BOND CONTRIBUTION TO WHITETOPPING PERFORMANCE ON LOW VOLUME ROADS

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ABSTRACT

This research was initiated in 1991 as a part of a whitetopping project to study the effectiveness of various techniques to enhance bond strength between a new portland cement concrete (PCC) overlay and an existing asphalt cement concrete (ACC) pavement surface. A 1,676 m (5,500 ft) section of county road R16 in Dallas County, Iowa was divided into 12 test sections. The various techniques used to enhance bond were power brooming, power brooming with air blast, milling, cement and water grout, and emulsion tack coat. As a part of these bonding techniques, two pavement thicknesses were placed; two different concrete proportions were used; and two sections were planed to a uniform cross-slope.

Bond strength was perceived to be the key to determining an appropriate design procedure for whitetopping. If adequate bond is achieved, a bonded PCC overlay technique could be used for design. Without sufficient bond development, an unbonded overlay procedure should be used.

The research found that bond was developed in every section, regardless of the bond enhancement technique used. The underlying ACC does contribute to the composite structure and can be considered in the design. The sections where the underlying ACC contributed the greatest amount of structure to the composite pavement were not the sections with the highest bond strength.

INTRODUCTION

Whitetopping, PCC resurfacing over existing ACC, has been used successfully throughout the country. In Iowa, approximately 420 km (260 mi) of whitetopping overlays have been placed. They have been predominantly placed on the county road system, with projects constructed in 1977 in Boone, Dallas and Washington Counties regarded as the beginning of whitetopping in Iowa. Nevertheless, an appropriate design methodology has not been determined for the design of the thicknesses of these overlays. The difficulty stems from how to treat the structural contribution of the underlying ACC. If it becomes a part of the monolithic pavement, then a bonded PCC overlay (new PCC bonded to existing PCC) design method utilizing the existing ACC should be appropriate. If no bond is formed, then the ACC should be considered as a base and the PCC thickness cannot be reduced. The bond between the PCC and ACC is the key to how the two materials act in relation to each other. This interaction then determines the appropriate design method. This research investigated that bond and the use of conventional methods to enhance that bond.

PROBLEM

The whitetopping procedure used in Iowa has traditionally not been concerned with a bond between the old ACC and the new PCC. Current practice is to simply broom the existing ACC surface and then place the new PCC pavement. Past projects have performed very well, but most have been constructed on relatively low volume roads of less than 1000 vehicles per day. In order to protect against damage to low volume roads that occasionally experience the extremely heavy loads of large grain wagons and to expand this overlay technique to roads of higher traffic volumes, an appropriate design procedure for whitetopping needs to be established.

In 1990, four existing county road whitetopping projects were selected and cores tested to determine bond strength. The bond strength was determined through the use of Test Method No. Iowa 406. This test measures direct shear strength and a photo of the test collar is shown in Figure 1. Two of the projects were in Boone County (Routes E18 and R18) and two projects were in Dallas County (Routes F31 and P46).

The R18 whitetopping project, constructed in 1981, yielded cores with bond strengths in excess of 1,380 kPa (200 psi) shear strength. This happened without special procedures to enhance bonding, and established that significant strengths could indeed be achieved. The two projects in Dallas County yielded cores with average shear strengths of approximately 690 kPa (100 psi). The F31 project was constructed in 1981 and the P46 project was constructed in 1989. The cores taken from Boone County E18, constructed in 1982, were either broken apart at the interface of the ACC and PCC or the ACC was deteriorated to such an extent that testing was not possible.

OBJECTIVE

The primary aim of this research project was to determine what techniques could be used to enhance the bond between the old ACC and the new PCC overlay. If sufficient bond strength is the key to the determination of an appropriate design technique, this research also should offer a basis for choosing an appropriate whitetopping design procedure.

LOCATION AND EXISTING CONDITIONS

The research project was constructed in Dallas County, Iowa on county route R16, from Dallas Center south 7.2 km (4.5 mi) to Ortonville. The existing pavement was 6.7 m (22 ft) wide and was built in 1959. The original pavement was composed of a 6.4 cm (2.5 in.) ACC surface placed on a 15 cm (6 in.) rolled stone base, over 10 cm (4 in.) of soil base. In 1971, the road received a 8 cm (3 in.) ACC resurfacing. The traffic on this route ranges from 830 to 1050 vehicles per day.

