EPOXY COATED REINFORCING STEEL IN BRIDGE DECKS

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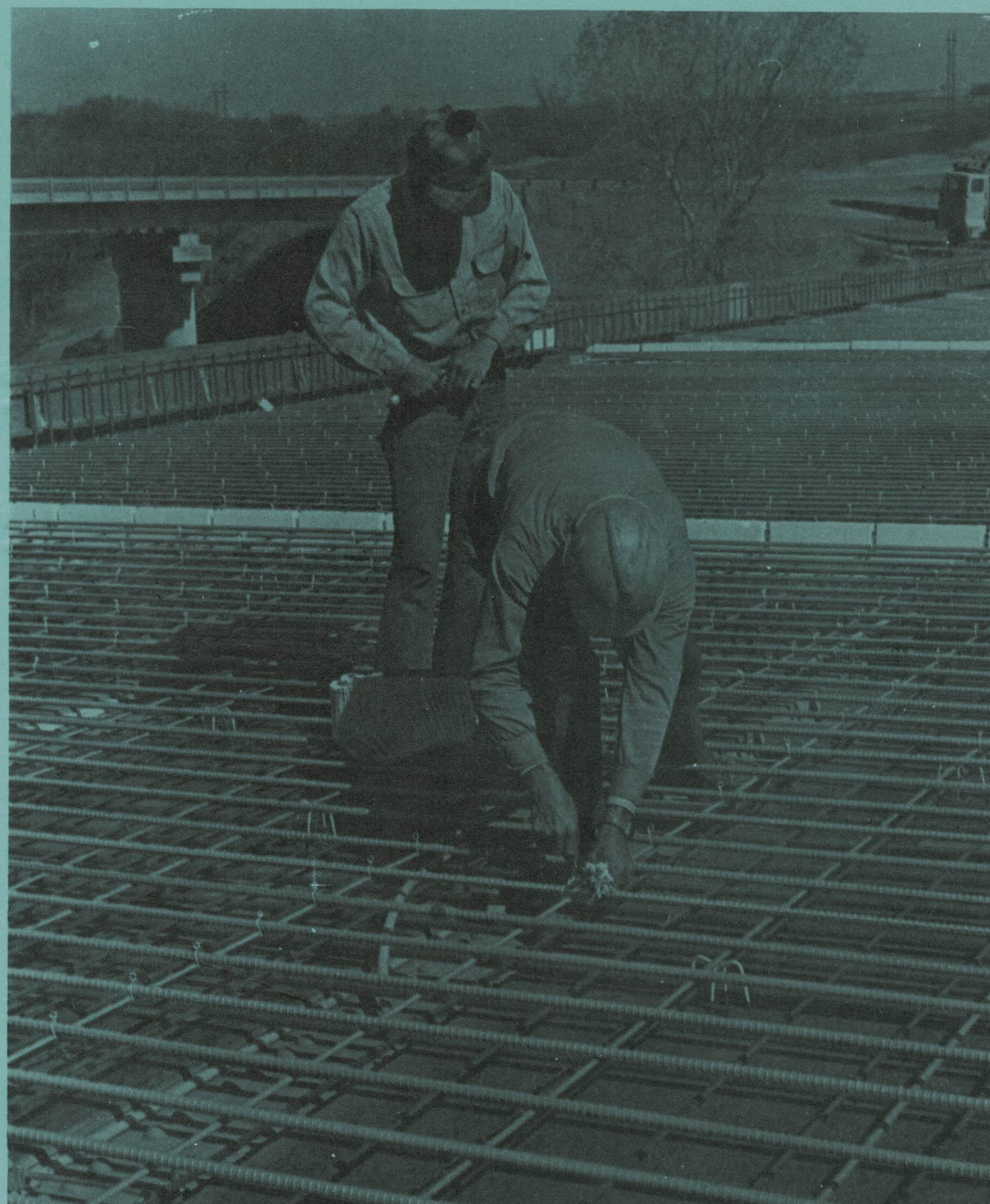

RESEARCH AND DEVELOPMENT DIVISION
OKLAHOMA DEPARTMENT OF TRANSPORTATION

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16. ABSTRACT

The objective of this project is to study the application of fusion-bonded epoxy coatings of rebars in bridge decks. A thin film of epoxy resin is fusion bonded to the reinforcing steel as a prevention against corrosion. A monitoring system was established to measure electrical resistance for several years after installation.

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EPOXY COATED REINFORCING STEEL IN BRIDGE DECKS

By

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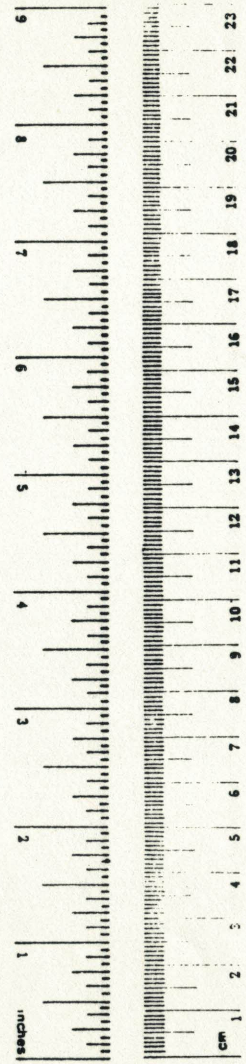
November, 1981

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

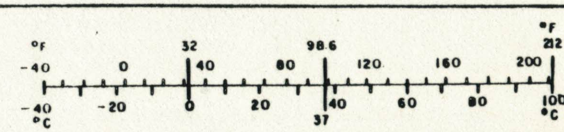
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

In the absence of preventive measures, the deterioration of concrete bridge decks can be a rapid process. The numerous variables causing this behavior include: poor quality control of concrete, construction practices, improper drainage systems, use of deicing salts, and the natural environmental exposure. Concrete being inherently a porous material, falls prey to freeze-thaw damage.

The reinforcing steel ("rebars") used in the bridge decks is an active (anodic) metal. Reinforcing steel is readily susceptible to corrosion due to its own metallurgical non-homogeneity, particularly with respect to oxygen and moisture concentrations. Under these conditions aerated wet concrete acts as an electolyte in spite of high pH (12.5-12.8). Chloride ions, present due to the salting of the bridge deck, break the existing passive film (tightly bonded layer of metal oxide on the surface of the rebar) and accelerate the corrosion activity.

The effective strength of the steel drops because of the material lost to the corrosion product (rust) and since this corrosion product occupies about twice as much volume as the parent material, very high pressure due to expansion is exerted locally. Pressures developed in excess of the compressive and tensile strength of the concrete result in local disintegration, thus creating a weak spot internally in the deck. With the passage of time, this process propagates away from the bar and eventually reaches the deck surface.

Freeze-thaw damage, through a different mechanism, also results in disintegration of the concrete but the damage propagates from the deck surface towards the reinforcing steel. The net effect of both the processes is to weaken the concrete and increase its porosity. An increase in porosity lets more salt and water percolate down into the deck. This forces the corrosion activity to proceed at a much faster rate and also increases the volume of the deck vulnerable to freeze-thaw deterioration. Both the activities aid each other in escalating their respective destructive attack on the deck and consequently the deck fails structurally and its replacement is necessitated.

A recent survey by the General Accounting Office (GAO) identified 32 states with 162,622 Federal-aid system bridges having a moderate to severe bridge deck problem. GAO estimated that about $6.3 billion are needed to restore these bridges. These figures indicate an average cost to restore each bridge is about $38,740. Based upon an average of 38 states (Better Roads, January 1980 issue), it is estimated that there is a total of about 635,000 bridges in the nation. If 40% of these bridges are assumed to be in distress, based upon the above restoration cost per bridge it will take about $10 billion to restore these bridges. Even after incurring such an expense, the present day rehabilitation procedures provide no technical guarantee that the restoration will be effective for more than a decade.

For a bridge, under simultaneous attack of corrosion and freeze-thaw, it is difficult to proportion the respective rehabilitation costs. This is due primarily to the lack of a clear understanding of the inter-action mechanism involved under such conditions. For all the bridges in distress nationwide, one can estimate the rehabilitation cost from corrosion alone to be in billions of dollars. During the 1979 FCP annual meeting, Kenneth C. Clear (FHWA), indicated that presently annual maintenance costs of bridge decks damaged by reinforcing steel corrosion are over $150 million. Both, the rehabilitation and maintenance costs are very high and should call attention to controlling the variables responsible for such high costs. Present day technology provides preventive techniques which can be adopted for both new decks and those old structures which require deck replacement. These techniques generally include use of impermeable concrete, membranes, steel coatings, heat pipe, and cathodic protection systems. Further evaluation and continued research is still warranted in each area.

Purpose

Epoxy coated rebars fall in the category of coating steel as a prevention against corrosion. A thin film 7 ± 2 mils (0.18 mm ± 0.05 mm) of epoxy resin is fusion bonded to the reinforcing steel. How long this film can stay intact and continue to protect steel from corrosive influences needs to be evaluated. This investigation is aimed at that goal.

Site Description

The project site is a rehabilitated bridge on I-35, north bound lanes over Cow Creek, located one mile south of the Perry exit in Noble County, Oklahoma. Figure 1 (all photographs are in Appendix B) shows the exact location. The average daily traffic count in 1979 for this section of I-35 was 4800 vehicles in one direction. The original bridge was built in 1959 and it was overlayed with asphaltic concrete in 1967. Chloride evaluation done in October 1976, indicated that the salt content at the steel depth (top mat) averaged 4.6 lbs/cu. yd. (274 kg/m^3) and ranged from a minimum of 1.4 lbs/cu. yd. (0.83 kg/m^3) to a maximum of 7.6 lbs/cu. yd. (4.52 kg/m^3). These figures are based upon 16 samples.

In 1978, the Bridge Division of the Oklahoma Department of Transportation (ODOT) rated the bridge deck condition at 1, in a range of 0-10, (10 being a new deck in excellent condition). It was decided to rehabilitate the bridge. Rehabilitation included one additional pier, a new wider deck, and use of epoxy coated rebars for the top steel mat. The construction was completed in April, 1979, and the bridge opened to traffic. The deck is 40 ft. (12.2 m) wide and 270 ft. (82.3 m) long and skewed at 45°. The deck slab has a thickness of 8 1/4 in. (210 mm).

CONSTRUCTION

Coating Material

The epoxy resin used for coating the reinforcing steel is manufactured by the 3M Company and is marketed under the trade name of SCOTCH KOTE 213. Product data for this epoxy resin and recommended specifications for its application to reinforcing steel, published by the 3M Company, are presented in Appendix A. The Oklahoma Department of Transportation (ODOT), Special Provision 511-1(a-c), dated 2-24-78, stipulating the specifications for the epoxy coated reinforcing steel and the certificate of compliance with these provisions, issued by the Materials Division of ODOT, are included in Appendix A. Compliance with these Special Provisions is mandatory for an epoxy resin system installed in Oklahoma.

Installation

After the epoxy coated rebars, wires, and chairs were tested according to Oklahoma Standard Specification for Highway Construction, they were shipped to the project site. The handling and shipping of the coated material (Figures 3 to 8) and surface preparation of the bridge deck (Figure 9) was done according to ODOT Special Provision 511-1(a-c). See Appendix A. To protect the epoxy coating, padded slings and straps should be used along with wooden cribbings. The coated rebars were placed on the deck using epoxy coated supports and wires (Figures 10, 11, and 12).

The longitudinal rebars are No. 4 and transverse bars are No. 6. All epoxy coated steel rebars in the top mat were supported on epoxy coated high chairs. The uncoated bottom mat was supported on approved metal low chairs with no epoxy.

The clearance of the top mat is 2 1/2 inches (63.5 mm) below the deck surface (Figure 9).

Styrofoam blocks were used to cover the cell components during the concrete pouring (Figures 15 and 16). The connections were covered with caulking material in order to protect them from weathering (Figures 25, 26, and 27).

The bridge deck was poured and finished by standard procedures according to ODOT Specifications Section 502 (Figures 17, 18, 19, and 20). The concrete had a 2 to 3 inch (51 to 76 mm) slump (Figure 21). The air content of the plastic concrete was about 6 percent (Figure 22). Three cylinders were made for strength determinations (Figure 23). The cylinder strengths ranged from 3930 lbs/in^2 to 5590 lbs/in^2 (27.1 to 38.5 MPa) with an average of 5019 lbs/in^2 (34.6 MPa) at 28 days.

<u>Monitoring System</u>

Six coated rebars selected at random had copper conductors tied to them (Figures 13, 14, and 15) in order to measure resistance after installation. The copper wires were placed parallel and close to the bars. The two epoxy coated rebars and the two inner copper wires constitute a measurement cell (Figure 33). Each cell is used to evaluate the stability of the epoxy resin coating. The various resistances are measured by means of a BARNSTEAD, Model PM 70CB, A.C. conductivity bridge meter (Figure 30).

The a.c. measurement of all the resistances shown in Figure 34 are to be taken once a month and this schedule of measurement will continue until 1984.

For the sake of staying consistent with the type of data taken nationwide concerning epoxy coated rebars, wet mop a.c. resistance measurements will also be taken. Fourteen additional bars were at random chosen for the purpose of wet mop measurement and direct electrical connection with the lead wires was made on the west side of the bridge and connected to the junction box (Figures 24, 28, and 29).

The measurements are to be taken every six months until 1984. Figures 31 and 32 show a typical wet mop apparatus. The completed bridge deck was opened to traffic in May, 1979 (Figure 2).

The data collected so far from both the measurement cells and the wet mop procedure is presented in Appendix C.

Discussion

In order to determine the performance of epoxy coated rebars imbedded in Portland cement concrete, a monitoring system needed to be established. According to J. R. Clifton, et. al., (1) resistance measurements are probably more reliable indicators than electrical potential measurements. The resistance values are primarily dependent on the integrity of the coating films. Figure 34 shows a general arrangement of a typical measurement cell that will be used to evaluate the stability of the epoxy film. The rebars B1 and B2 are epoxy coated transverse bars. The bare copper wires C1 and C2 are placed parallel to the rebars B1 and B2 respectively. Resistance B1C1 or C2B2, measured between the epoxy rebar and the copper conductor, will indicate how well the epoxy film is performing.

The resistance readings other than B1C2 and C2B2 in the network should help in judging the accuracy of each resistance measurement.

Resistance C1C2 between the two copper wires will normally indicate the moisture content in the bridge deck. An increase in C1C2 resistance indicates a moisture decrease in the bridge deck or vice versa.

There are several mechanisms that could alter resistance readings. A rapid decrease in resistance can be attributed to emergence of "holidays", which are pinholes in the coating not normally visually discernible. An increase in resistance is a possible indication of some type of holiday healing mechanism (1). The peak in resistance readings noted in Appendix C indicates such an increase. Other possible explanations include the thorough drying of the deck - January is the driest month.

It is also possible that the freezing of the remaining free water in the voids in the concrete may raise the resistance - January is also the coldest month. The flat portion of the curve indicates stable conditions within the deck.

Problems

There were no problems encountered during application, fabrication, shipping, or handling of epoxy coated rebars. The installation and concrete pouring was accomplished without any difficulty. Epoxy paint was applied by hand to a few epoxy coated reinforcing steel rebars which were damaged during shipping and handling (Figure 12).

COST SUMMARY

The table below reflects the costs of the epoxy rebars. It also includes the costs for the materials involved with the cell measurement procedures.

Item	Quantities	Unit	Unit Price	Total
Standard Rebars	33,760	lb.	$.28*	$ 9,453
Epoxy Coated Rebars	34,220	lb.	$.70*	$23,954
Class AA Concrete	102.1	c.y.	$170*	$17,357
Miscellaneous				$ 100
Conductivity Bridge Meter				$ 444 ea.

* Lowest bid as of May 1978.

