

# Nickel-Coated Dowel Pins

## Exposed in Tidal Zone

### Harbor Island, North Carolina

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•THE International Nickel Co. has been engaged in developing nickel coatings for the surfaces of various steel mill products to provide corrosion resistant protection of carbon steel. Prior to the early stages of this development, the problems associated with the corrosion of dowels in highway load-transfer devices had been brought to the company's attention. The studies of Van Breemen (1) were reviewed and, in addition, the various methods employed and proposed to provide corrosion resistant dowels were investigated. Development effort was then directed toward determining the utility of a hot-rolled, nickel-coated dowel bar; and for this purpose approximately 5 tons of nickel-coated bar stock were produced experimentally. The product was fabricated into load-transfer devices and placed in six highway test projects (Table 1).

In addition to the highway performance tests which have been in progress up to 5 years, an accelerated corrosion test was conducted in tidal sea water at the company's corrosion test station at Harbor Island, N. C. Similar accelerated exposure tests were conducted in tidal waters at Old Saybrook, Connecticut and reported by Mitchell (2). Accelerated corrosion tests under controlled laboratory conditions were set up at Purdue University (3). This study investigated various types of nickel coatings and stainless steel sheathing on carbon steel bars and showed their influence on reducing the restraining action of dowels cast in concrete.

Also, marine and industrial atmospheric exposure tests of a qualitative nature have been made and are continuing at Kure Beach, N. C., and Bayonne, N. J., respectively.

This report is concerned primarily with the pull-out tests of plain uncoated, hot-rolled carbon steel dowels and hot-rolled nickel-coated steel dowels after exposure in the tidal zone at Harbor Island, N. C.

TABLE 1  
HIGHWAY TEST PROJECTS

State	Nickel-Coated Dowels		Location of Installation
	No.	Size (in.)	
Conn.	288	1 diam. × 18	US 9, Middleton
Kan.	240	1¼ diam. × 18	US 36, between Seneca and Maysville
Mich. <sup>a</sup>	240	1¼ diam. × 18	US 16, Proj. 34044, Portland
N. J.	240	1¼ diam. × 18	US 202, north of Flemington
N. Y.	240	1¼ diam. × 18	Interstate 502, Colonie
D. C.	240	1¼ diam. × 18	Eastern Ave.

<sup>a</sup>Also, 132 each steel dowels sheathed with types 430, 304 and 316 stainless steel and Monel; same size.

## EXPERIMENTAL MATERIAL

In producing the nickel-coated bars, a typical industrial type, heavy nickel coating was electrodeposited by standard methods on commercial grade carbon steel billets. The nickel-plated billets were then heated to rolling mill temperatures, approximately 2,100 F, and hot-rolled to the final round bar size.

Figure 1 shows a typical 3- by 3-in. plated carbon steel billet cross-section with corresponding nickel-coated bar section and longitudinal piece of  $1\frac{1}{4}$ -in. diameter nickel-coated bar stock after hot rolling.

The nominal nickel thickness on the finished hot-rolled bars used in the highway performance tests and the tidal zone exposure ranged from 0.007 in. to 0.010 in. Figure 2 shows cross-sections of three typical bars which have been polished and acid etched. The steel was blackened to reveal the nickel coating.