The pavement surface was very distorted with some ruts in excess of 2.5 cm (1.0 in.). There were many cracks in the pavement, both transverse and random, and some areas of alligator cracking.

VARIABLES AND TECHNIQUES TESTED

The research test sections were developed to evaluate a number of factors. Five variables were tested. Table 1 lists the makeup of each of the twelve test sections and Figure 2 shows the layout of the research.

Surface Preparation

The surface preparation was considered the most important. The current Iowa Specification requires only that the surface of the ACC be power broomed prior to concrete placement. Therefore, four sections were prepared in that fashion in order to compare this research to past projects.

Cleanliness is very important with bonded PCC overlays. Therefore, one power broomed section was also air blasted prior to concrete placement.

With bonded overlays, the surface is milled or shotblasted in order to increase the texture of the concrete and help create some mechanical bonding. The same principle was employed and the surfaces of six sections were milled. This milling was not deep but only roughened the surface.

Bonding Agents

When PCC overlays are bonded to existing PCC in Iowa, a cement and water grout is required. When ACC overlays are placed over existing ACC, a tack coat is used. With this in mind, test sections were placed utilizing each of these bonding agents.

Planing

Whitetopping in Iowa has developed with the premise that rutting in the existing ACC is an advantage. The ruts provide extra PCC thickness in the wheel tracks where the loads are concentrated, as well as providing some minor keying action. The resulting lack of uniform overlay thickness has been a point of concern for some. Therefore, two test sections were planed to eliminate the distorted surface and create a uniform cross section thickness.

Thickness

Dallas County chose to place a nominal 13 cm (5 in.) minimum thickness overlay. If the assumption is made that a bond is formed between the old ACC and the PCC overlay, the methodology used for bonded PCC overlays would show that a 10 cm (4 in.) PCC overlay would provide a 20 year life. Sections were constructed of each thickness.

Mix

Two standard Iowa Department of Transportation mixes were used in this research. Traditionally, counties have used a Class B concrete in highway paving. A Class C concrete is required on the primary system and many counties are now using these proportions for county paving. Therefore, sections with each class of concrete were constructed. See Table 2 for a description of the concrete proportions.

CONSTRUCTION

The contract for this 7.2 km (4.5 mi) PCC overlay was awarded to Cedar Valley Corporation of Waterloo, Iowa. The week of June 17-21, 1991 was devoted to surface preparation of the selected research sections. An Iowa DOT milling machine was used to plane the distorted cross section in two test sections and to mill the surface to a depth that merely roughened it in four sections. The concrete paving began on Monday, June 24, 1991, starting at the north end of the project and progressed southward. The contractor located the batch plant at the south end of the project just north of US 6. The temperature was 28°C (83°F) and winds gusted to 26 km per hour (16 mph).

It was discovered during the construction of section 6 that the batch trucks tracked dust onto the roadway. The trucks used a rock drive to turn around and as they backed up to the paver, tracked dust onto the ACC surface. Unfortunately, the bond strength in this section may have been reduced due to this dust contamination on the surface of the ACC.

The second day of paving, June 25, 1991, brought a considerable change in the weather with the temperature climbing to 31°C (88°F) and wind gusts up to 45 km per hour (28 mph).

A paver malfunction, an intersection where a high early strength mix was placed, and a section of wet pavement had potential to adversely affect part of section 10. The portion south of Sta. 156+00 was not affected and was used for testing purposes.

Sections 11 and 12 involved the use of a cement and water grout as a possible bond enhancer. The grout was delivered in ready mix trucks, dumped onto the surface, and spread with hand squeegees. In section 11, the grout was much too dry (like cream of wheat) and sufficient water was not available on site to dilute it to a more fluid consistency. Therefore, only a 61 m (200 ft) section was placed. The grout used in section 12 was of a proper watery consistency and placement was much easier. The section was also shortened to 91 m (300 ft) to expedite the paving operation. Tracking of the grout occurred in both sections as the trucks backed into the grouted area as they dumped the concrete. This dried grout from the tracking may have actually reduced bond strength in those tracked areas.

Section 13 was placed on Thursday, June 27. The tack coat was applied at approximately 7:30 PM on June 26 in an area that would be paved the next morning. Unfortunately, the batch trucks had to back through the tack and it picked up on the tires. Also, wind had blown dust across the surface during the night. CSS-1H was the only asphalt emulsion available for use.