CONCLUSION AND RECOMMENDATION

There seemed to be no unusual difficulties in the procurement or installation of epoxy-resin coated reinforcing steel in a bridge deck. Although long term performance is not known, ODOT (Appendix C) feels that the inclusion of epoxy rebars in subsequent installations is desirable. The installation at Cow Creek will continue to be observed monthly for resistance readings.

Knowledge of the resistance readings will provide a means of determining the integrity of the epoxy coating. A failure in the coatings would signal the onset of deterioration. Hopefully, the manner and rate of decrease in resistance should be helpful in indicating the life of the bridge deck.

REFERENCE

1. J. R. Clifton, H. F. Beeghly, and R. G. Mathey, Nonmetallic Coatings for Concrete Reinforcing Bars, Report No. FHWA-RD-74-18, Federal Highway Administration, Washington, D.C. (1974).

APPENDIX A

SPECIFICATIONS

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS
FOR
EPOXY COATED REINFORCING STEEL

These Special Provisons revise, amend, and where in conflict, supersede applicable Sections of Standard Specifications for Highway Construction, 1976 Edition.

511.02 MATERIALS (Add the following) Epoxy Coated Reinforcing Bars. These special requirements cover organic protective coatings electostatically applied to steel bars, which meet the requirements of Section 723, and are to be used for concrete reinforcement.

(a) Coating Material. A list of prequalified coating materials may be obtained from the Materials Division. The prequalification testing is performed by the National Bureau of Standards to Specifications of the Federal Highway Administration.

The powdered resin shall comply with the specifications of the manufacturer and shall be of the same composition and quality as the resin samples submitted to and approved by the National Bureau of Standards.

The manufacturer of the powdered epoxy resin, hereinafter called the manufacturer, shall supply to the coating applications company, hereinafter called the applicator, essential information on the proper use and performance of the resin as a coating. The manufacturer shall also furnish the applicator written certification signed by a responsible officer that the material furnished for coating reinforcing bars is the same formulation approved by the National Bureau of Standards for prequalification.

The applicator shall supply to the Department two representative samples of four (4) ounces each of the resin powder used to coat each given lot of bars. Each sample shall be packaged in an airtight container with identification by lot number.

(b) Coating Process. 1. General. The coating material shall be applied as recommended by the manufacturer in a smooth, uniform coat. The applicator shall make a trial run of the coating process to insure that the process meets the specificed requirements. All required tests shall be performed on the trial specimens before production is started on the reinforcing bars for the project. The applicator shall notify the Department's Bridge Division at least 30 days before the date of the trial run.

2. Surface Preparation. The surface of bars to be coated shall be clean and free from rust, scale, oil, and grease and similar surface contaminants. The surface shall be blasted to near white metal in accordance with the requirements of Section 506.04 (d)1.5 of the Standard Specifications. All traces of grit and dust from the blasting shall be removed.

The coating material shall be applied to the cleaned surface of the bars as soon as possible after cleaning and before visible oxidation of the surface occurs.

3. Coating Thickness. The thickness of the coating after curing shall be 7 ± 2 mils. Thickness of the coating film shall be measured on a representative number of bars from each production lot by the method outlined in ASTM G-12.

4. Curing. The coating film shall be fully cured. The applicator shall check a representative portion of each production lot by the method he has found most effective for measuring cure to insure that the entire coated production lot is supplied in a fully cured condition.

(c) Patching Material. The manufacturer shall supply suitable patching or repair material that is compatible with the coating and inert in concrete. Patching will be done in accordance with the manufacturer's recommendations and to the prescribed coating thickness.

(d) Continuity of Coating. The applicator shall check the coated bars after curing for continuity of coating. The coating shall be free from holes, voids, contamination, cracks, and damaged areas. A 67 1/2-volt holiday detector such as Tinker and Rasor Model M-1 or approved equivalent shall be used to check the coating for holidays. The shall be no more than two holidays (pinholes not visually discernible) in any linear foot of a coated bar. This holiday limitation will not apply to electrical contact points. Patching material shall be used to touch-up these contact points.

(e) Flexibility of Coating. The flexibility of coating will be evaluated by the Department Inspector on a representative number of bars selected from each production lot and subjected to the following bending test for acceptance of the lot:

The coated reinforcing bar to be tested shall be exposed to room temperature (77±9°F) for a sufficient time to reach thermal equilibrium. The bending test shall be conducted at room temperature.

The test specimen shall be bent 120 degrees (after rebound) around a pin having a diameter equal to eight times the bar diameter. The bend shall be made at a uniform rate and may take up to one minute to complete. The two longitudinal deformations may be placed in a plane perpendicular to the pin radius.

No cracking of the coating shall be visible to the naked eye on the outside radius of the bent bar.

(f) Accessories. Tie wire shall be plastic coated. Chairs, supports, and clips shall be one of the following:

1. Steel, fully coated with epoxy or plastic.
2. Galvanized steel, with the cradle and the upper three inches of the chair, support, or clip coated with epoxy or plastic.
3. The plastic or epoxy coating shall be of sufficient thickness to prevent physical damage to the coated rebars during installation. The coating of accessories will be visually inspected and approved by the Engineer prior to use.

(g) Inspection and Testing. The applicator shall furnish a Certificate of Compliance for each shipment of coated bars. The Certificate shall state that representative samples of the coated bars have been tested and that the test results comply with the requirements of this Subsection. Test results shall be retained and made available as provided in Section 9.1 of AASHTO M-218.

Sample lengths of coated bars may be taken by the Engineer from the production run at the point of coating application for testing and evaluation purposes.

511.04 CONSTRUCTION METHODS. (Add the following) Epoxy Coated Reinforcing Bars. (a) Fabrication. Where fabrication damages the epoxy coating, the fabricator shall repair the bars with patching material complying with the requirements given above for "Patching Material" in accordance with proceedures recommended by the manufacturer of the powdered epoxy resin.

(b) Handling. In order to protect epoxy coated reinforcing bars from damage, the Contractor shall use padded or non-metallic slings and padded straps for handling. The bars shall not be dropped or dragged and shall be stored on wooden cribbing.

(c) Placing Reinforcing Bars and Concrete. Accessories and hardware used for placing, supporting, or tying epoxy coated reinforcing bars shall comply with the requirements given above for "Accessories". Reinforcing shall be placed, supported, and tied carefully to avoid damage to the epoxy coating. Concrete shall be placed and vibrated with care.

(d) Patching. Sheared ends and other cuts and exposed areas shall be patched promptly before detrimental oxidation occurs. Areas to be repaired shall be clean and free from surface contaminants. Patching material shall be applied at the coating shop or fabricating shop or in the field, as required. Damaged areas shall be patched as soon as possible and before visible oxidation of the steel occurs.

Coating breaks on coated bars shall be patched if the total damaged area is not more than ten (10) percent of the total coated area. If more than ten percent of the total coated area of the bar is damaged it shall be rejected for use. Rejected materials shall be removed in accordance with Section 106.09.

511.05 METHOD OF MEASUREMENT. (add the following) Epoxy coated reinforcing steel will be measured by the pound, based on the theoretical number of pounds calculated on the nominal weight before application of the epoxy coating materials. No allowance will be made for the epoxy coating material, the coating process, accessories, or the testing required by the manufacturer or applicator as specified above.

511.06 BASIS OF PAYMENT. (add the following) The accepted quantities of epoxy coated reinforcing steel, as measured above, will be paid for at the contract unit price per pound for:

EPOXY COATED REINFORCING STEEL ----- LB

which shall be full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

RECOMMENDED SPECIFICATION FOR
PLANT APPLICATION OF
"SCOTCHKOTE" BRAND RESIN 213 ON
REINFORCING BARS

1.0 GENERAL

1.1 This specification covers the requirements for plant application of "SCOTCHKOTE" Brand 213 to reinforcing bars. "SCOTCHKOTE" is a product trademark of 3M Company.

1.2 The work includes the furnishing of all plant, labor, materials, tools and equipment, and the performance of all operations and incidentals necessary for the coating, handling, storing and shipping of plant coated reinforcing bars.

1.3 Coating materials shall be handled, stored, and applied in accordance with the manufacturer's specifications, or as directed by an authorized representative of the coating manufacturer.

1.4 All references to SSPC shall be interpreted as Steel Structures Painting Council.

1.5 All references to NACE shall be interpreted as National Association of Corrosion Engineers.

2.0 SURFACE PREPARATION

2.1 Prior to blast cleaning, surfaces shall be inspected and precleaned according to SSPC-SP1-63 to remove oil, grease and loosely adhering deposits. Visible oil and grease spots shall be removed by solvent wiping. Only approved safety solvents which do not leave a residue shall be used.

2.2 The exterior bar surface shall be blast cleaned to NACE near-white finish using steel grit after preheating of bar to sufficient temperature to remove all moisture.

NACE near-white finish is interpreted to mean that all metal surfaces shall be dry sand or grit blasted to remove all dirt, mill scale, rust, corrosion products, oxides, paint and other foreign matter. Very light shadows, very slight streaks or slight discolorations shall be acceptable; however, at least 95% of the surface shall have the uniform gray appearance of a white metal blast cleaned surface. Oil and grease shall be removed with a non-oily solvent prior to blasting.

2.2.1 The cleaning media shall be selected to achieve an anchor pattern profile of not less than 1.5 mils (.038 mm) nor more than 2.5 mils (.064 mm). Standards for comparison shall be made available by contractor.

2.2.2 For consistent surface finish a stabilized working mix of the cleaning media shall be maintained by frequent small additions of new grit commensurate with consumption; infrequent large additions shall be avoided.

2.2.3 The cleaning media working mix shall be maintained clean of contaminants by continuous effective operation of blasting machine scalping and air wash separators.

2.3 Prior to coating, the cleaned bar shall be inspected to ensure that all cleaning steps have been adequately performed. Presence of contaminants indicates a malfunction of the cleaning equipment, which shall be corrected immediately.

2.4 The cleaned bar surfaces shall be protected from conditions of high humidity, rainfall, or surface moisture. The bar surface shall not be allowed to flash rust before coating.

3.0 COATING APPLICATION

3.1 Bars which have been cleaned shall be preheated. The optimum bar temperature at the entrance of the coating station is between 450°F (232°C) and 463°F (239°C). The heat source shall not leave a residue or contaminant on the bar surface. Graduated "Tempilstik"* crayons may be used to measure the temperature. Only a small spot of bar shall be touched with the "Tempilstik". Optical pyrometers may be used in addition to, or in lieu of, "Tempilstik"s. The calibration of the optical pyrometer shall be checked at least twice daily. Oxidation of the steel prior to coating in the form of "blueing" or other apparent oxide formation is not acceptable. If such oxidation occurs, the bar shall be cooled to ambient temperature and recleaned.

3.2 "SCOTCHKOTE" 213 shall be applied to the bar at 7 ± 2 mils (.178 ± .05 mm) thickness (unless otherwise specified by the customer) using electrostatic spray. The powder shall be applied over the full length of the bar.

3.3 Seven (7) seconds after application at optimum coating temperature, the coated bar may be supported on wetted rubber rollers. The coated bar shall not be force cooled sooner than 28 seconds after the application of "SCOTCHKOTE" 213 at the optimum application temperature.

3.4 During the period of coating and curing, the bar shall be handled so as to avoid damage to the coating.

3.5 After the coating has cured it shall be cooled with air or water spray to a temperature not to exceed 250°F (121°C) for inspection and repair.

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*"Tempilstick" is a registered trademark of the Tempil Corporation.

4.0 INSPECTION

4.1 Upon completion of the coating operation, but prior to storage, the coating shall be inspected for continuity using a 67-1/2 volt DC detector to check for holidays, pinholes, and discontinuities.

4.2 The thickness of the coating shall be checked with a properly calibrated "Mikrotest" magnetic gauge.

5.0 COATING REPAIR

5.1 Bars requiring limited repair due to scars, slivers, coating imperfections and other minor defects shall be repaired as follows:

5.1.1 Areas requiring small spot repairs shall be cleaned to remove dirt, and damaged coating using surface grinders or other suitable means. All dust shall be wiped off. For pinholes only, surface preparation is not required other than removing surface dirt, oil, grease and other detrimental contaminants which impair the adhesion of the repair material.

5.1.2 The 100 percent solids liquid epoxy compound "SCOTCHKOTE" 309 shall be applied in small areas to a minimum thickness of 10 mils (0.254 mm). The freshly coated area shall be allowed to properly cure prior to handling and storage. Liquid epoxy shall not be applied if the pipe temperature is 55°F (13°C) or less, except when manufacturer's recommended heat curing procedures are followed. Alternatively, the heat bondable polymeric hot melt patch compound "SCOTCHKOTE" 202P shall be applied in small areas to a minimum thickness of 15 mils (0.381 mm). A non-contaminating heat source shall be used to heat the area to be repaired to approximately 350°F (177°C). While continuing to heat the cleaned and prepared area, the patch compound shall be applied by rubbing the stick on the area to be repaired in a circular motion to achieve a smooth neat appearing patch. The patch shall be allowed to cool before handling.

5.2 Bars with major coating defects such as partially coated joints, unbonded coating, or inadequate film thickness shall be set aside for a decision by the Purchaser to accept, repair or reprocess.

6.0 STORAGE, HANDLING & SHIPPING

6.1 Bars shall be handled and stored in a manner to prevent damage to bars or coating. Bars or coating damaged in handling or other operations shall be satisfactorily repaired.

6.2 Stacking in the yard shall be in accordance with good safety practices or in accordance with Purchaser's specifications. Sufficient spacers and padding shall be used to prevent damage to the bars and coating.

6.3 Bars will be transported from the coating yard to the jobsite by truck, rail or barge as specified in the purchase order. Bars shall be shipped using sufficient dunnage to adequately protect the bars and their external coating. Chains or steel bands shall not be used without sufficient padding to prevent damage to the coating.

6.4 Bars shall be loaded for shipping in compliance with existing shipping standards and regulations.

IMPORTANT NOTICE

All statements, technical information and recommendations contained herein are based on tests we believe to be reliable, but the accuracy or completeness thereof is not guaranteed, and the following is made in lieu of all warranties, express or implied:

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Electro-Products Division 3M COMPANY

3M CENTER · SAINT PAUL, MINNESOTA 55101

E-PS213-1(36.5)R

LITHO IN U.S.A.

PRODUCT DATA

Scotchkote® BRAND

213 FUSION BONDED EPOXY COATING

1. Product Description

"SCOTCHKOTE" Brand 213 Fusion Bonded Epoxy Coating is a one-part, heat curable, thermosetting powdered epoxy coating designed to provide maximum corrosion protection of pipe, girthwelds and rebars.

Features:

- Can be used on reel barge girthwelds, accepts bend without cracking
- Superior flexibility, exceeds FHWA bending requirements for rebars
- Self priming
- Economical
- Fast curing for high speed application
- Protects over a wide temperature range
- Long term storage in all climatic conditions
- Can be shipped with minimum damage
- Is not damaged by concrete imbedment
- Resistant to cathodic disbondment
- Lightweight for lower shipping costs
- Will not sag, cold-flow, or become soft in storage
- Easy visual inspection

2. Properties

Property	Value
Color	Green
Specific gravity	1.22
Coverage	156 ft²/lb/ mil thickness
	.724 m²/kg/ millimeter thickness
Gel time at 400°F (204°C)	5-8 seconds
Explosibility (minimum explosive concentration)	.03 oz/ft³ 30.6 gms/m³

3. General Application Steps

A. Remove oil, grease and loosely adhering deposits

B. Abrasive blast to NACE near-white

C. Preheat to approximately 450° F - 463° F (232° C - 239° C)

D. Deposit "SCOTCHKOTE" 213 powder electrostatically to the thickness required

E. Allow to cure according to Section 4

F. Electrically inspect for holidays after coating has cooled to 250° F (121° C) or lower

G. Repair all holidays

4. Cure Specifications

"SCOTCHKOTE" 213 must be cured according to the following schedule if maximum performance properties are to be achieved:

Application Temperature	Minimum Time to Quench
450° F - 463° F (232° C - 239° C)	28 seconds

Cure by residual heat, post bake normally not required; however, if applied at lower temperatures, or on light weight metal, additional curing may be necessary.

