, and making trial batches to verify the design for final use shall be furnished by the Contractor and the entire cost thereof shall be borne by the Contractor. Costs of State personnel monitoring or performing check tests will be borne by the Division.

509.14 MC Mixture Tolerances and Limits - The MC shall be a workable mixture uniform in composition and consistency with the following properties or limits:

Material or Property	Unit	Quantity	Specification or Test Method
Percent fine aggregate	percent of total aggregate by weight	45-55	
Cement content	lbs./cu.yd.	660	
Dry microsilica	lbs./cu.yd.	52	701.12
Water/cement ratio (incl. free moisture in aggregate and non-solids in microsilica slurry)	lb. water/ lb. cement	0.35 max.	OSHD TM 729
Air content	percent of plastic mix	4.0 - 8.0	AASHTO T 152 509.15(c)
MC temperature	degrees F	50 min. 80 max.	ASTM C 1064
Slump	inches	4.0 - 8.0	AASHTO T 119
Compressive strength at 7 calendar days	psi	3,300 min.	OSHD TM 719 509.13(d) & 509.16(a)

509.15 Process Control - The Contractor shall be responsible for quality control in accordance with 106.18(a) and (b) of the Supplemental Standard Specifications and shall perform process control sampling and testing according to 509.15(b) and 509.15(c):

(a) Certified technicians - The Contractor shall provide a certified CCT and two certified QCT's, with authority to control the production of MC. These certifications shall be from a Division accredited organization. A list of the accredited organizations may be obtained from the Engineer. If there are none, the Division will serve in this capacity. Certification will be required by the Engineer before the CCT and QCT's are allowed to commence work on the project. The Contractor shall allow at least 14 calendar days for the Division certification process to be completed.

(a-1) Concrete control technician - The CCT shall develop and verify MC mix designs. The CCT shall instruct the plant control personnel how to adjust the batch weights of the ingredients required to maintain the proper water-cement ratio, cement content, air content, and aggregate proportions to produce the specified MC. When MC is placed, the CCT shall be present at the plant, or at the jobsite if radio contact is maintained with the plant, to supervise control or adjustment of the mix.

However, the MMTR required in 509.02 shall have final authority as to batching sequence and addition of micro-silica and chemical admixtures.

(a-2) Quality control technicians - The QCT's shall perform tests on plastic MC according to 509.15(c). The QCT's shall be assigned at the location where MC is being placed any time placement is in progress. The QCT's shall be responsible for insuring all MC complies with specifications, shall reject MC not complying with specifications, and shall notify the CCT of such rejection and the cause for rejection.

(b) Aggregates - Each size of aggregate shall be stockpiled separately. The Contractor shall take samples and perform the following tests on each size aggregate:

(b-1) Required tests:

Test	Test Method	Aggregates	Minimum Frequency Schedule: Start of Production	One per 5 Shifts*	One per Shift*
Dry Rodded Unit Weight	AASHTO T-19	Coarse	X		
Bulk Specific Gravity and Absorption	AASHTO T-85 AASHTO T-84	Coarse Fine	X X		
Friable Particles	OSHD TM 221	All	X	X	
Wood Particles	OSHD TM 225	Coarse	X	X	
Elongated Pieces	OSHD TM 229N	Coarse	X	X	
Fineness Modulus**	OSHD TM 771	Fine	X		X
Sand Equivalent**	OSHD TM 101	Fine	X		X
Sieve Analysis** (with P200 from OSHD TM 205)	OSHD TM 204	All	X		X

*A shift means: a production shift or 500 cubic yards whichever results in the greatest sampling frequency.
**Perform at least 3 tests per project.

(b-2) Split samples - The Contractor shall provide split samples to the Engineer.

(b-3) Additional testing - The Engineer may perform any of the above testing under (b-1) and additional tests such as lightweight pieces, and qualifying tests for soundness, degradation, abrasion and organic impurities. The test results will be provided to the Contractor.

(b-4) Removal of failing material - The Contractor shall make appropriate operational adjustments and conduct a second test immediately whenever a test result does not meet specifications. The Contractor shall remove all failing material from the stockpile if the second test result does not meet specifications.