CONSTRUCTION TESTING

Iowa DOT research personnel performed pre and post construction tests on this project. The tests included rut depth measurements, Road Rater™ (a nondestructive testing device) structural measurements, beam and cylinder strengths, core shear strengths, slump, and entrained air. The air, slump, and strength test results are shown in Table 3. The shear strengths are shown in Table 4.

DISCUSSION

Testing

The Road Rater™ was used to determine the structural rating of the pavement, both before and after the overlay was placed. Two areas of the project were rated prior to construction. Each was 1.6 km (1.0 mi) long. The structural ratings (SR) were 2.30 and 2.23. Since these numbers are very similar, it is assumed they represent the condition of the old ACC on which this project was constructed.

Cores taken from the whitetopped pavement were used to determine the shear strength of the bond at the concrete/asphalt interface. Once this testing was completed, the thickness of the concrete was measured. The shear strengths and the PCC thicknesses are shown in Table 4. The measured SRs of the whitetopped pavement are shown in Table 5.

The 25 Foot California Profilograph was used to measure the smoothness of the completed overlay. Test results are shown in Table 6.

Structural capacity determination, crack survey, and smoothness measurements will be taken annually for three years and again after five years.

Broken Cores

A number of cores could not be tested for shear strength because the PCC was not bonded to the ACC, or in some cases, the ACC was broken into pieces. Apparently some cores had been taken over cracks in the ACC or cracked areas. The structural ratings generally were not measured near these core areas. The Iowa Department of Transportation will continue to monitor the overlay for five years so any weakness that may be present, as indicated by the broken cores, will be evaluated. The cores that could not be tested are indicated with a dash in Table 4.

High Bond Strength

The average shear strengths at the bond interface of the cores tested in each test section are listed in Table 7. Four sections demonstrated an average shear strength significantly greater than the other sections. Of those, three were milled prior to PCC placement. The other was the broomed section which was air blasted just prior to placement. The other three milled sections produced shear strengths which were in the midrange of all strengths. It appears milling yielded better shear strength and air blasting also aided in increasing that strength.

Lowest Bond Strength

The section where a tack coat was applied yielded a significantly poorer bond than the other sections. Having like electrical charges, the cationic emulsion and limestone in the concrete may have inhibited bond strength. The tack picked up on the truck tires and the dust blown onto the surface of the tack may also have contributed to the reduced bond strength.

Structural Contribution of Old ACC

Iowa uses the Road Rater™ as a nondestructive testing device to measure the pavement structure. Measurements are reported as structural ratings (SR). During the original calibration of the Road Rater™, a calibration coefficient of 0.5 was developed for new PCC pavement. It can be used to convert between SR and effective thickness. The Road Rater™ measurements are taken along outside wheel tracks. Two of the three sample cores also were taken in this location in each test section. The lengths of the PCC portion of these two cores were averaged and are shown in the second column of Table 5. A theoretical structural rating was then determined for this average value and is shown in the third column. The average measured SR for the whole test section is shown in column four. This is the SR for the total whitetopped section, which includes both the PCC overlay and the old, underlying ACC. If the PCC SN is subtracted from the total SR (column 4 minus from column 3), the result is the theoretical SN for the contribution to the structure by the old ACC. This value is shown in the fifth column.

These values, which represent the contribution of the old ACC, are very significant. They demonstrate that in all sections, sufficient bond has been developed for the ACC to contribute to the structure, regardless of bond enhancement.

The SR for the ACC prior to construction was 2.30 and 2.23. The contribution of the ACC to the whitetopped section ranged from 1.70 to 0.97. Therefore, not all the ACC structure is utilized as structure in the new whitetopped pavement. But, it shows that in all but two sections, the SR of the contribution of the old ACC is more than half the SR of the original ACC pavement.

Design Methodology

One aspect of this research was to determine what methodology is appropriate for whitetopping.

Iowa's current whitetopping design methodology considers the ACC as support for the PCC pavement. In this research, pavement structure was measured before and after the placement of the overlay. These tests revealed a partial contribution to the structure of the overlayed pavement by the original ACC pavement.

Bonded overlay design methods, on the other hand, consider the original pavement and the overlay to be monolithic. In a bonded overlayed pavement, the structure is the sum of the effective contribution of the original pavement and the overlay.

Neither Iowa's whitetopping design procedure nor current bonded overlay methods are appropriate for whitetopping design. A new design methodology is needed which considers the PCC to ACC bond at the interface as well as utilizes the partial contribution of the existing ACC structure.