5. Test Data — Coating

FHWA APPROVED

Property	Test Description	Results
Impact	ASTM G-14-72 1/8 in. x 3 in. x 3 in. (.32 cm x 7.6 cm x 7.6 cm) steel panel 5/8 in. (1.6 cm) radius tup	Passes 160 in. lbs. (1.8 kg meters)
	FHWA-NEEP No. 16	Passes 80 in. lbs. (.9 kg meters)
Abrasion Resistance	ASTM D-1044 CS 17, 1000 gm wgt 5000 cycles	0.1013 gm loss
Penetration	ASTM G-17-72 -40° F to 240° F (-40° C to 116° C)	0

5. Test Data — Coating (Cont.)

Salt Crock	90 day, 5 volt, 5% NaCl	Disbondment dia. 37 mm average 35 - 40 mm range
	90 day, 1.5 volt 3% ASTM G-8-72 salt solution	Disbondment dia. 33 mm average 27 - 44 mm range
	FHWA-NEEP No. 16 2 volt 7% NaCl 30 days @ 70° F (21° C) No intentional holidays until last 24 hours	Anode: No disbondment Cathode: Slight disbondment around intentional holiday
Chemical Resistance	FHWA-NEEP No. 16 45 days @ 70° F (21° C)	
	3 molar (25%) CaCl	No blistering, cracking or peeling
	3 molar (10.7%) NaOH	No blistering, cracking or peeling
	Saturated $Ca(OH)_2$	Slight reduction in adhesion. No sign of blistering, peeling or cracking
Bendability	Weld seam bend	.325 in. (8.25 mm) wall pipe, .500 in. (12.7 mm) thick weld seam: Pass 9.2 Pipe diameters
	Rebar Bend	3.75 in. (95 mm) diameter mandrel, 1 minute bending time. Passes 180° at 20° F (-7° C)

6. Handling Precautions

As with any finely divided organic material, dust clouds of resin can be ignited by open flames or weak electrical sparks. Resin dust collection equipment should be provided with adequate explosion release. Adequate ventilation should be provided and possible sources of ignition should be eliminated. To avoid build-up of static electricity, equipment should be grounded.

Inhalation of the dust or of vapors arising during cure should be avoided.

Use only in well-ventilated areas. Many of the reactive materials used with epoxy resins have been reported to cause skin irritation to sensitive skin. If contact occurs, the skin should be washed with mild soap and water. In case of eye contact, flush immediately with water and secure medical attention.

Electro-Products Division
3M COMPANY
3M CENTER · ST. PAUL, MINNESOTA 55101

APPENDIX B

FIGURES

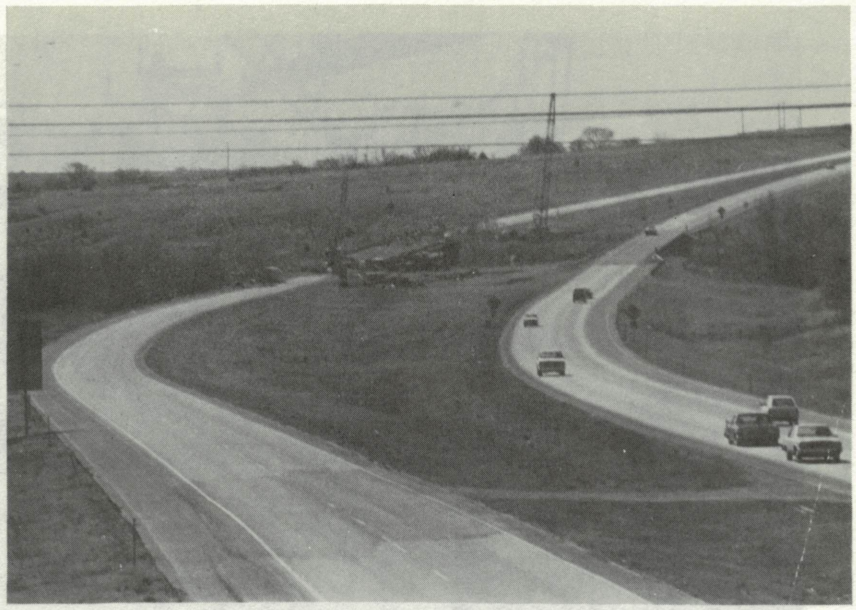


Figure 1: The project site is located on the northbound lanes of the Cow Creek Bridge on I-35 south of Perry, Oklahoma.

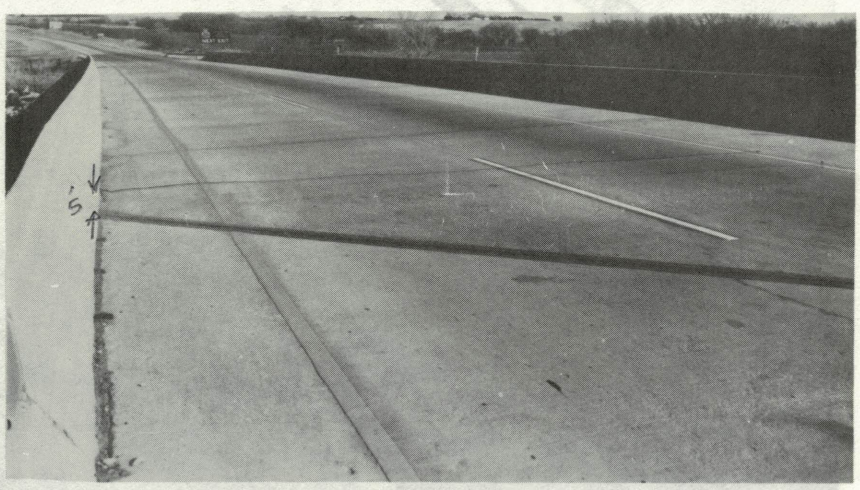


Figure 2: The completed bridge deck as it was opened to traffic.

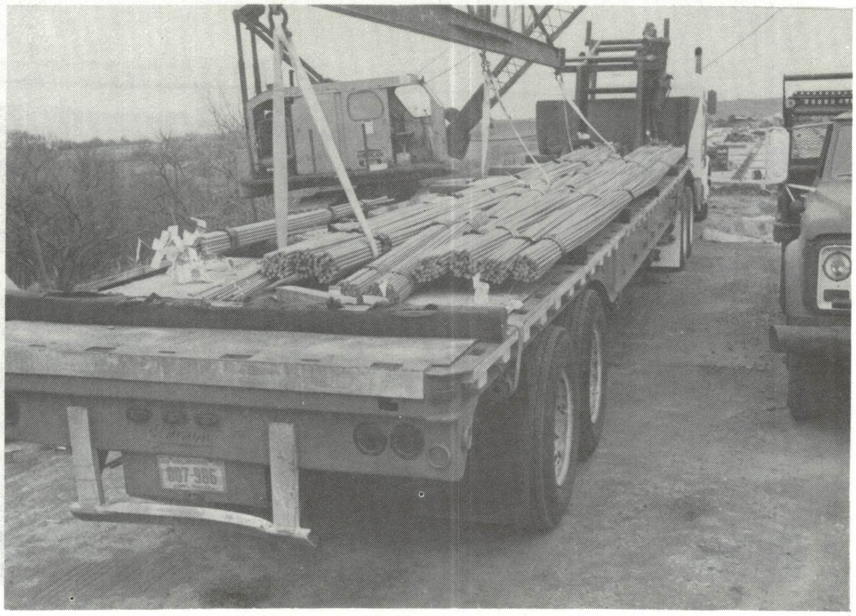


Figure 3: Epoxy coated rebars were shipped from a Tulsa firm on a flat bed semi-trailer truck. To avoid damaging the epoxy coating, the rebars were placed on carpet covered studs and held by nylon attached to the truck.

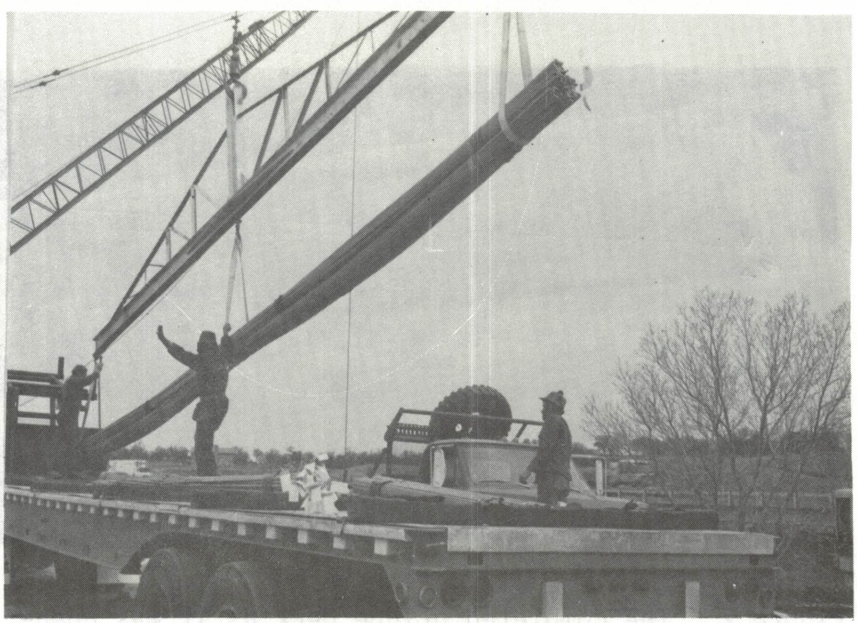


Figure 4: Unloading was accomplished by an overhead crane also using nylon slings.

Figure 5: Carefully guiding bundled rebars to the wooden beams.

Figure 6: Coated rebar bundles were shipped and stored on wooden 2 x 4's.

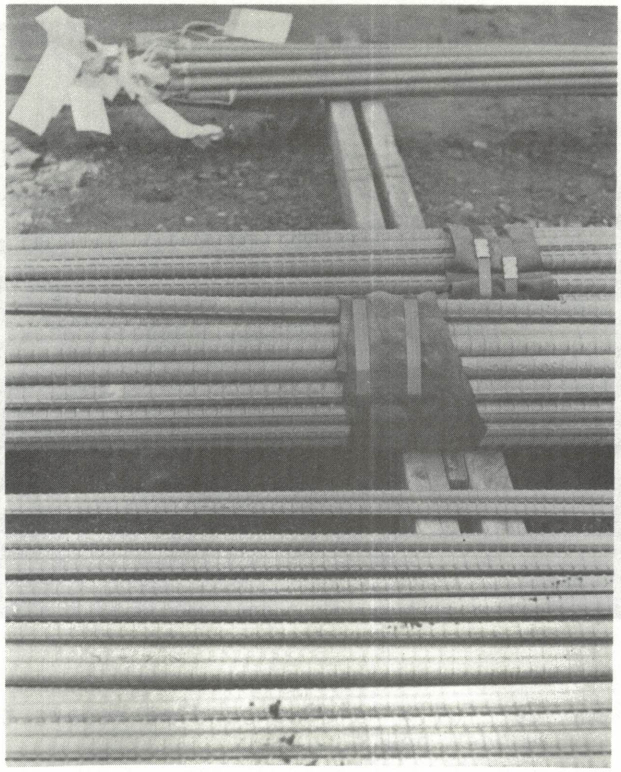


Figure 7: Individual rebar groups were bundled together with rubber sleeves and bound with steel straps. The only handling nicks found in the epoxy coatings were the few shown in this photograph.

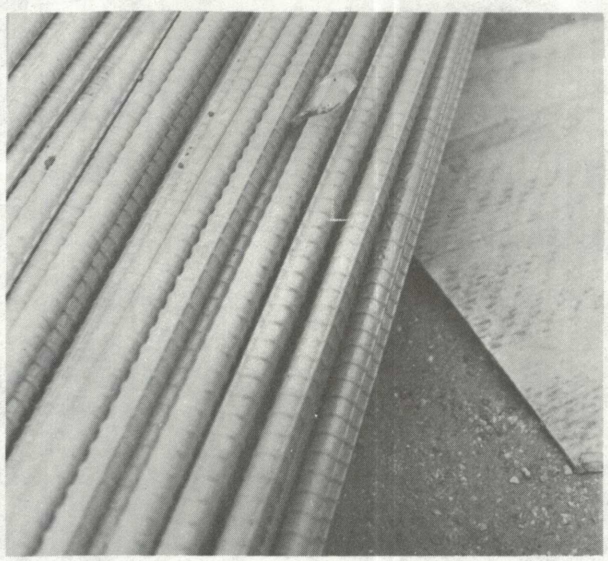


Figure 8: Debris such as pieces of glass, occasional dirt, and wooden slivers did not harm the coatings.

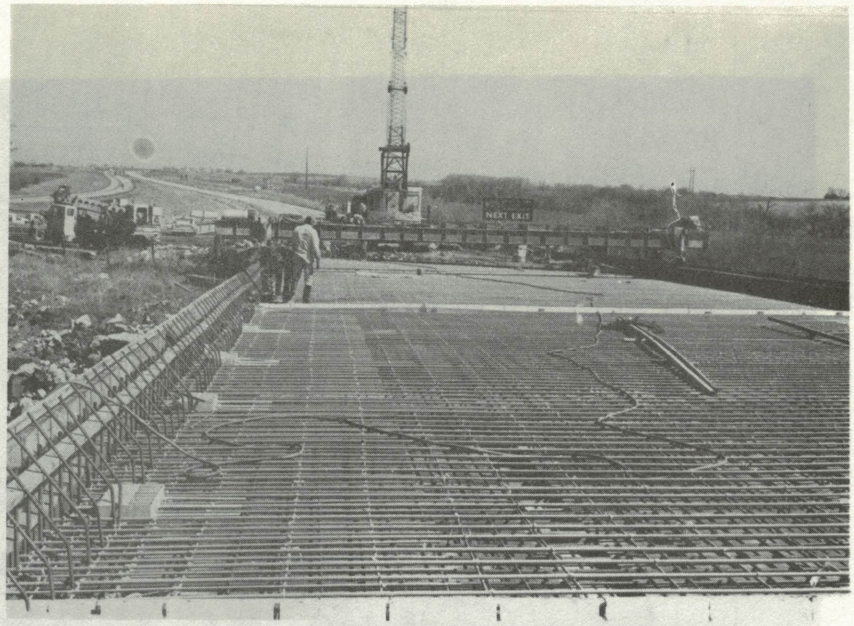


Figure 9: Overall view of the site while concrete was being poured.

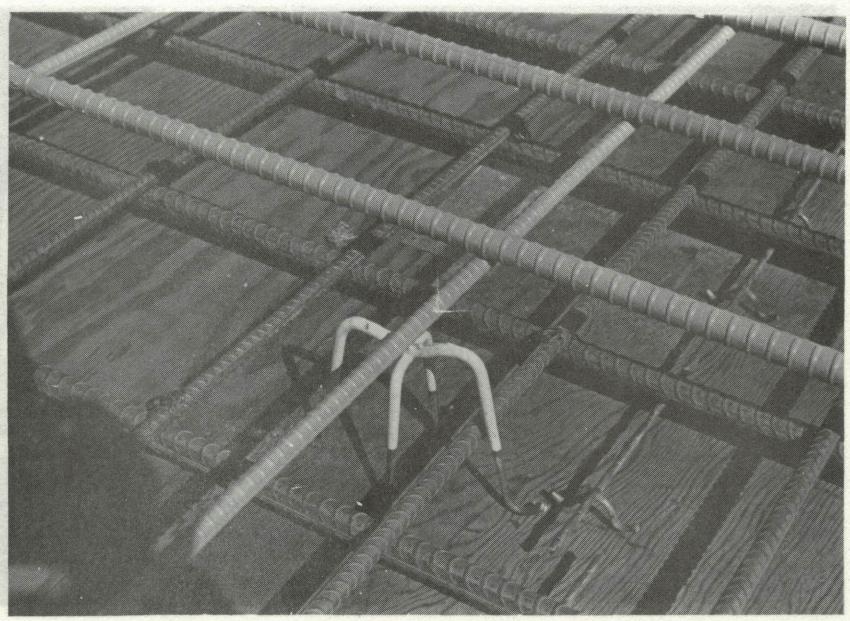


Figure 10: Epoxy coated chairs were used to electrically insulate the top mat of steel from the bottom mat.