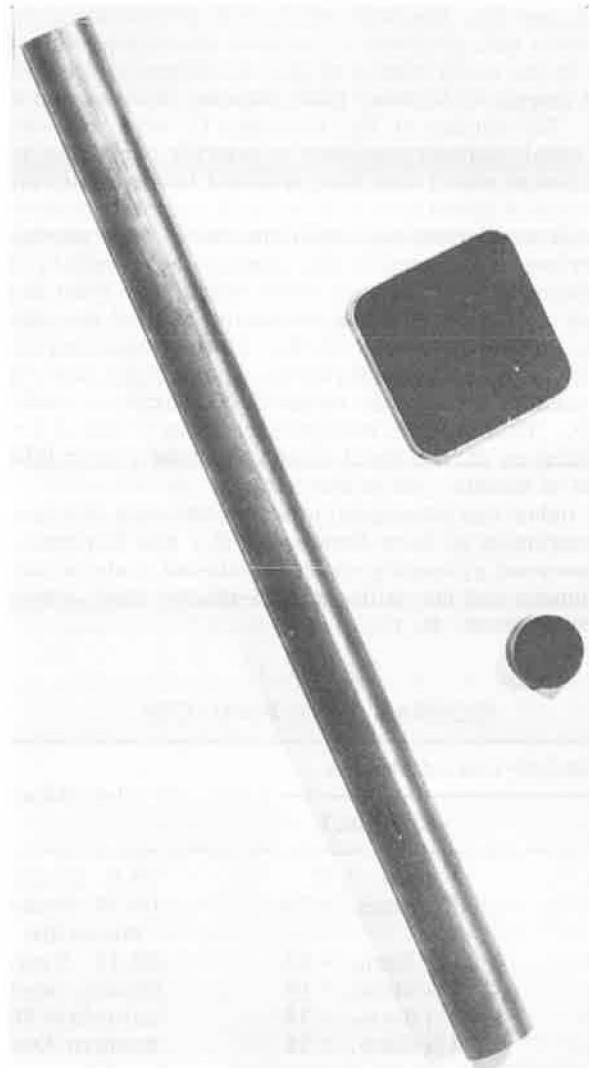


Figure 1. Nickel-plated steel billet section (3 x 3 in.) and  $1\frac{1}{4}$ -in. hot-rolled nickel-coated bar.

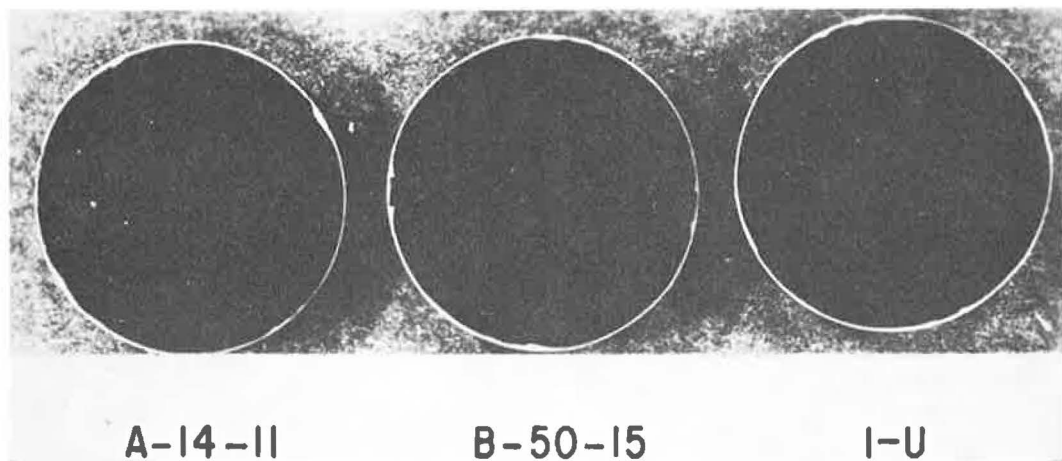


Figure 2. Nickel-coated dowel pins (1.25-in. diameter).

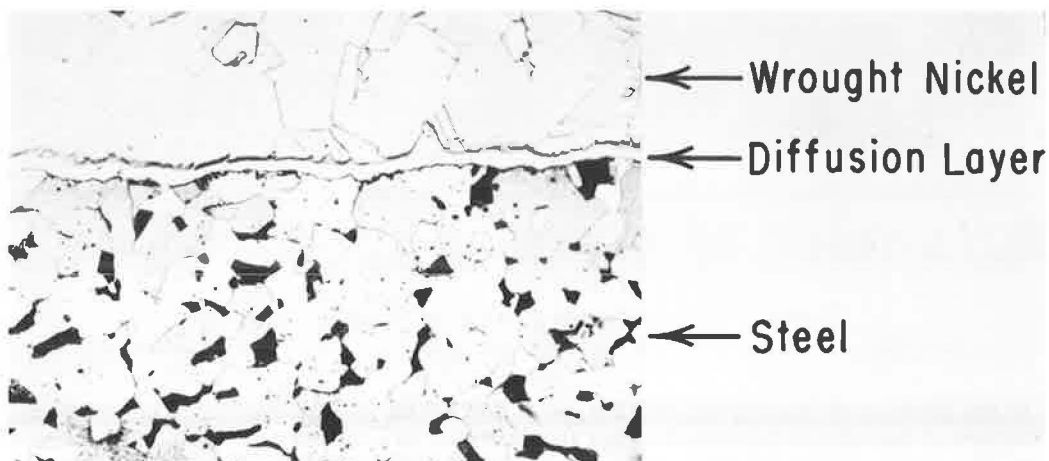
In the process of heating and rolling the plated billet, the typical cast-like columnar structure of the electrodeposited nickel is converted to a wrought type nickel structure (Fig. 3). Also, during heating, diffusion occurs at the nickel-iron interface which improves the original metallurgical bond of the nickel to the basis metal. Thus, by the method of manufacture the nickel becomes an integral part of the bar without changing the mechanical properties of the steel. This type of dowel, along with the more familiar plain, hot-rolled carbon steel dowels, was employed in the exposure and pull-out tests.