Bonding Enhancement

The test sections of this research were constructed to determine what bond enhancement techniques were most effective. As discussed above, milling and air blasting tend to increase the shear strength.

Bond Importance

When the data were analyzed, a very interesting feature became evident. There were four sections which had superior shear strengths. When the sections which demonstrated the highest utilization of the underlying ACC were ordered from best to least (Table 7), none of the top four shear strength sections were among the top five in highest contribution of the old ACC. In fact, the section with the best average shear strength yielded the second smallest contribution of effective thickness of the old ACC.

When this research was begun, it was assumed that bond was the key factor in the degree of utilization of the underlying ACC. Instead, it was discovered that a high structural contribution of the existing ACC does not correspond to a high shear strength at the PCC/ACC interface. The bond enhancing techniques have been evaluated but they are not necessary in order to develop adequate bond.

Both the old ACC and new PCC overlay do contribute to the structure. The only bond necessary is that which anchors the PCC to the old ACC in order to utilize some of the underlying structure. This discovery is very significant. It provides insight into why over 420 km (260 mi) of whitetopping in Iowa, which have not utilized bond enhancement techniques, have been very successful. Some of these projects are now fifteen years old.

CONCLUSIONS

1. The tack coat may reduce bond strength when a cationic emulsion is used.

2. The sections which utilized cement and water grout demonstrated no significant advantage in bond strength or contribution of the old ACC when compared with all test sections. Thereby, the use of grout would not justify the extra handling problems and the interference with the paving operation.

3. Milling and air blasting are techniques which generally produced enhanced bond strengths.

4. Bond strength did not directly relate to the structural contribution of the existing ACC. The bond enhancement techniques evaluated in this research could increase the bond but that increase did not relate to increased structure.

5. Current bonded overlay design procedures are not appropriate for whitetopping. On the other hand, the existing ACC does contribute to the structure without special surface preparation and a structural contribution from the ACC should be considered in the overlay thickness design. This research

would suggest that conservatively one-half of the existing ACC contributes to the structure of the final composite pavement.

FUTURE RESEARCH NEEDS

This research established that the ACC does contribute to the structure of the final whitetopped pavement. The degree of this contribution can be determined for this project, but further study is needed to determine what the contribution to the structure of the final pavement will be for various thicknesses of existing ACC. This will then allow proper design techniques to be used for whitetopping design.

Even though bond was achieved in all sections, higher traffic loadings may produce stresses which exceed the stress limits of that bond. Research is needed to determine the limits of traffic loadings as they relate to bond strength. This would provide an upper limit for traffic loadings past which the ACC could not be utilized as part of the pavement structure.

ACKNOWLEDGEMENT

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We want to extend our appreciation to the Dallas County Board of Supervisors, the Iowa Department of Transportation, the Iowa Concrete Paving Association and Cedar Valley Corporation for their support in the development and implementation of this project.

DISCLAIMER

The contents of this report reflect the views of the authors and do not necessarily reflect the official views of the Iowa Department of Transportation. This report does not constitute any standard, specification or regulation.

TABLE TITLES

TABLE 1

SECTION DESCRIPTIONS

SECTION	SURFACE PREPARATION	BONDING AGENT	PLANING	PCC DESIGN NOMINAL THICKNESS, cm	MIX
2	Broomed	None	No	13	B
3	Milled	None	No	10	B
4	Milled	None	No	10	C
5	Milled	None	Yes	10	C
6	Broomed	None	No	10	C
7	Broomed	None	No	13	C
8	Broomed w/air blast	None	No	13	C
9	Milled	None	No	13	C
10	Milled	None	Yes	13	C
11	Milled	Cement & Water Grout	No	13	C
12	Broomed	Cement & Water Grout	No	13	C
13	Broomed	Tack Emulsion	No	13	B

1 cm = 0.394 in   10 cm = 4 in   13 cm = 5 in

TABLE 2

CONCRETE PROPORTIONS

MIX No.	Cement kg per m^3	Fly Ash (Class C) kg per m^3	Fine Aggregate kg per m^3	Coarse Aggregate kg per m^3	Air Entr. Admix. ml/kg	Water Reducer Admix. ml/kg
B-4-C	248	44	952	938	0.54	----
C-4WR-C	298	56	933	914	0.56	2.6