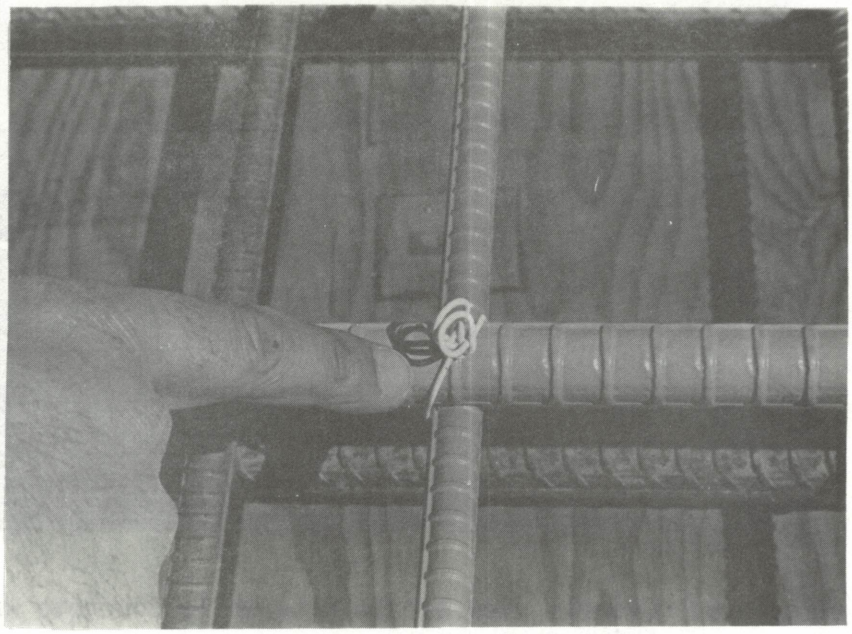


Figure 11: Epoxy coated ties were used.

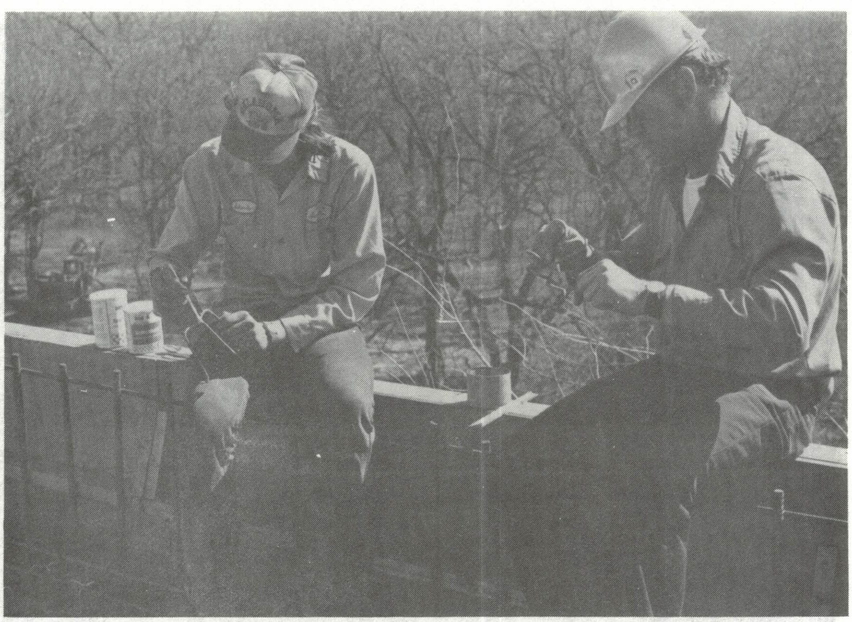


Figure 12: The contractor paints additional chairs with epoxy resin after running out of coated chairs.

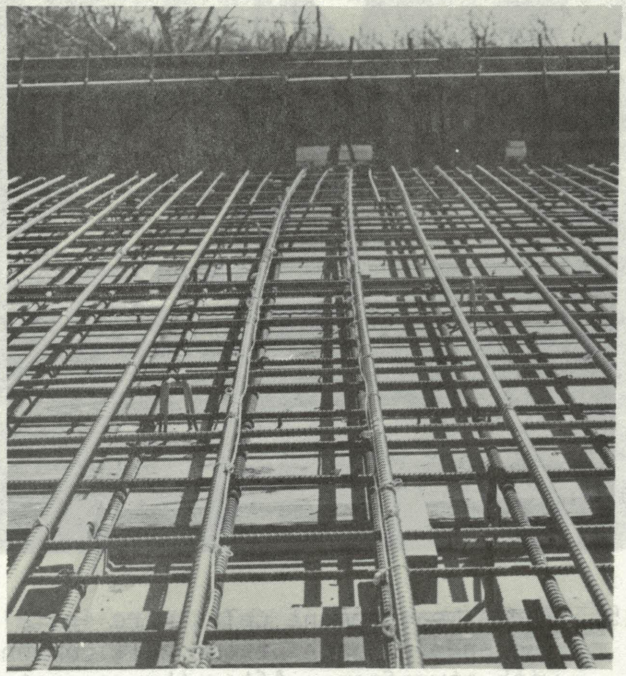


Figure 13: Shown here is the formation of a resistance measurement cell. A typical measurement cell consists of two epoxy coated rebars and two bare copper conductors. Shown here are the bare copper conductors, each placed as close as possible to the respective epoxy bar.

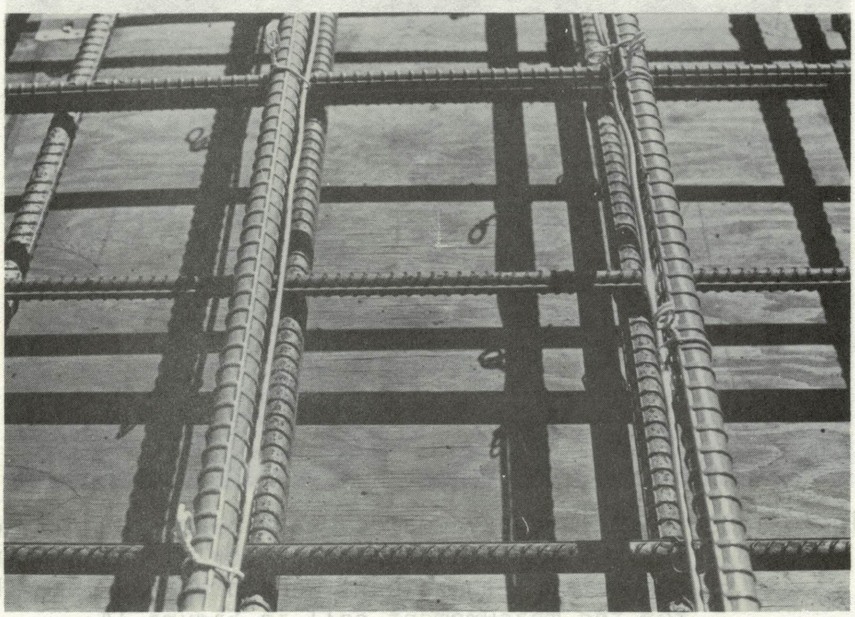


Figure 14: A close view of copper conductors tied to coated rebars.

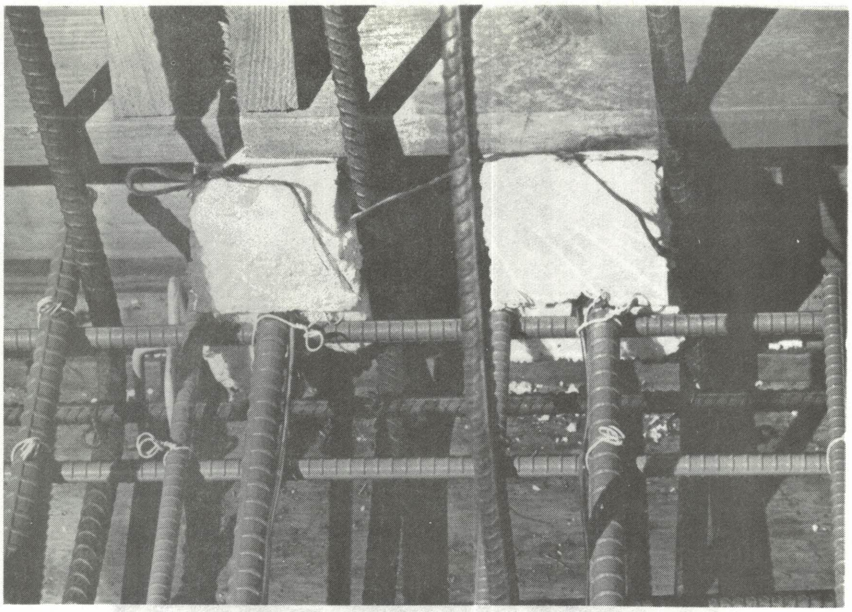


Figure 15: Three measurement cells were installed in the bridge. The ends of each of the cell components were covered with styrofoam. After the concrete was poured and set, the foam was removed leaving free access for direct electrical connection.

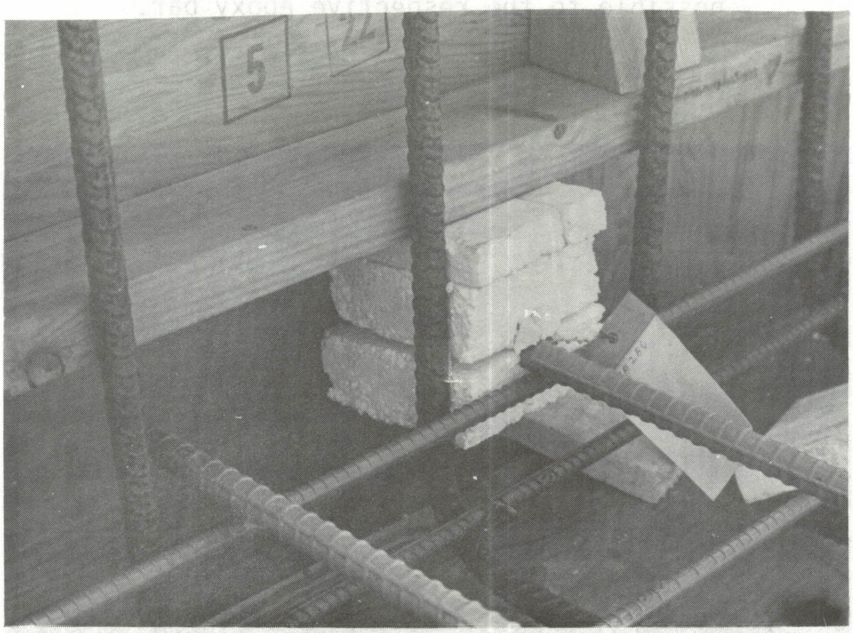


Figure 16: Fourteen epoxy coated rebars were randomly chosen for wet mop measurements. For direct electrical connection, these bars were prepared like the bars for the measurement cell in Figure 14.

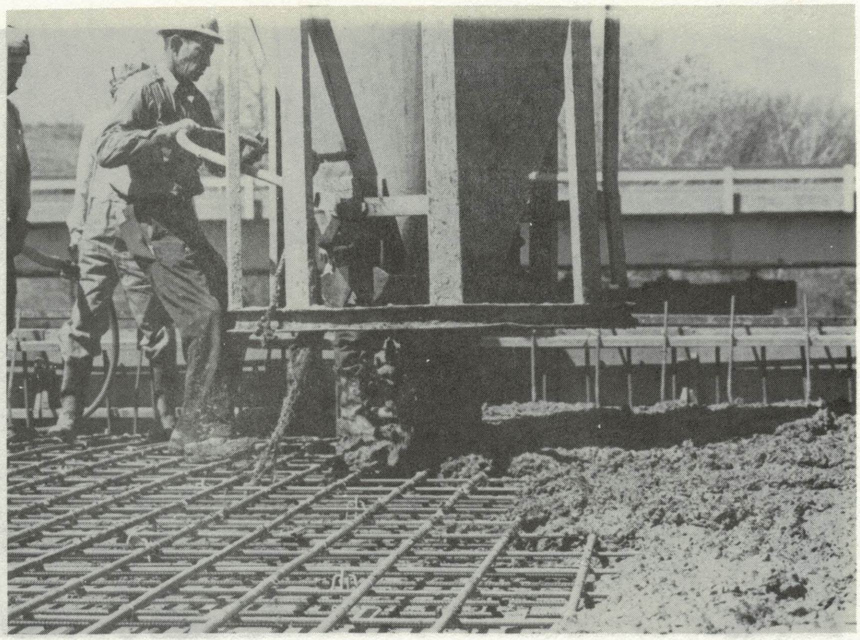


Figure 17: Bucket supported by an overhead crane pours concrete into the bridge deck grid.

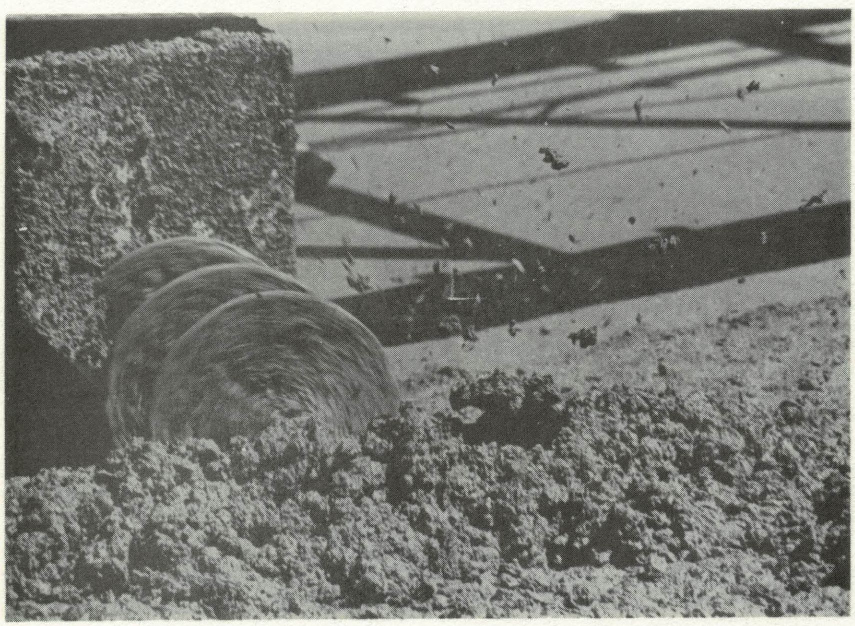


Figure 18: Concrete was distributed by means of an auger.