#### TIDAL ZONE EXPOSURE SPECIMENS

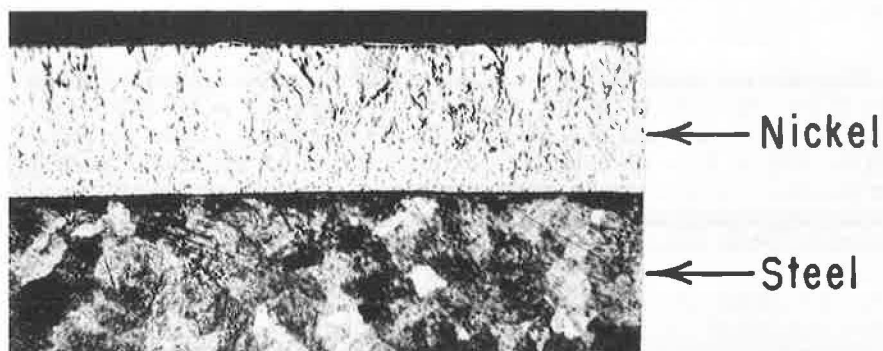
On June 23, 1959, sixteen dowel pins were exposed on the Harbor Island bulkhead in the upper part of the tidal zone (Fig. 4). They were immersed 2 to 3 hours a day in sea water. Six inches of each end of a dowel pin had been cast in a concrete cylindrical form,  $7\frac{1}{2}$  in. long by 6 in. in diameter. From 5 to 6 in. of the middle portion of the dowel was not covered by concrete, thus providing a dumbbell like configuration. The concrete consisted of about  $2\frac{3}{8}$ -in. cover of a Class "A" air mixture of the following composition: 94 lb cement, 156 lb sand, 363 lb gravel, 5 gal water, and  $\frac{3}{4}$  oz Darex admixture.

Before casting, six inches of one end of each dowel was thinly coated with Esso Nebula EP-1 multi-use industrial grease, to prevent bonding of one end of the dowels to the concrete in a way similar to the practice employed in highway, doweled joint construction to provide a sliding member. This portion of the dowel will be referred to as the "greased end." The other end of the dowel cast in concrete was not greased so that the concrete would adhere to this portion of the dowel to simulate the fixed end of a doweled pavement joint. This end of the dowel will be referred to as the "fixed end."

Four of the specimens contained plain hot-rolled carbon steel dowels and 12 contained hot-rolled nickel-coated steel dowels. All specimens were subjected to frequently agitated and generally highly aerated sea water during the immersion periods. The agitation and aeration were caused by high velocity pumps operating nearby and discharging large volumes of sea water at several feet above the surface. This also subjected the specimens to considerable splashing before and after each tidal immersion cycle.



HOT ROLLED NICKEL  
ON STEEL



NICKEL ELECTRODEPOSITED  
FROM WATTS TYPE BATH

Figure 3.