1 kg/m^3 = 1.686 lbs/yd^3

1 ml/kg = 0.015 oz/lb

---- not used

TABLE 3

STRENGTH TEST RESULTS

Section	Sample ID	Mix	% Air	Conc. Slump (cm)	28-Day Compression Strength (MPa)	28-Day Flexural Strength (MPa)
2	25-1-A	B	7.4	6.5	23.2	4.34
2	25-2-A	B	6.0	5.5	26.8	4.52
3	25-3-A	B	6.3	5.0	26.5	4.60
4	25-1-B	C	7.2	6.5	27.8	4.75
5	25-2-B	C	7.5	6.5	28.4	4.75
6	25-3-B	C	9.5	7.5	26.3	4.56

Flexural Strength is centerpoint loading

1 cm = 0.394 in

1 MPa = 145 psi

TABLE 4A

CORE INFORMATION

Section	Core No.	Lane	Lateral Location	Measured Core Length (cm) ACC	Measured Core Length (cm) PCC	Shear Strength (kPa)
2	1	SB	1/4 PT	13.5	12.7	----
	1B	NB	OWP	15.0	12.4	950
	2	SB	OWP	13.2	10.2	----
	3	NB	OWP	15.2	13.0	----
3	4	NB	OWP	7.6	11.4	1500
	5	NB	OWP	15.2	10.7	1100
	6	SB	1/4 PT	13.2	11.4	1300
4	7	NB	1/4 PT	14.0	11.2	1350
	8	SB	1/4 PT	13.0	11.2	1250
	9	SB	OWP	13.7	11.7	950
5	10	NB	OWP	14.0	12.2	2350
	11	NB	1/4 PT	12.2	12.4	1050
	12	SB	OWP	14.7	12.4	1100

TABLE 4B

CORE INFORMATION

Section	Core No.	Lane	Lateral Location	Measured Core Length (cm) ACC	Measured Core Length (cm) PCC	Shear Strength (kPa)
6	13	SB	1/4 PT	12.4	9.2	650
	14	SB	OWP	17.3	10.9	1000
	15	NB	OWP	2.0	11.2	----
7	16	NB	OWP	15.2	14.5	1300
	17	NB	1/4 PT	15.2	13.3	----
	18	SB	OWP	12.7	13.7	250
8	19	NB	OWP	15.2	13.7	1850
	20	SB	OWP	14.5	12.7	900
	21	SB	1/4 PT	13.5	12.2	750
9	22	NB	OWP	16.0	13.0	1050
	23	NB	1/4 PT	15.2	13.0	950
	24	SB	OWP	14.0	13.0	800

TABLE 4C

CORE INFORMATION

Section	Core No.	Lane	Lateral Location	Measured Core Length (cm) ACC	Measured Core Length (cm) PCC	Shear Strength (kPa)
10	25	SB	OWP	15.2	15.2	850
	26	SB	1/4 PT	14.0	16.5	1100
	27	NB	OWP	15.5	15.0	800
11	28	NB	OWP	15.7	14.0	950
	29	NB	1/4 PT	15.2	11.4	1050
	30	SB	OWP	12.4	16.0	----
12	31	NB	OWP	14.5	13.5	1200
	32	SB	1/4 PT	16.8	11.7	650
	33	SB	OWP	16.5	14.0	----
13	34	NB	OWP	14.5	13.0	650
	35	NB	1/4 PT	13.5	12.0	450
	36	SB	OWP	9.7	14.2	700

1 cm = 0.394 in   1 kPa = 0.145 psi   ---- Broken Core

TABLE 5

STRUCTURAL RATING

Section	Avg. PCC Thickness (wheel path, cm)	Theoretical Structural No. From PCC Thickness	Average Measured Structural Rating of Whitetopped Section	Structural No. of Contribution From Original ACC
2	12.6	2.48	3.86	1.38
3	11.0	2.16	3.31	1.15
4	11.4	2.24	3.38	1.14
5	12.3	2.42	3.50	1.08
6	11.0	2.16	3.70	1.54
7	14.1	2.78	4.03	1.25
8	13.2	2.60	3.95	1.35
9	14.2	2.80	4.31	1.51
10	15.1	2.97	4.76	1.79
11	15.0	2.95	4.21	1.26
12	13.7	2.70	4.16	1.46
13	13.6	2.68	3.65	0.97