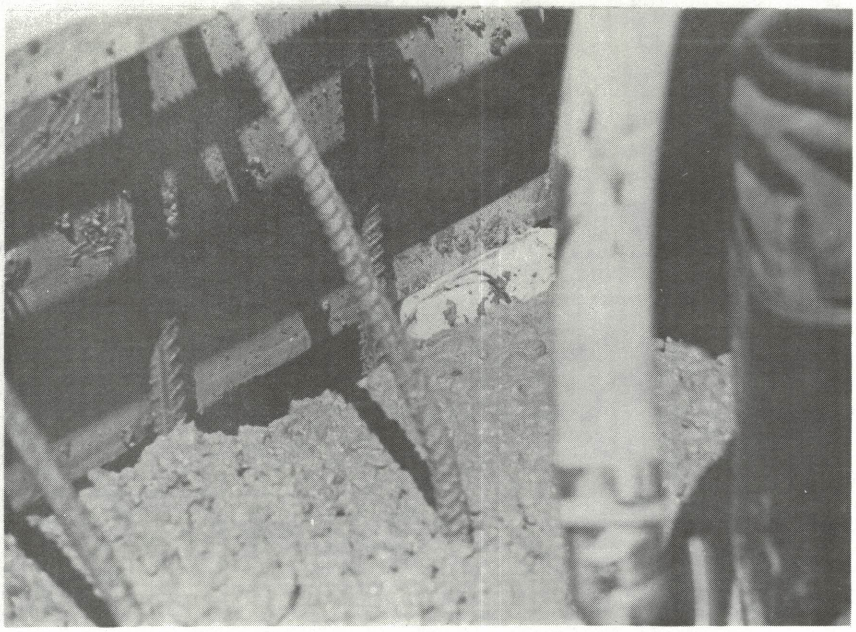


Figure 19: Concrete covers styrofoam placed at the end of one of the rebars. Vibrator tip is at right.

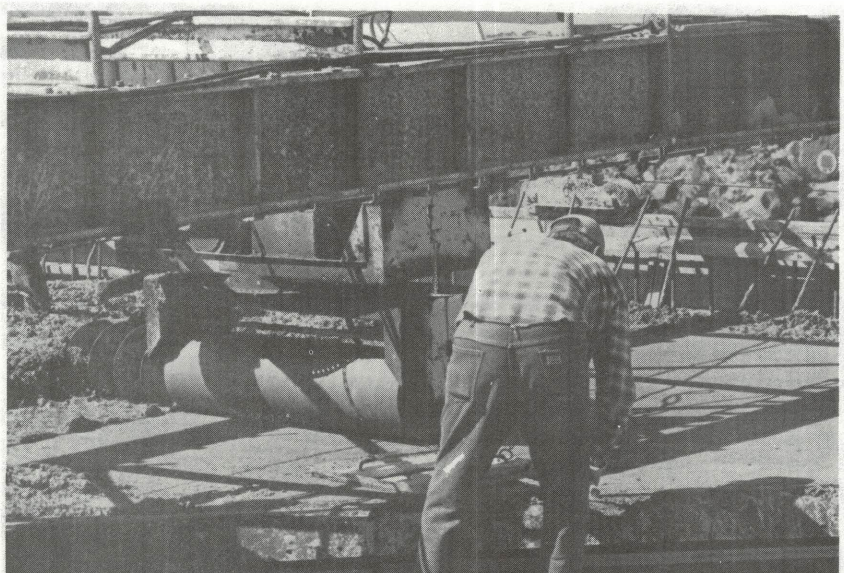


Figure 20: Concrete finish was done with a roller plus some additional handfinishing.

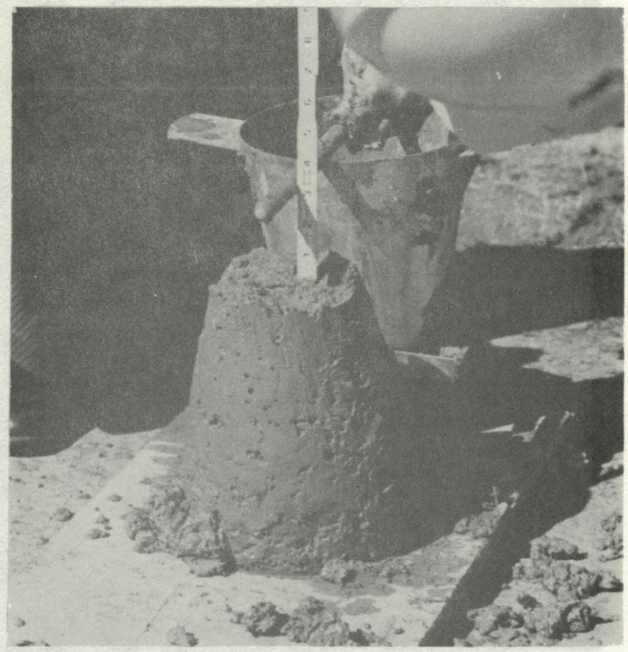


Figure 21: Inspector measures 3 inches of slump.

Figure 22: Reading air content in concrete.

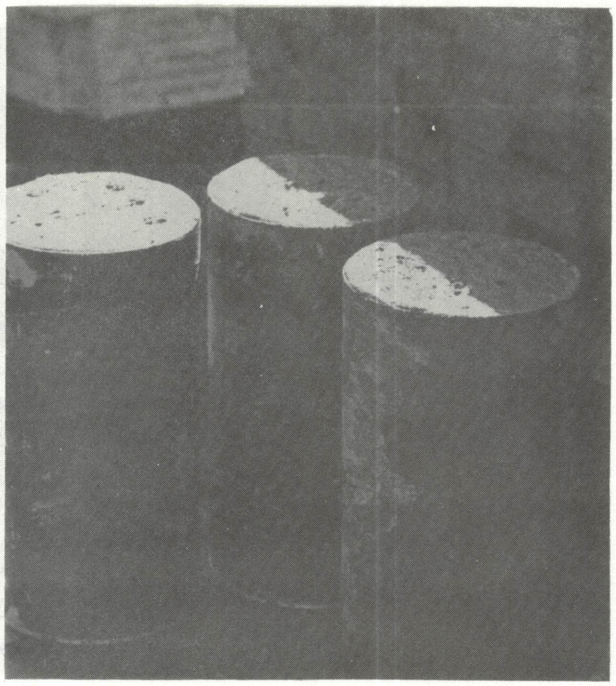


Figure 23: Cylinders were cast for strength measurements.

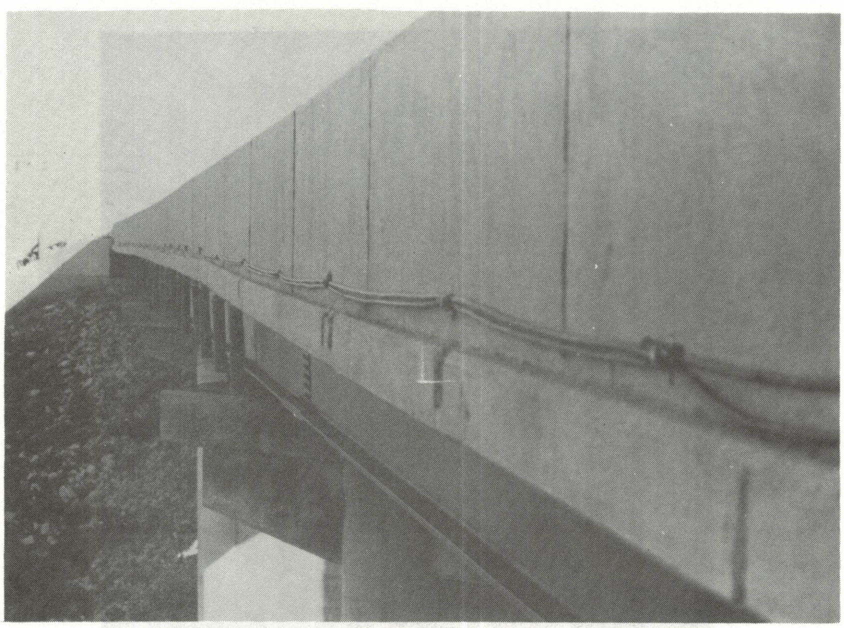


Figure 24: Cable containing individual connecting wires from the ends of the various epoxy coated rebars and copper conductors is attached to the west side of the bridge and continues to the junction box placed at the southwest corner of the bridge.

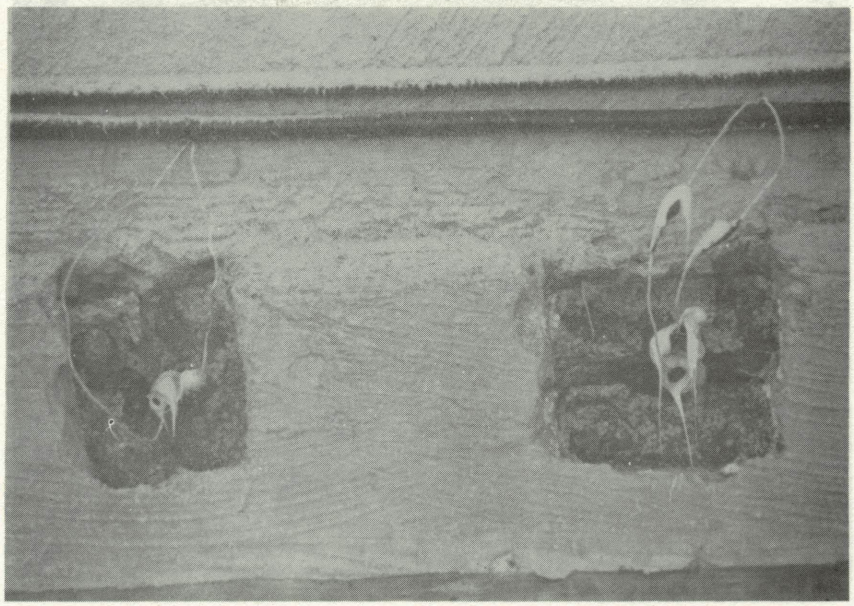


Figure 25: Direct electrical connections to a resistance measurement cell are insulated with caulking material. (A measurement cell consists of two copper conductors and two coated rebars).

Figure 26: A close up of half of a resistance measurement cell. The copper conductor is to the right and the epoxy coated rebar is to the left.

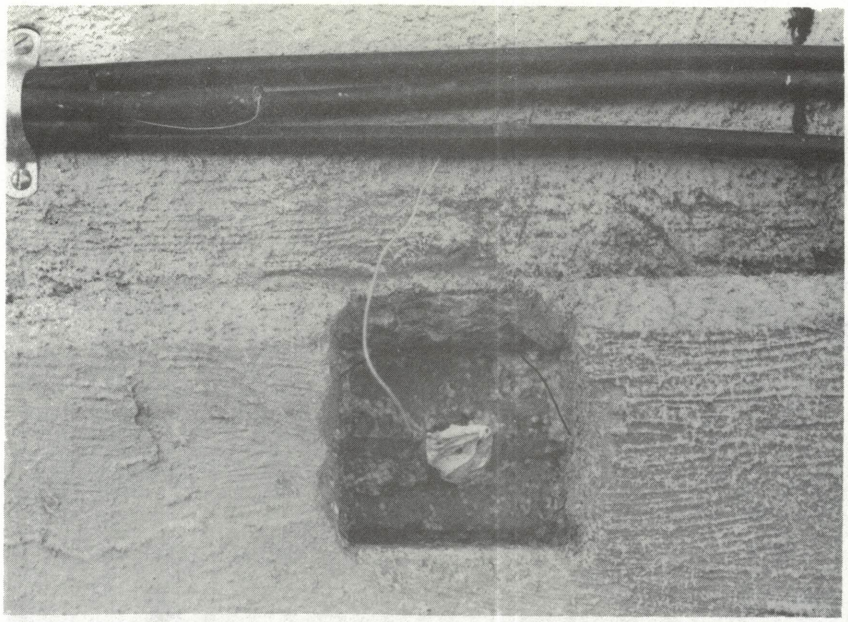


Figure 27: An epoxy coated rebar is connected for wet mop measurement.

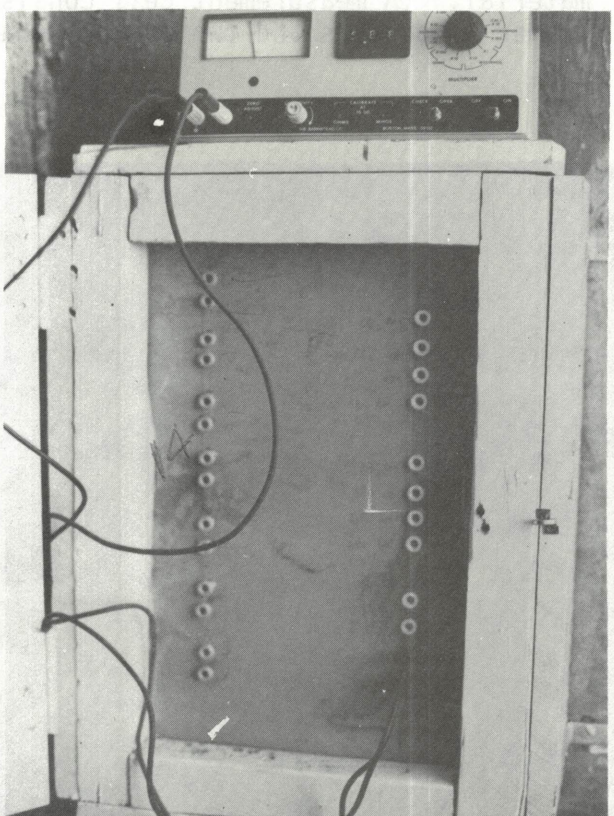


Figure 28: Junction Box.

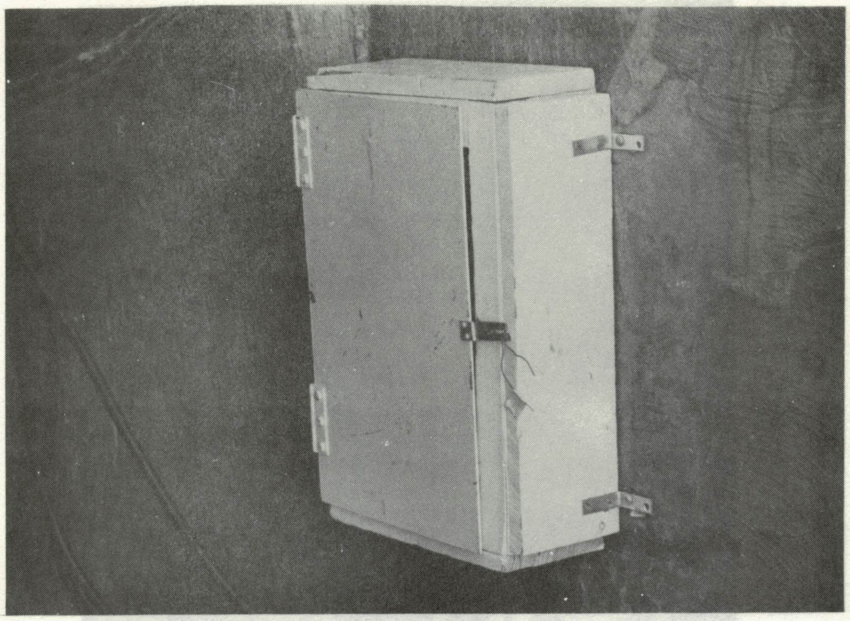


Figure 29: Wooden junction box can be padlocked for safety.