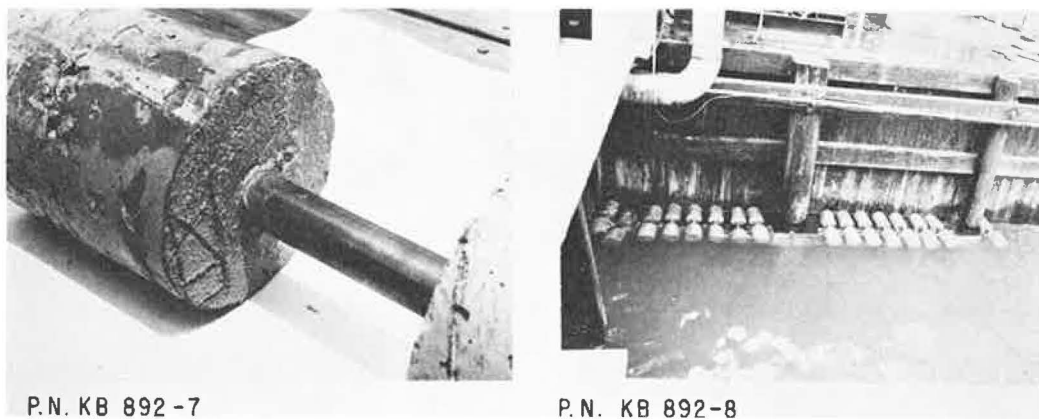


Figure 4. Dowel pin specimens at time of tidal zone exposure: (left) pin cast into concrete, specimen XII; (right) specimens in exposure location—tide four-fifths high.

### PULL-OUT TESTS

After  $1\frac{3}{4}$  years continuous exposure to tidal action, 10 specimens containing nickel-coated hot-rolled dowels and 3 specimens containing plain, hot-rolled carbon steel dowels were removed from exposure and prepared for the pull-out tests. This was done by cutting the dowel pin midway between the cement blocks and drilling and tapping the cut end to accommodate a pull rod (Fig. 5). Irregularities of the cement blocks were rectified through the use of capping material. The possibility of misalignment in the actual test was minimized by using a universal alignment head. As the dowels were pulled, only the initial ultimate loads that caused movement were recorded as these were considered the loads necessary to free the dowel bar from the concrete. The area of the dowel pin actually in the concrete was then used to calculate the apparent shear stress.

$$S = \frac{L}{A}$$

in which

S = apparent shear stress;

L = ultimate load measured; and

A = measured area of the dowel in concrete.

### TEST RESULTS

The pull-out test data (Table 2) have been plotted in Figure 6. From the average apparent shear stress data, the plain carbon steel dowels required 7.5 times the force to initiate movement as compared to the nickel-coated steel dowels. Also, there is very little difference between the shear stress of the plain carbon steel dowels that had been greased and the same dowels without grease.

Following the pull-out tests all dowels were removed from the concrete specimens and the hole in the concrete was inspected and evaluated for residual corrosion products, smoothness of surface, and pitting (Table 2). Figure 7 compares the conditions of the plain dowel pins with the nickel-coated dowel pins at the greased and fixed ends. The nickel-coated dowels retained their original finish although those that were initially greased were slightly tarnished. It is believed that the grease was eventually washed away thus permitting the corrosive medium to come in contact with the metal surfaces within the concrete.

The plain hot-rolled carbon steel dowels were cleaned to remove all corrosion products without disturbing sound steel. The segment of these dowels between the concrete blocks where the pins were exposed to sea water was measured and found to