(b-5) Preproduced aggregate - Compliance of aggregates produced and stockpiled before the award date of this contract will be determined by either:

a. Continuing production records meeting the requirements of 509.15(b-1) through (b-4), or

b. Sampling and testing the entire stockpile according to AASHTO T 2 on the following minimum frequency schedule:

- "Start of production", meaning one set of tests per stockpile.

- "One per 5 shifts", meaning one set of tests per 2,500 cubic yards.

- One per shift", meaning one set of tests per 500 cubic yards, with a minimum of 3 sets of tests per project.

(c) Plastic MC - Mix control and documentation will be performed by the Contractor. Sampling and testing of the plastic MC shall be performed in accordance with the following:

Test	Test Method	
	AASHTO	OTHER
Molding Concrete Specimens in the Field.	T 23*	
Sampling Fresh Concrete.	T 141#	
Slump.	T 119	
Cement Content	T 121**	OSHD TM 713
Air Content.	T 152***	OSHD TM 714
Water-cement Ratio		OSHD TM 729
Yield.	T 121**	
Concrete Temperature		ASTM C 1064

*Except cylinders will be cast in single-use plastic molds.
**Except the same measuring bowl and strike off procedure used in AASHTO T 152 may be used.
***Except the same strike off procedure used in AASHTO T 121 may be used.
#Samples will be obtained from the discharge of the delivery vehicles.

(c-1) Mix control and documentation:

a. Before batching is started and at any time there is a visibly detectable change in the moisture content of the aggregate the CCT shall:

1. Test fine aggregate for total moisture content, initially according to AASHTO T 255. Subsequent testing may be by an alternate method approved by the Engineer.

2. Visually inspect the coarse aggregate for moisture content.

9/26

3. Calculate the amount of free water present in the aggregate and adjust the batch weights accordingly.

4. Calculate the total allowable amount of water (including liquid admixtures and free water in aggregate) for each batch.

5. Provide the QCT with the mix design and the information from 509.15(c-1)a.

b. The Contractor shall:

1. Have the MMTR's at the batching plant and at the jobsite as required in 509.02.

2. Provide an automatic plant with a calibrated sand moisture probe and an automated printer that records on a ticket the OSHD Mix Design number, day, time of batch(es), size of load and quantity of individual constituents in the load. For those plants not fully meeting these automation requirements the Contractor shall pay the Division's actual costs including payroll additives for a Division Inspector to monitor all batching required by the project.

3. Make sure all water is removed from the transit-mix trucks before each loading.

4. Not add water after initial batching and mixing.

5. Reject the load if the materials in any load are outside the specified limits of the mix proportions.

6. Send the ticket with each load.

c. For each load the QCT shall:

1. Check the ticket on arrival at the jobsite for the designed mix proportions.

2. Not allow placement of MC until it is determined by testing that it meets specifications.

3. Perform temperature, slump and air content tests at the jobsite before the addition of admixtures.

4. After the addition of admixtures authorized by the MMTR according to 509.32(a-3), perform temperature, slump and air content tests.

5. Retest the mix for temperature, slump and air content if more than 20 minutes elapse between last test and placement.

6. Reject those loads which do not meet specifications after all admixtures are added in accordance with 509.32(a-3).

d. The QCT shall also:

1. Compute the water/cement ratio on the first load of each placement, any time there is a change in batch proportions, and whenever a set of cylinders is obtained by the Engineer.

2. Record all information needed to compute the water/cement ratio of all loads of concrete delivered to the project.

3. Perform mix temperature, air content, slump and yield tests whenever a set of cylinders is cast by the Engineer.

(c-2) Records - All tickets, water-cement ratio calculations, and all other records required by 509.15(c) shall be delivered to the Engineer upon availability but no later than one hour after the end of the shift.