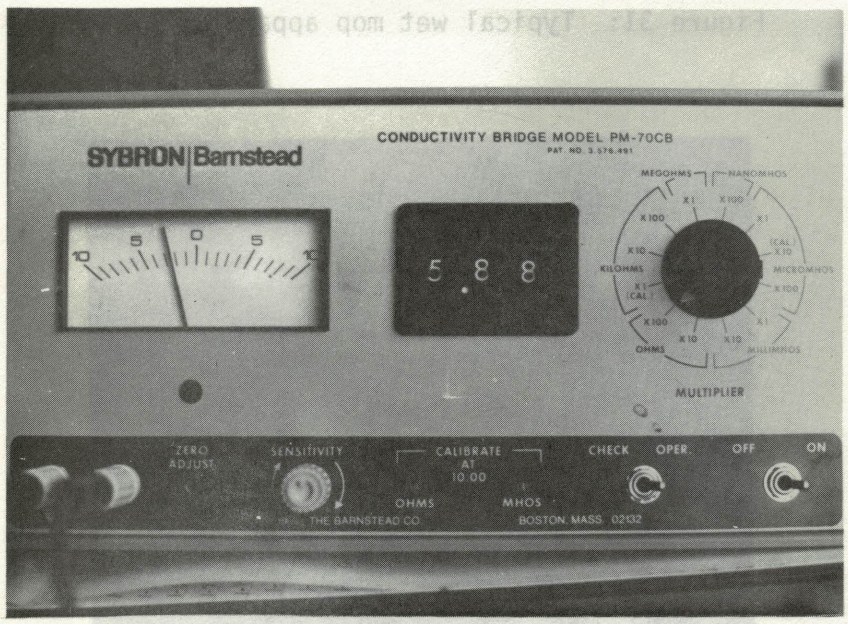


Figure 30: The conductivity bridge meter used for A.C. resistance measurements. It operates @ 400 cycles and uses a wheat stone bridge circuit to identify null deflection measurements.

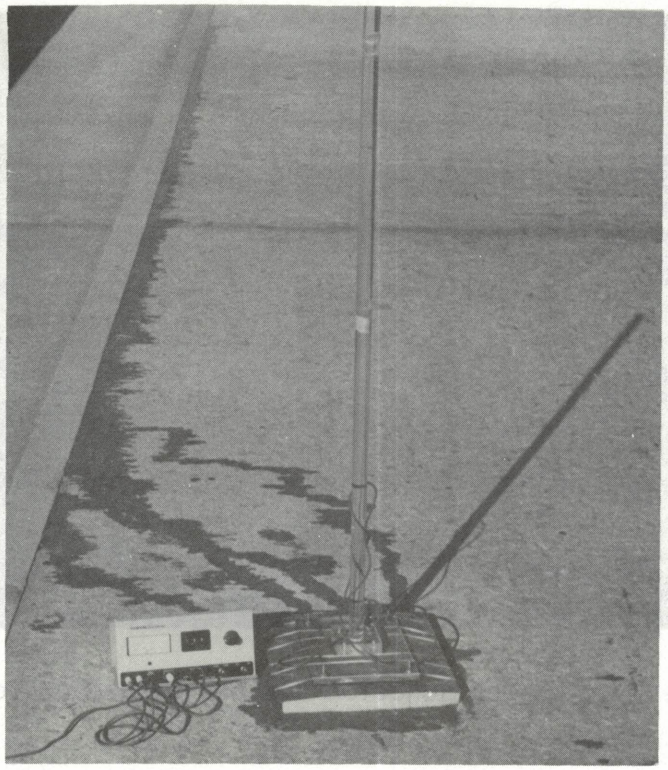


Figure 31: Typical wet mop apparatus.

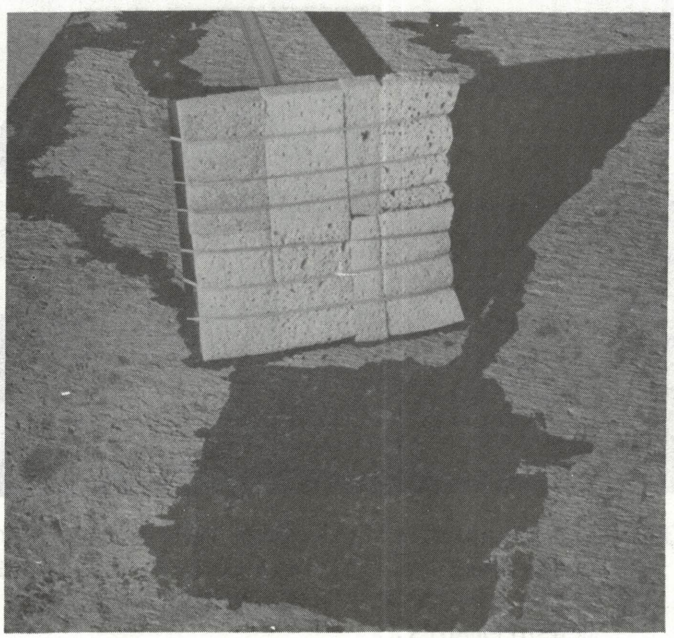
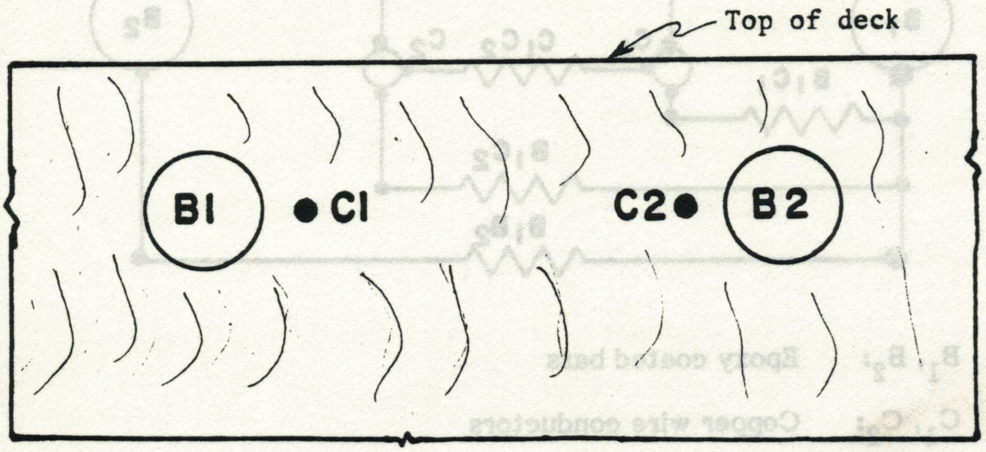


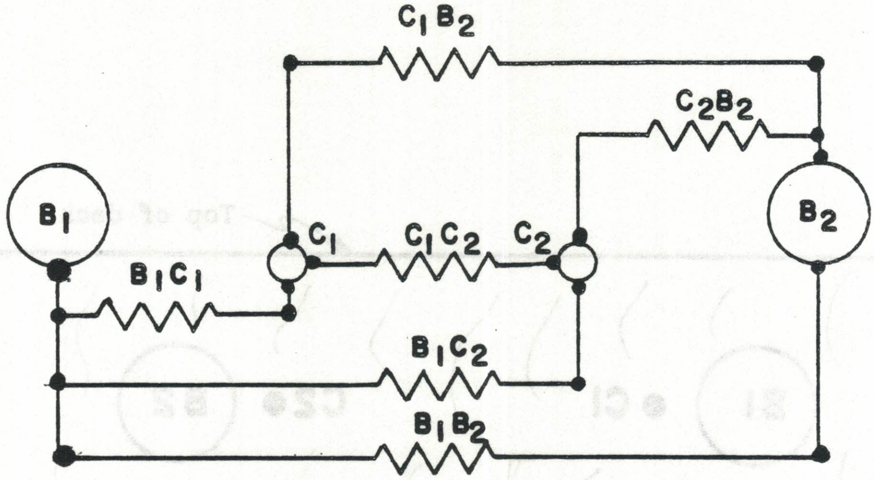
Figure 32: Detail of the wet mop used. Sponges were fastened to the copper plate by means of a few rubber bands.



B_1 B_2 are epoxy coated rebar.

C_1 C_2 are bare copper wires.

Figure 33. A typical measurement cell used to evaluate the stability of epoxy.



B_1, B_2: Epoxy coated bars

C_1, C_2: Copper wire conductors

$B_1 C_1$, $B_1 C_2$, $B_1 B_2$, $C_1 C_2$, $C_1 B_2$, and $C_2 B_2$ are various resistance as shown in the network and can be measured individually.

To establish the accuracy of each resistance measurement, the following five equations should be satisfied:

$$B_1 C_2 = B_1 C_1 + C_1 C_2 \quad \ldots\ldots\ldots\ldots 1$$

$$C_1 B_2 = C_1 C_2 + C_2 B_2 \quad \ldots\ldots\ldots\ldots 2$$

$$B_1 B_2 = B_1 C_1 + C_1 C_2 + C_2 B_2 \quad \ldots\ldots\ldots\ldots 3$$

$$= B_1 C_1 + C_1 B_2 \quad \ldots\ldots\ldots\ldots 4$$

$$= B_1 C_2 + C_2 B_2 \quad \ldots\ldots\ldots\ldots 5$$

Figure 34. Equivalent resistance network and constraints on measured values of resistance.

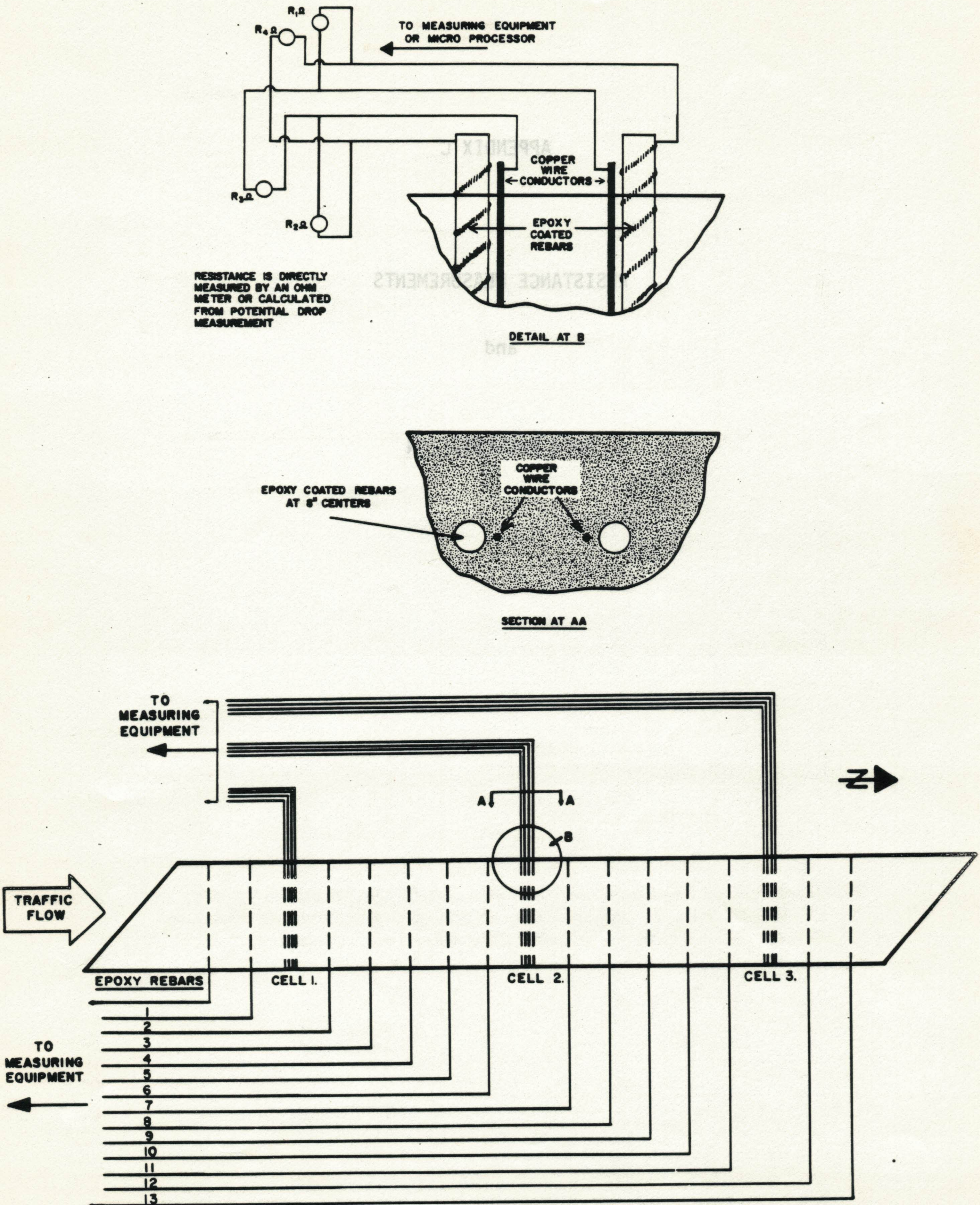


FIG. 35. A TYPICAL ELECTRICAL LAYOUT FOR MONITORING ELECTRIC RESISTANCE OF EPOXY COATED REBARS.

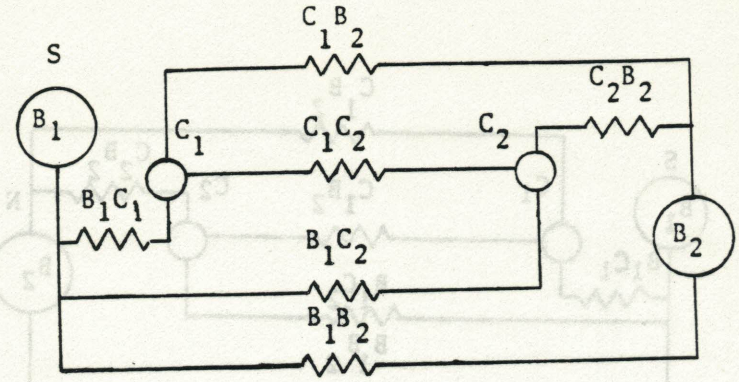
APPENDIX C

RESISTANCE MEASUREMENTS

and

DATA PRESENTATION

Schematic and Tables of Resistance Measurements from 11-79 to 4-80



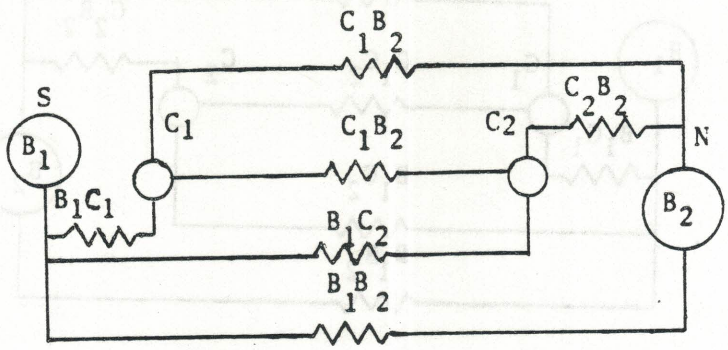
① Healing
② dry deck
③ freezing

		A.C. Resistance Measured in OHMS					
Date		11-79	12-79	01-80	02-80	03-80	04-80
C	B_1C_1	439	470	603	416	388	354
E	B_1C_2	442	479	615	425	394	359
L	B_1B_2	1470	1096	1970	1330	1278	1230
L	C_1C_2	16	17.7	23.6	16.2	14.5	12.9
	C_1B_2	1049	637	1360	918	890	868
1	C_2B_2	1036	628	1350	909	885	859

C	B_1C_1	559	629	877	564	512	457
E	B_1C_2	568	639	892	575	525	466
L	B_1B_2	1330	1500	2110	1370	1238	1090
L	C_1C_2	20.0	21.6	28.6	20.0	19.4	16.2
	C_1B_2	761	867	1210	807	722	628
2	C_2B_2	750	856	1200	799	712	621

C	B_1C_1	478	510	720	485	460	426
E	B_1C_2	478	501	709	477	436	384
L	B_1B_2	1062	1100	1560	1072	960	853
L	C_1C_2	20.0	22.3	28.8	20.8	19.2	17.5
	C_1B_2	583	589	845	588	548	492
3	C_2B_2	591	598	858	596	530	470