1 cm = 0.394 in

TABLE 6

PROFILOGRAPH TEST RESULTS

	Profile Index (cm/km)*
Northbound	4.5
Southbound	5.0

*25 Foot California Profilograph

1 cm/km = 0.634 in/mi

TABLE 7A

CONTRIBUTION OF OLD ACC AND SHEAR STRENGTH BY SECTION

(Rank Order - Highest to Lowest)

Section	Contribution of Old ACC (SN)	Average Shear Strength (kPa)	Section	Contribution of Old ACC (SN)	Average Shear Strength (kpa)
10	1.79	900	5	1.08	1500
6	1.54	800	3	1.15	1300
9	1.51	950	8	1.35	1200
12	1.46	900	4	1.14	1150
2	1.38	950	11	1.26	1000
8	1.35	1200	2	1.38	950
11	1.26	1000	9	1.51	950
7	1.25	800	12	1.46	900
3	1.15	1300	10	1.79	900
4	1.14	1150	6	1.54	800
5	1.08	1500	7	1.25	800
13	0.97	600	13	0.97	600

1 kPa = 0.145 psi

FIGURE CAPTIONS

1. Test Method No. Iowa 406 Test Collar
2. Test Sections Layout

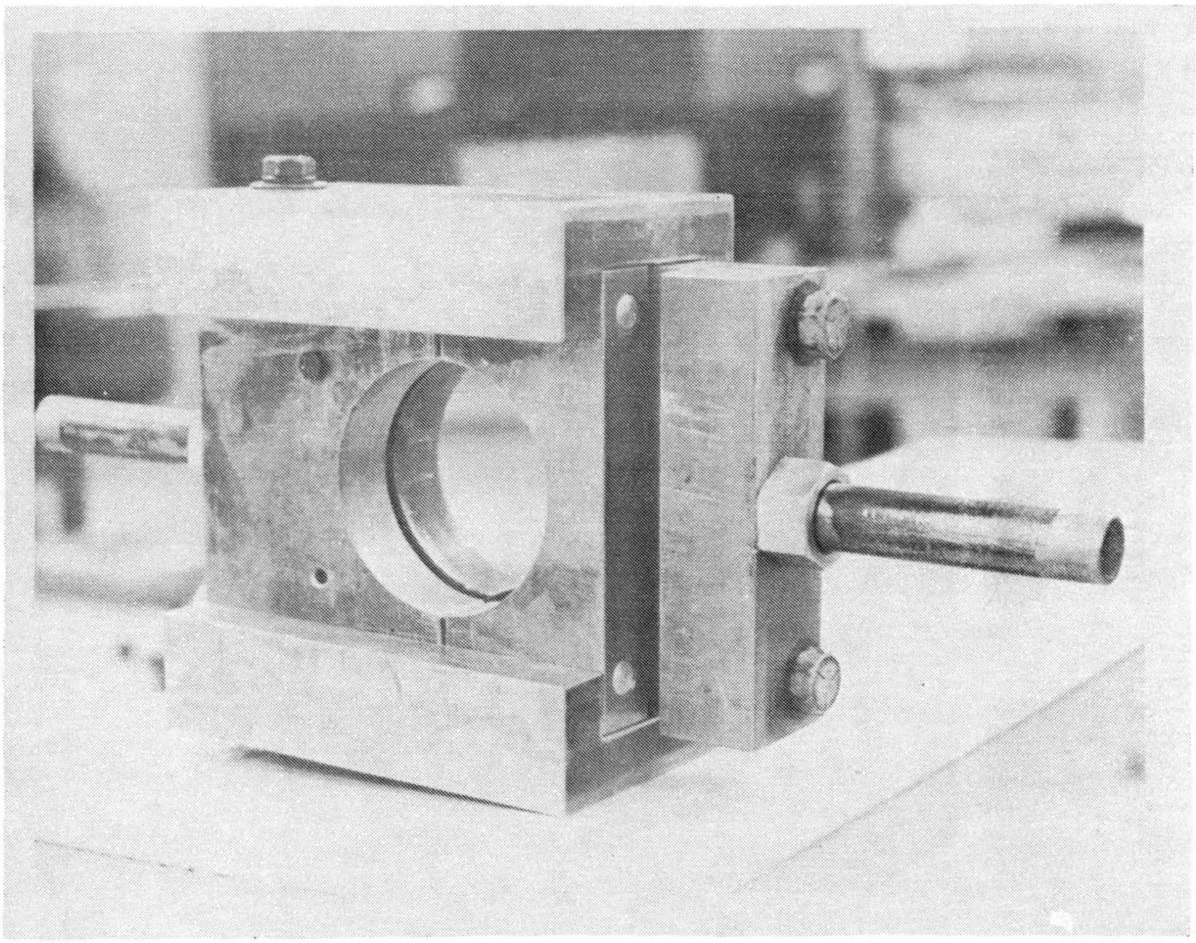

FIGURE 1

Test Method No. Iowa 406 Test Collar

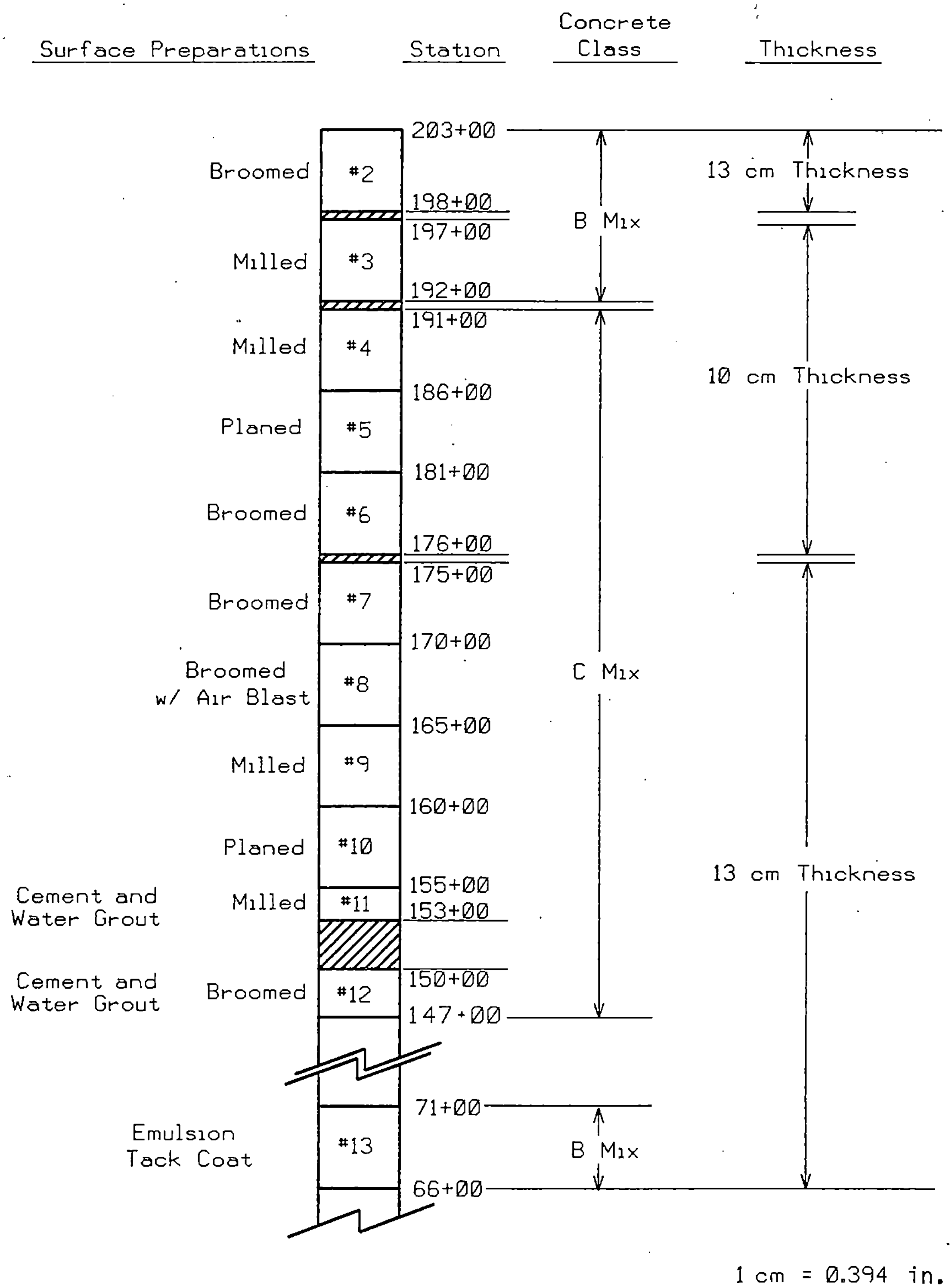

FIGURE 2

Test Sections Layout