509.16 Acceptance Sampling and Testing - Acceptance sampling and testing will be performed according to the following:

(a) Compressive strength - One set of three cylinders will be cast by the Engineer from each 50 cubic yards of MC placed on the project. A minimum of one set will be cast per production shift. The MC will be sampled in accordance with AASHTO T 141. The cylinders will be cast and cured in accordance with AASHTO T 23 using 6"x12" single-use plastic molds. The cylinders will be tested by the Engineer for compressive strength at 7 days. The average strength of the three cylinders will constitute the test result. Material represented by a test result of less than 3,300 psi shall be removed and replaced at the Contractor's expense, unless the Engineer determines the material can be left in place at a reduced price.

(b) Surface tolerance - The finished work, when tested with a 12-foot straightedge, shall not vary from the testing edge by more than 0.01-foot at any point. The Contractor shall furnish the straightedge and operate it under the direction of the Engineer. If the MC does not conform to the prescribed limits of deviation, the operations shall be stopped until revised methods, changes in equipment, or correction of procedures are proposed, and are approved by the Engineer for trial. The revised operation shall also be stopped if it does not produce a surface complying with specified requirements.

The Contractor shall correct all nonspecification surface tolerance with a diamond grinder at the Contractor's expense, including required traffic control.

(c) Bond - The Contractor shall cut cores, conduct bond tests on all cores, and the Engineer will analyze the tests as required by this subsection. The Contractor shall then restore the area voided by the cores by bush hammering all faces, air blowing, wetting, and then filling with MC. Cost of cutting the cores, making the bond tests, and restoring the deck or pavement shall be borne by the Contractor except as modified in 509.16(c-2). All areas which are damaged, fail to develop bond, or are delaminated shall be removed and replaced at the expense of the Contractor.

(c-1) Bond test - The Contractor will be required to make two satisfactory bond tests per pour in the presence of and at locations designated by the Engineer prior to opening to traffic and within 28 days of placement. The tests shall consist of coring through the MC overlay and about 1 inch into the existing concrete, attaching a device to the top of the core, and exerting a tensile load to the core sufficient to cause failure. Bond strength of the test core less than 100 psi will be considered unsatisfactory. All cores shall be pulled to failure.

(c-2) Delamination survey - The MC resurfacing will be surveyed by the Engineer for delaminations, bond failure or other damage by use of a chain drag and coring or other suitable devices. The cost of any core with a bond strength of less than 100 psi will be borne by the Contractor. The cost of any coring, except those required in 509.16(b-1) and 509.33, with a bond strength of 100 psi or greater will be paid for by the Division as Extra Work.

Equipment

509.21 Equipment - The Contractor shall furnish and operate equipment meeting the following requirements for the work specified. Equipment shall not be used until approved by the Engineer. Any equipment leaking oil or any other contaminant, shall be immediately removed from the jobsite until repaired.

(a) Surface preparation equipment:

(a-1) Sawing equipment - The Contractor shall provide power driven concrete saws for sawing joints and as required for surface texture. The saws and related equipment shall be of proven adequacy and design to perform efficiently and shall be subject to immediate replacement if the specified results are not obtained.

(a-2) Scarifying equipment shall be power-operated diamond grinders or water blast machines capable of uniformly removing the existing surface to depths required.

a. Diamond grinders shall be a power driven self-propelled unit with the cutting head made up of diamond cutting blades.

b. Water blasting equipment shall be capable of removing at least ten cubic feet of concrete per hour. All water used shall be potable.

(a-3) Power-driven hand tools for removal of unsound concrete will be permitted with the following restrictions:

a. Class 2 preparation equipment - Chipping hammers equal to or less than a nominal 15-pound class shall be used.

b. Class 3 preparation equipment - Jackhammers equal to or less than a nominal 30-pound class shall be used.

(a-4) Hand tools such as hammers and chisels shall be used to remove final particles of unsound concrete or to achieve the required depth.

(a-5) Air compressor shall be equipped with functioning oil traps and deliver oil-free air.

(a-6) Water spraying system shall be readily available to all parts of the deck or pavement being resurfaced and shall discharge potable water. Placement shall not start until potable water is available.