Schematic and Tables of Resistance Measurements
from 5-80 to 8-80



		A.C. Resistance Measured in OHMS					
Date		05-80	06-80	07-80	08-80	09-80	10-80
C	B_1C_1	390	419	556	389		
E	B_1C_2	392	424	434	393		
L	B_1B_2	1170	1109	1920	1490		
L	C_1C_2	12.2	11.8	31.3	11.1		
	C_1B_2	778	683	1480	1080		
1	C_2B_2	770	673	1430	1080		

C	B_1C_1	450	438	482	443		
E	B_1C_2	456	444	488	448		
L	B_1B_2	1150	1108	1190	1093		
L	C_1C_2	15.8	15.3	15.8	14.6		
	C_1B_2	630	631	698	635		
2	C_2B_2	622	624	690	629		

C	B_1C_1	410	392	454	393		
E	B_1C_2	385	384	432	398		
L	B_1B_2	845	839	994	837		
L	C_1C_2	18.1	18.6	31.9	61.4		
	C_1B_2	475	453	567	479		
3	C_2B_2	462	456	558	494		

WET MOP MEASUREMENTS

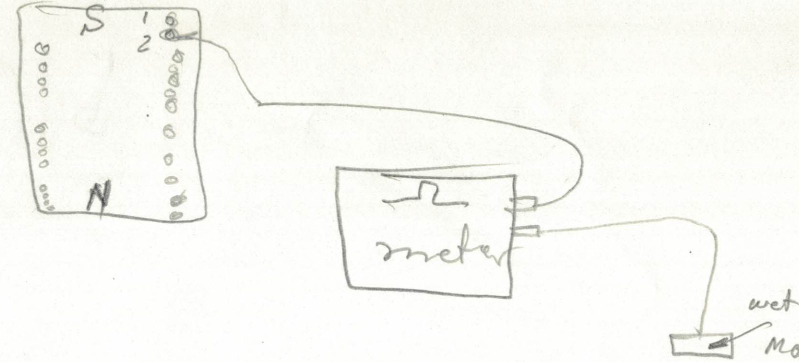
November 1979

(Readings in Ω)

Distance from East	5	8'4"	21'5"	48'7"	69'7"	81'7"	110'2"	128'4"	138'11"	165'10"	193'11"	215'10"	228'	231'2"
36'	513	833	268	412	704	405	494	647	635	770	736	1036	241	834
31'	525	860	312	438	749	422	540	643	646	787	768	1086	243	843
26'	529	846	335	462	779	444	590	668	669	834	796	1114	264	835
21'	532	877	337	461	787	487	585	668	663	816	780	1126	292	880
16'	632	909	324	710	783	658	549	940	687	799	836	1380	483	933
11'	561	909	345	478	791	438	597	699	670	797	831	1154	281	895
6'	551	917	332	461	788	419	583	674	674	790	813	1143	299	878
1'	500	875	310	454	743	404	556	662	599	783	782	1095	245	846

Distance from South

44



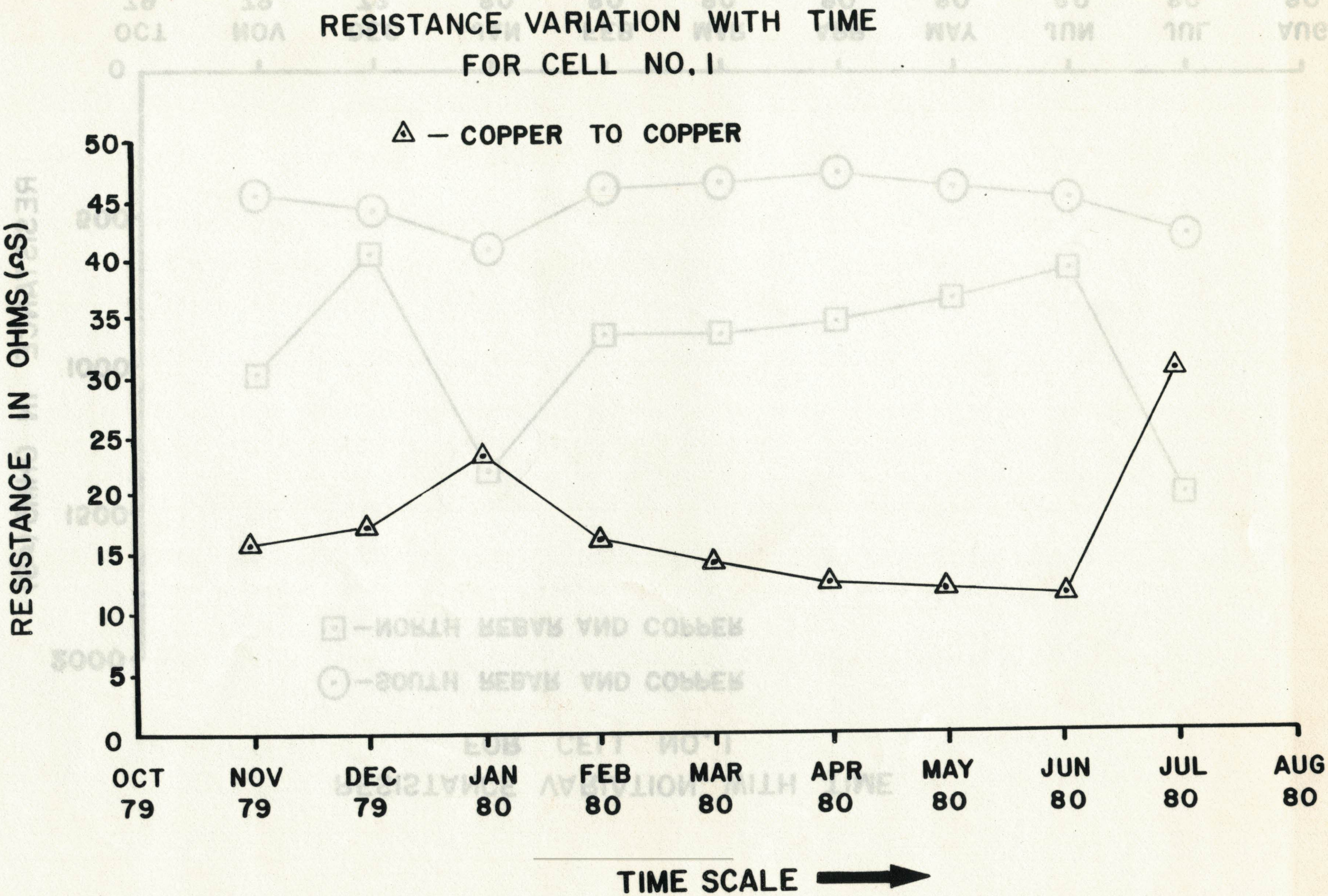
WET MOP MEASUREMENTS

May 1980

(Readings in Ω)

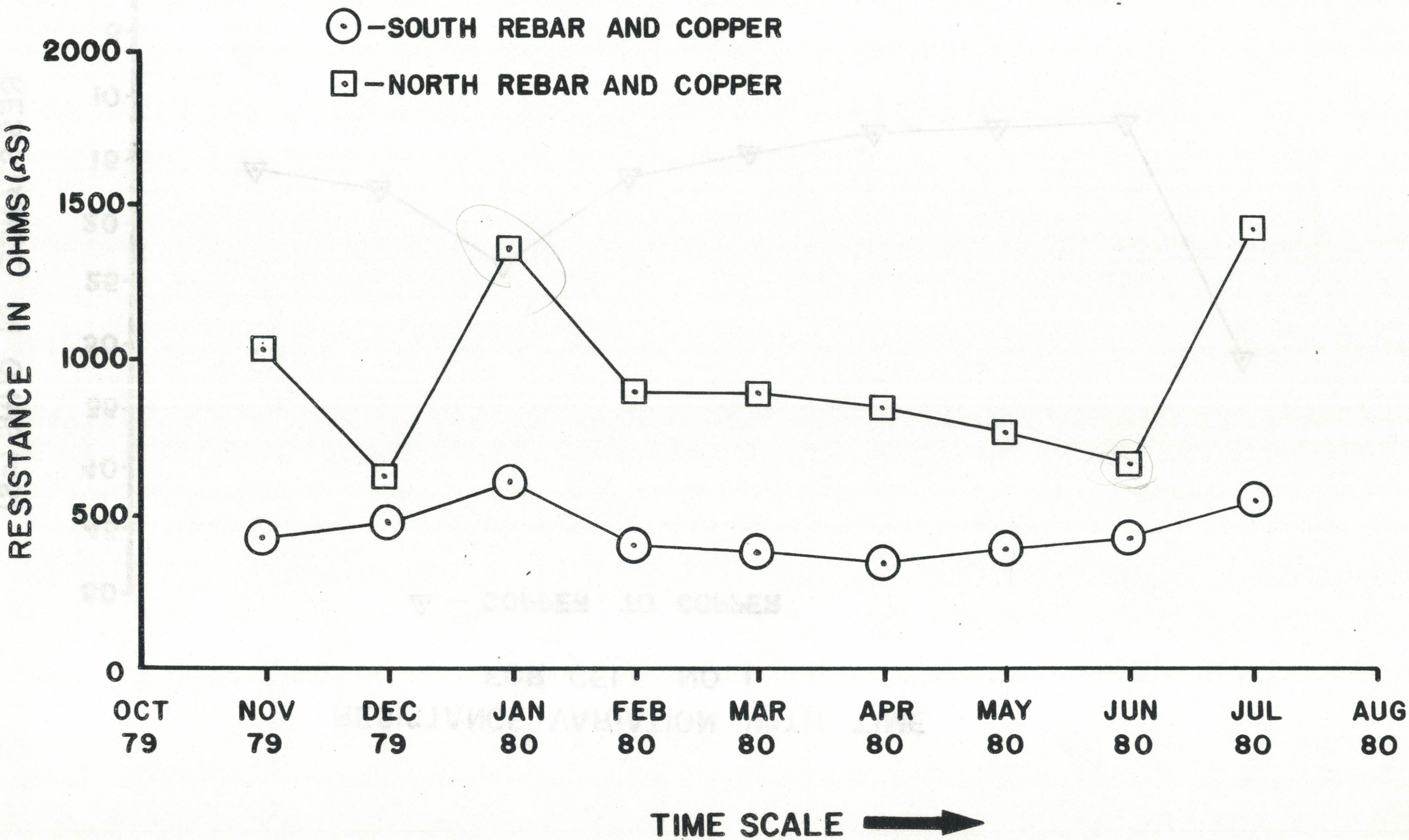
Distance from East	5'	8'4"	21'5"	48'7"	69'7"	81'7"	110'2"	128'4"	138'11"	165'10"	193'11"	215'10"	228'	231'2"
36'	534	600	204	337	592	332	398	495	477	600	598	802	179	589
31'	523	620	238	344	621	323	430	499	500	621	620	822	198	597
26'	532	633	254	361	638	354	474	518	515	637	622	815	218	606
21'	529	642	286	383	658	346	461	514	513	627	614	850	228	610
16'	579	781	318	554	757	638	541	884	640	722	753	1168	459	745
11'	524	777	320	432	750	415	558	635	619	712	750	974	263	742
6'	545	785	320	404	755	403	549	636	624	727	737	985	273	740
1'	490	740	275	392	720	388	523	612	547	710	715	930	224	722

Distance from South

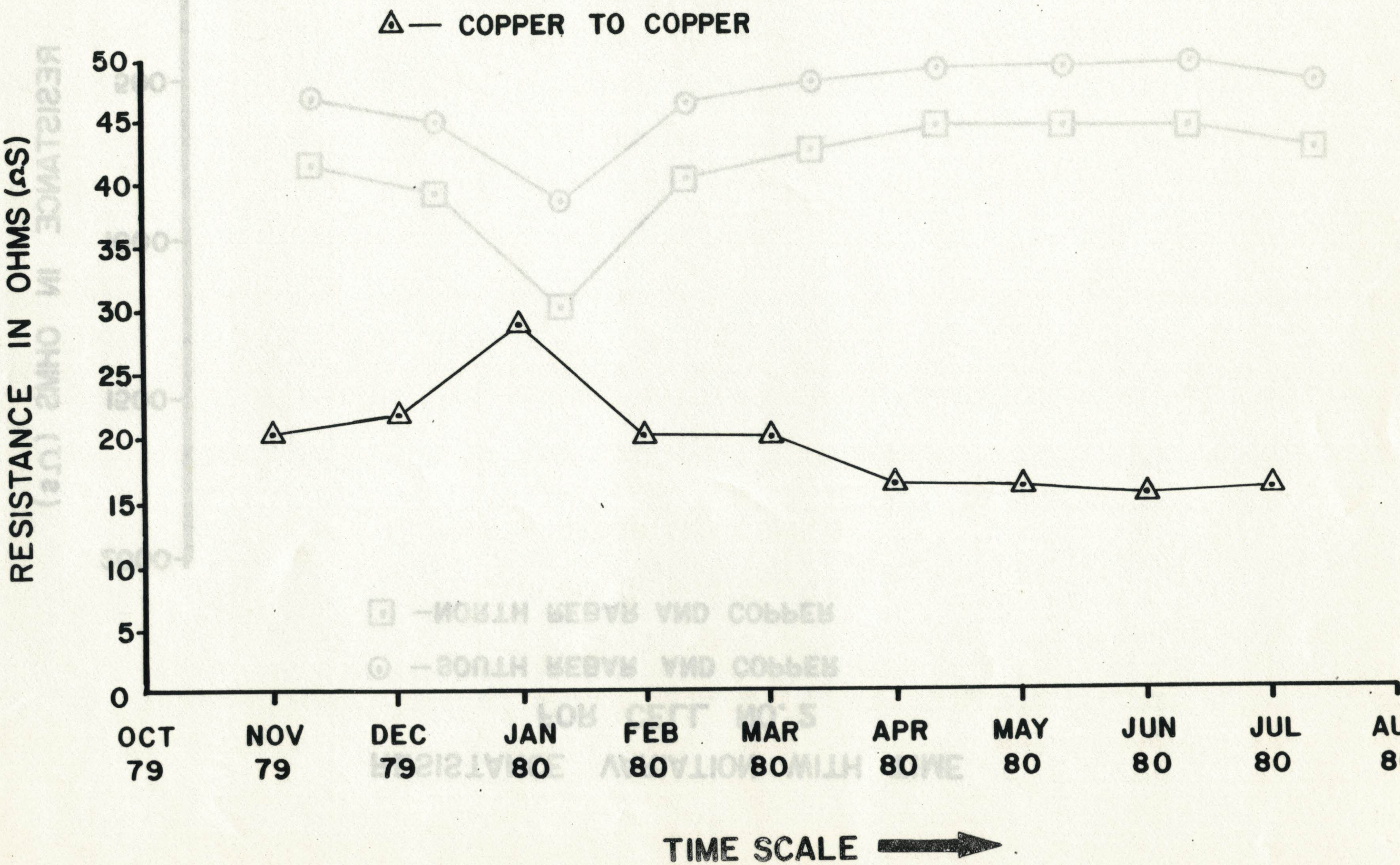


RESISTANCE VARIATION WITH TIME
FOR CELL NO. 1
△ – COPPER TO COPPER
RESISTANCE IN OHMS (Ω)
50
45
40
35
30
25
20
15
10
5
0
OCT 79
NOV 79
DEC 79
JAN 80
FEB 80
MAR 80
APR 80
MAY 80
JUN 80
JUL 80
AUG 80
TIME SCALE