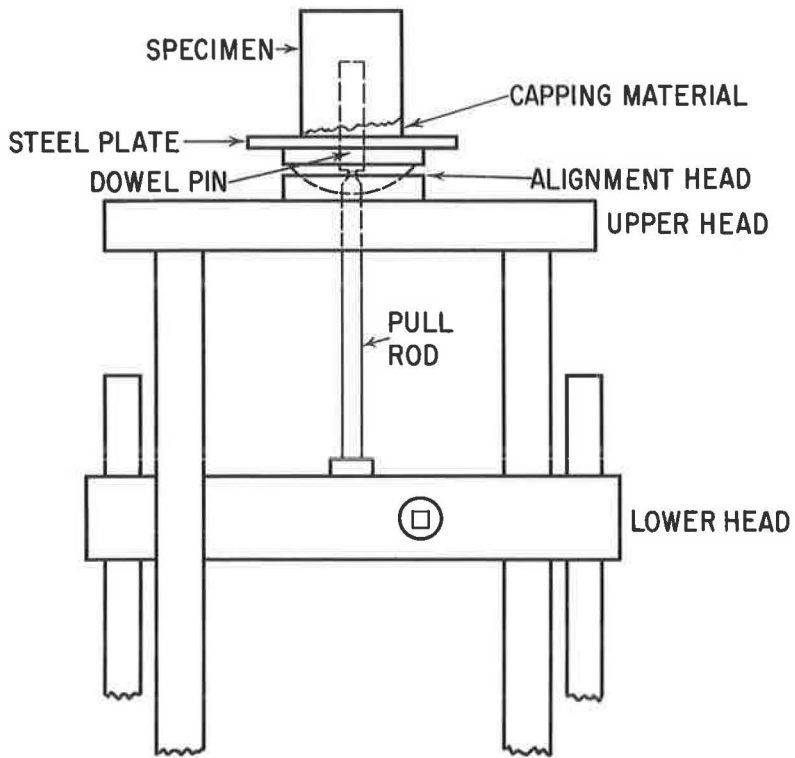


Figure 5. Pull-out test apparatus.

TABLE 2  
PULL-OUT TEST DATA

Specimen No.	Nickel Coated	Bond Breaker Greased	Ultimate Load (lb)	Apparent Shear Stress (psi)	Condition of Hole in Concrete Block <sup>a</sup>
I	Yes	No	9,600	348.2	S-C, no CP
I	Yes	Yes	2,900	124.6	S-C, no CP
II	Yes	No	9,500	356.6	S-C, no CP
II	Yes	Yes	2,300	97.5	R-C, no CP
III	Yes	No	9,100	345.7	S-C, no CP
III	Yes	Yes	2,850	122.5	R-C, no CP
IV	Yes	No	4,500	184.8	S-C, no CP
IV	Yes	Yes	2,900	120.7	S-C, no CP
V	Yes	No	5,500	211.6	S-C, no CP
V	Yes	Yes	3,150	137.0	S-C, no CP
VI	Yes	No	14,000	558.3	S-C, no CP
VI	Yes	Yes	3,250	144.7	S-C, no CP
VII	Yes	No	8,100	342.6	S-C, no CP
VII	Yes	Yes	2,500	169.8	S-C, no CP
VIII	Yes	No	5,600	207.2	S-C, no CP
VIII	Yes	Yes	2,300	83.3	S-C, no CP
XI	Yes	No	9,550	386.7	R-C, no CP
XI	Yes	Yes	2,400	102.4	S-C, no CP
XII	Yes	No	7,300	290.1	S-C, no CP
XII	Yes	Yes	2,350	99.7	S-C, no CP
XIII	No	No	24,300	924.3	S, some CP
XIII	No	Yes	18,800	784.3	R-P, some CP
XIV	No	No	27,050	1,064.9	R, some CP
XIV	No	Yes	23,900	995.1	S, some CP
XVI	No	No	23,500	852.2	R, some CP
XVI	No	Yes	24,600	1,026.6	R-P, some CP

<sup>a</sup>S = smooth, R = rough, C = clean, P = pitted, and CP = corrosion products.

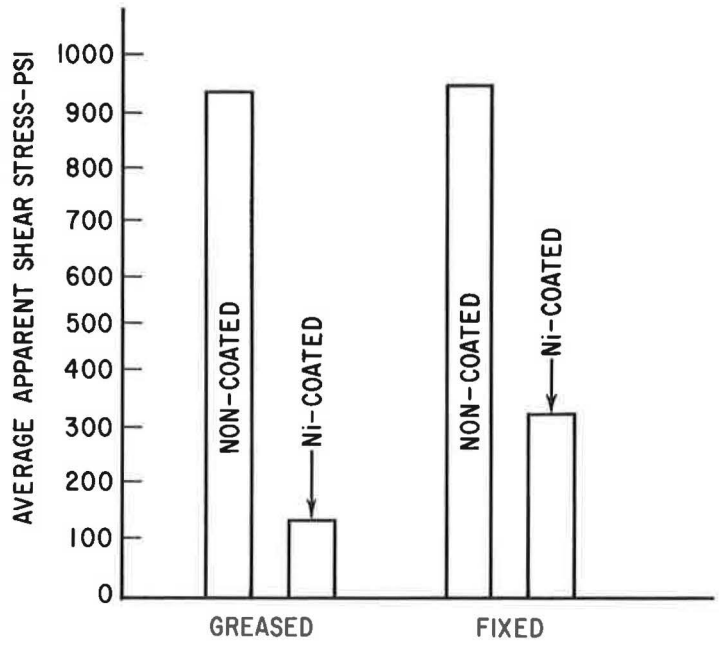


Figure 6. Average apparent shear stress for nickel-coated and plain carbon steel.