(b) Batch plant - The batch plant shall be adequate to handle materials within specified proportions and tolerances. Provisions shall be made to measure components of the mix at the batch plant or at the mixer. The batch plant shall comply with the following:

(b-1) Storage bins - Bins shall have adequate separate compartments for fine aggregate, each size of coarse aggregate, cement, and fly ash. Bins and compartments shall be tight and ample to prevent spilling from one bin to another. Separate compartments, including weighing hoppers, shall discharge freely and provide positive control of the quantities in each batch.

(b-2) Weigh hoppers - Scales for weighing aggregates and cement in weigh hoppers shall:

- Be either beam, springless dial, or electronic load cell type.
- Be accurate within 0.5 percent under operating conditions throughout the range of use.
- Be tested and certified at the Contractor's expense prior to use on this project and every 6 months thereafter and as often as necessary to assure their continued accuracy by either the State Department of Agriculture or a scale service company.

(b-3) Water and admixture dispensers - Equipment for dispensing water and admixtures shall:

- Provide separate feed.
- Accurately measure each quantity of material.
- Inject each material at the time in the mixing process to insure thorough and complete mixing throughout the batch of MC.

In addition the device for measuring water shall:

- Accurately show the quantity in gallons or pounds. Water is assumed to weigh 8.34 pounds per gallon.
- Be designed so that the water supply will be automatically cut off at the specified amount of water.
- Be calibrated and certified by the Contractor within 6 months prior to use on this project.
- Be accurate within 0.5 percent.

(b-4) Automatically controlled batches - Automatically controlled batches shall have automatically interlocked mechanisms.

- Positive weighing and discharge of cement and of each separate size of aggregate.
- Interlocking between weighing hoppers to prevent any part of the batch from being discharged until each separate hopper has been filled with the correct proportion.
- Simultaneous discharge of all hoppers.

(c) Mixers - MC shall be mixed in a batch plant mixer or in a revolving drum type truck mixer. MC mixed in a central plant mixer shall be delivered to the jobsite in a truck mixer.

All mixers shall be equipped with a metal plate or plates on which the manufacturer has marked the mixing speed of the drum and the maximum mixing capacity.

(c-1) Batch plant mixers - Batch plant mixers shall:

- Be a revolving drum type. Other types may be used with the written permission of the Engineer.
- Be equipped with mechanical means for automatically preventing the discharge of the mixer until the materials have been mixed the specified minimum time.

(c-2) Truck mixers - Truck mixers shall:

- Be the revolving drum type.
- Be watertight
- Be constructed and maintained within tolerances of the manufacturer's specifications.
- Contain a tank for carrying mixing water.
- Contain a device to measure the quantity of mixing water added.
- Contain a device to indicate the number of drum revolutions.

(d) Placing and finishing equipment - Placing and finishing equipment shall include hand tools for placement of MC and for work down to approximately the correct level for striking off with the screed. Manual type screeds or metal plates with approved vibrators attached shall be used to consolidate and finish the smaller areas. Spud vibrators will be required when depths exceed 2-1/2 inches, along edges, and adjacent to joint bulkheads. Supplemental vibration shall be provided along the meet lines where adjacent pours come together and along curb lines. Hand finishing with a wood float may be required along the edge of the pour.

(d-1) MC finishing machine - The MC finishing machine shall be:

- Self-propelled with positive control in both forward and reverse direction.

- Capable of raising screed, pan and rolls to clear the screeded surface and capable of positive, vertical control to the specified grade.

- Equipped with augers.

- Equipped with an oscillating, vibrating screed or a vibrating pan, followed by (a) finish roller(s). All screeds, pans and rolls shall travel laterally at a rate between 60 and 65 feet per minute.

- Capable of vibration frequency between 4000 and 4500 vpm.

- Used on all new surfaces except those noted in 509.21(d).

The finishing machine shall travel upon continuous supporting rails which are supported at 2-foot centers. The rails shall be sufficiently rigid that there is no visible deflection under the weight of the machine. Anchorage for supporting rails shall provide horizontal and vertical stability. Hold-down devices shot into new MC will not be permitted. Screed and bulkhead rails shall not be treated with parting compound to facilitate their removal.

When placing MC in a lane abutting a previously completed lane, the side of the finishing machine adjacent to the completed lane shall be equipped to