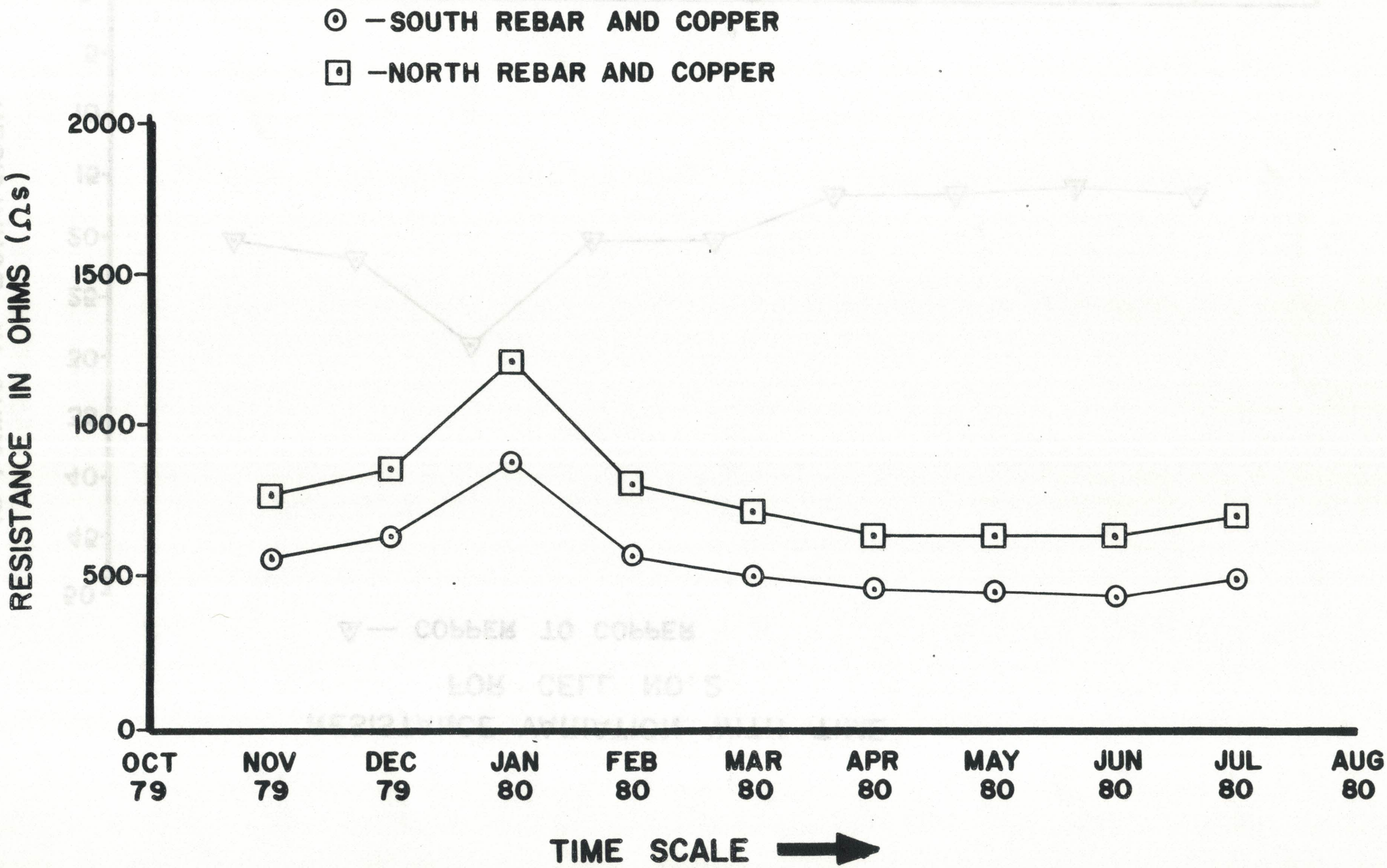
RESISTANCE VARIATION WITH TIME
FOR CELL NO. 1



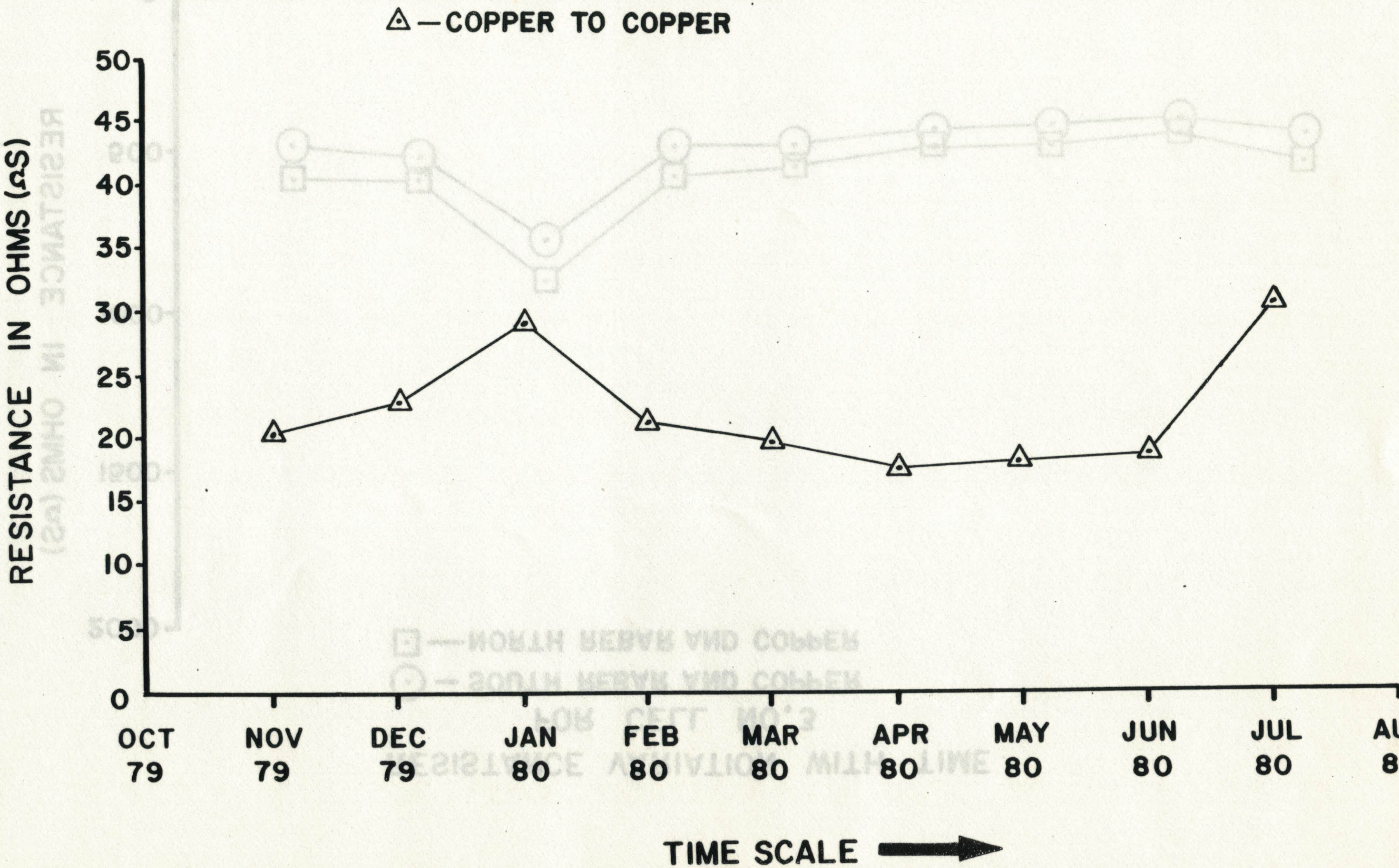
RESISTANCE VARIATION WITH TIME
FOR CELL NO. 2

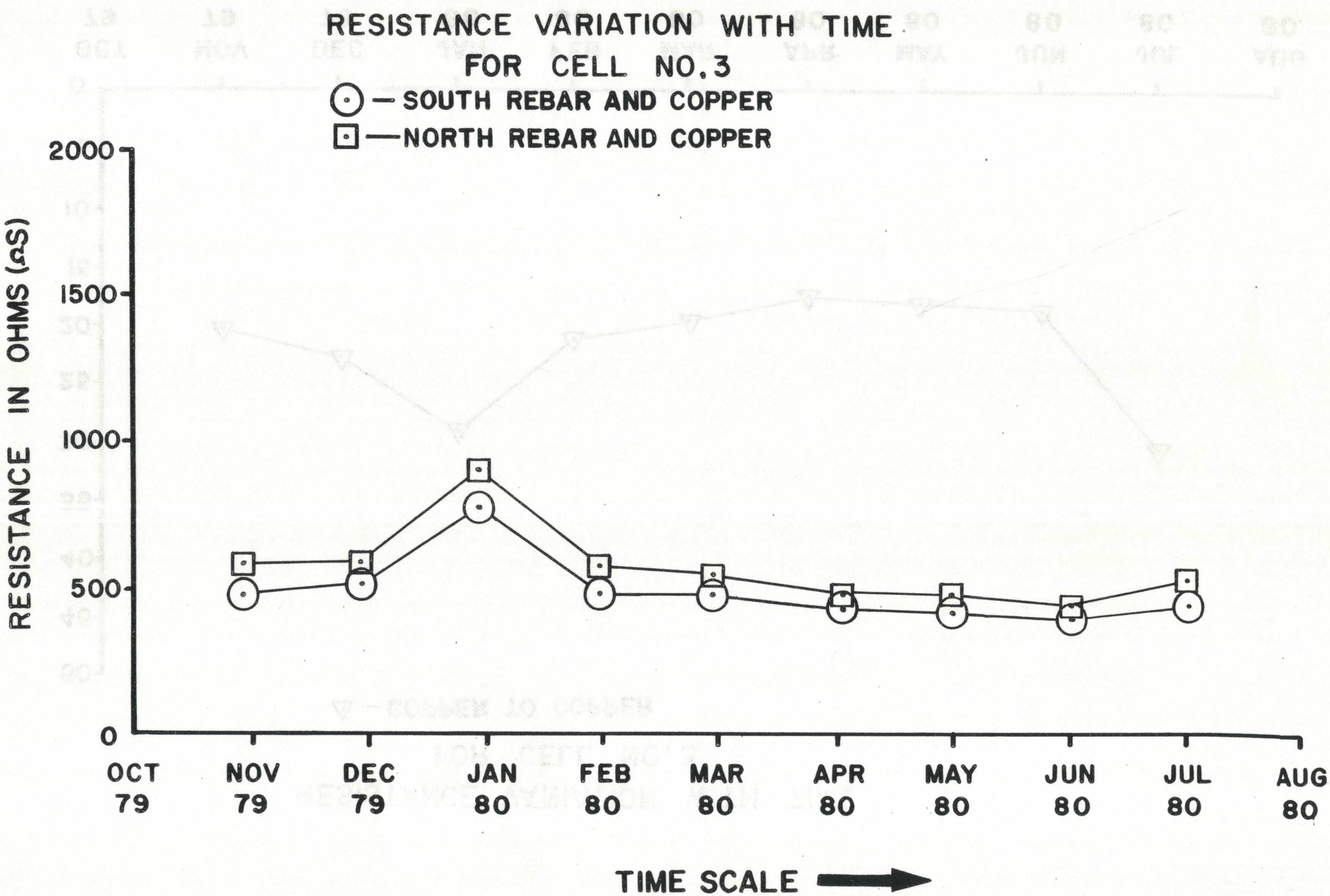


RESISTANCE VARIATION WITH TIME
FOR CELL NO. 2



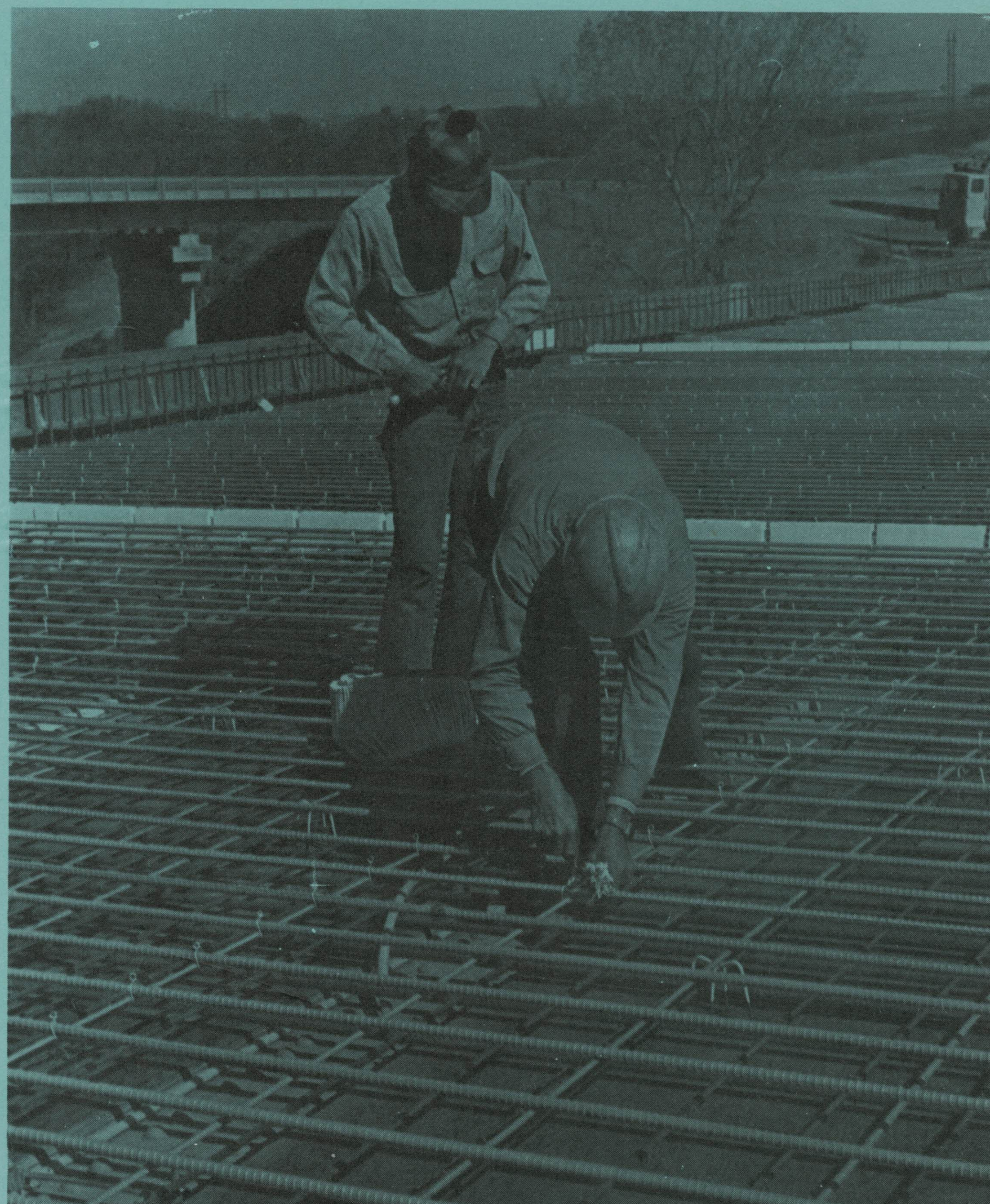
RESISTANCE VARIATION WITH TIME
FOR CELL NO. 3




RESISTANCE VARIATION WITH TIME
FOR CELL NO.3
— SOUTH REBAR AND COPPER
—NORTH REBAR AND COPPER
RESISTANCE IN OHMS (Ω)
2000
1500
1000
500
0
OCT 79
NOV 79
DEC 79
JAN 80
FEB 80
MAR 80
APR 80
MAY 80
JUN 80
JUL 80
AUG 80
TIME SCALE

EPOXY COATED REINFORCING STEEL IN BRIDGE DECKS

GUS'S COPY



RESEARCH AND DEVELOPMENT DIVISION
OKLAHOMA DEPARTMENT OF TRANSPORTATION