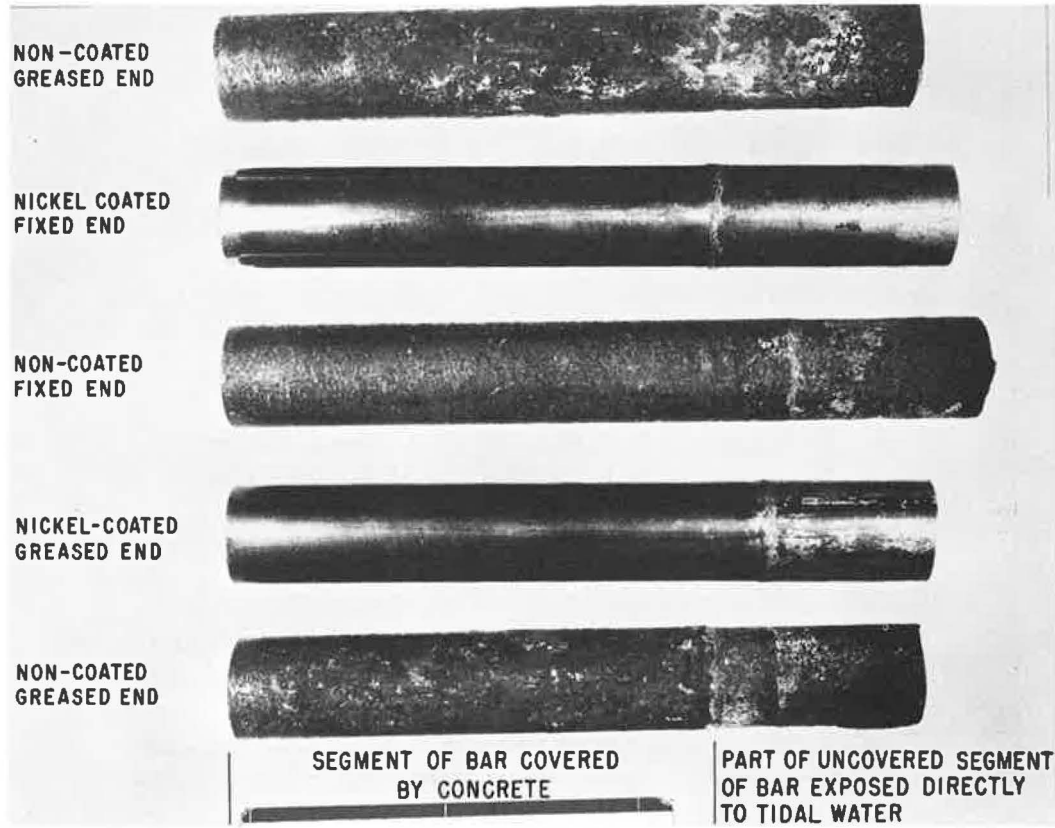


Figure 7. Dowel bars after 21 months' tidal zone exposure.

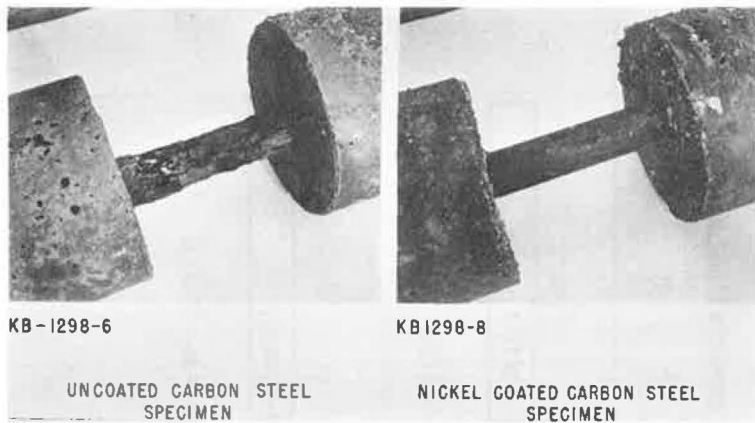


Figure 8. Dowel pin specimens after 3 years and 4 months of exposure in tidal zone.

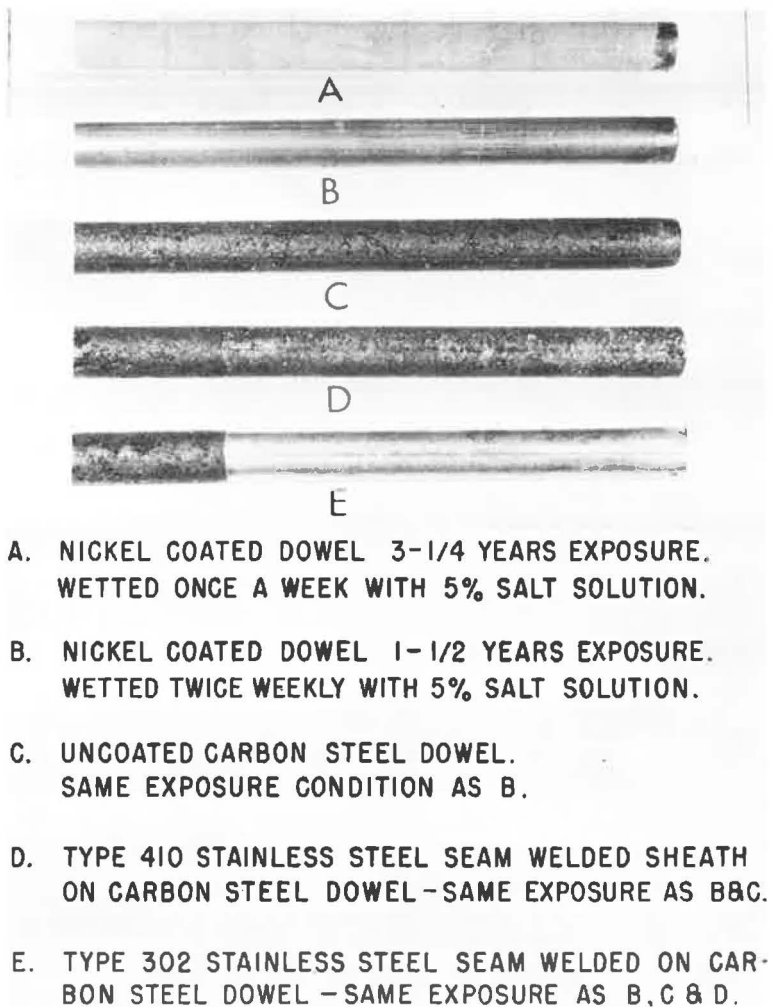


Figure 9. Atmospheric exposure of dowels at Bayonne, N. J.



have been reduced in cross-sectional area by approximately 6.5 percent. The nickel-coated dowels had no measurable reduction in cross-sectional area.

Of the original 16 specimens, two containing nickel-coated dowels and one containing plain carbon steel dowels have remained on the tidal zone rack. The comparative condition of these dowels after 3 years and 4 months of exposure is shown in Figure 8.

It is evident that during the tidal zone exposure the corrosive media had reached the surface of the greased or free end of the dowels. Judging from appearance, corrosive media had also reached the fixed end but to a somewhat less degree. The plain, hot-rolled carbon steel dowels were restrained from movement at the greased end of the concrete specimen to nearly the same extent that the fixed end was restrained. Thus, the possible utility of nickel-coated dowels for highway use in concrete road joints is indicated by the low degree of restraint offered when compared with the plain carbon steel dowels.

Two types of stainless steel-sheathed dowels, nickel-coated dowels and a plain carbon steel dowel from the atmospheric exposure test are shown in Figure 9.

### CONCLUSIONS

1. Sufficient time has not elapsed to provide conclusive results from the several state highway department performance tests. All types of corrosion-resistant dowels appear to be functioning properly as nearly as can be determined from seasonal measurements of joint opening and closing.

2. The tidal zone exposure and accompanying pull-out data confirm Mitchell's (2) conclusion that a nickel-coated dowel is promising.

### REFERENCES

1. Van Breemen, William, "Experimental Dowel Installations in New Jersey." HRB Proc. 34: 8-33 (1955).
2. Mitchell, R. G., "The Problem of Load Transfer Dowels." HRB Bull. 274, 57-69 (1960).
3. Wood, L. E., and Lavoie, R. P., "Corrosion Resistance Study of Nickel-Coated Dowel Bars." HRB Research Record 32, 25-34 (1963).