EVALUATION OF HOOK BOLTS FOR LONGITUDINAL BULKHEAD CONSTRUCTION JOINTS

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Research Laboratory Division
Office of Testing and Research
Research Project R-58 F-50
Research Report No. R-485R

Michigan State Highway Department
Lansing, January 1965

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The usefulness of hook bolt couplings several years after their installation, in tieing new slabs to existing concrete pavement in widening projects, is directly related to corrosion prevention measures that were employed when they were originally installed. The Department formerly specified protection of these coupling components by inserting graphite grease, and then sealing with a cork prior to placement of shoulder material against the slab edge. However, this method was rated unsatisfactory by the Office of Construction in 1958.

The Research Laboratory was then requested to find a better method of protection. As a result, a laboratory experiment was conducted using various types of rust inhibitors and sealing with several types of plugs. From the information gained in this experiment, two types of rust inhibitor and three types of plugs were selected for a full-scale experimental field installation, in which the rejected graphite-cork treatment was also included for purposes of comparison. This field installation was completed in the Fall of 1959, and subsequently two performance observations were made. Results of both the laboratory and the field studies were informally reported, and were used to upgrade Departmental specifications.

In a memorandum dated August 12, 1964, it was requested by W. A. Sawyer, Assistant Engineer of Bridge and Road Design, that the Research Laboratory report on the desirability of continuing the installation of hook bolt couplings on projects where future widening is anticipated. As a result of this request, it was decided that the earlier studies should be reviewed for a full report of research findings. In addition, a third inspection of the 1959 field installation was scheduled, and a new survey was undertaken to determine the present condition of hook bolt couplings installed in recent years on various regular construction projects.

This report includes discussion of the laboratory and field experiments, summarizes the field survey of couplings on regular construction projects, and presents recommendations for the inclusion of hook bolts on future projects where widening is anticipated.

Laboratory Experiment

Three small concrete blocks were cast with a total of sixteen 5/8-in. NC hook bolts and threaded couplings embedded in them. Table 1 summarizes the corrosion preventive treatments to which the couplings were subjected. After inserting the rust inhibiting materials the couplings were sealed by pressing the plugs into place and striking lightly with a hammer.

TABLE 1
CORROSION PREVENTIVE TREATMENT OF HOOK BOLT SLEEVES

Block No.	Coupling No.	Corrosion Preventive Treatment	Sealing Method
1	I	Texaco liquid rust inhibitor	Neoprene plug(1)
	II	Texaco liquid rust inhibitor	Neoprene plug
	III	No rust inhibitor	No plug
	IV	No rust inhibitor	No plug
	V	Graphite grease	Neoprene plug
	VI	Graphite grease	Neoprene plug
2	I	Graphite grease	Cork plug
	II	Graphite grease	Cork plug
	III	Texaco 1976 rustproof compound L	Neoprene plug
	IV	Texaco 1976 rustproof compound L	Neoprene plug
	V	Texaco 1976 rustproof compound L (modified)(2)	Neoprene plug
	VI	Texaco 1976 rustproof compound L (modified)(2)	Neoprene plug
3	I	Texaco liquid rust inhibitor	Lead washer and bolt(3)
	II	No rust inhibitor	Lead washer and bolt
	III	Texaco liquid rust inhibitor	Rubber and cooper washer and bolt
	IV	Texaco liquid rust inhibitor	Asbestos and rubber washer and bolt

1 Neoprene coated rubber plugs were used because neoprene plugs of the proper size were not readily available at the time the experiment was prepared.
2 Modification consisted of thinning and adding rust inhibitor to resemble Military Specification, "Corrosive Preventative Compound, Petrolatum, Pigmented." MIL-C-15167 B (Navy).
3 Bolts used were 5/8 x 1 NC hex cap screws.

In Block No. 3 an attempt was made to protect the exposed end of the threaded coupling as well as the internal threaded area. In the two cases using the lead washers, protection was accomplished by exerting sufficient torque on the bolts to crush the washer against the end of the coupling. Coupling III of this block used a butyl rubber washer backed up by a copper washer of the same size, with the bolt tightened sufficiently to compress the rubber to approximately half its original thickness. Coupling IV, the last for this block, used an unbacked washer fabricated from rubber and asbestos. No appreciable compression of this washer occurred when the bolt was tightened.

After the couplings were treated, the blocks were placed in the bottom of a 14-in. deep tank equipped with a close fitting cover and bottom drain. Pavement shoulder material was then packed around the edges containing the couplings, and a 2-gal brine solution consisting of 76 parts calcium chloride, 0.8 parts copper sulfate, and 0.05 parts potassium nitrate to each 1000 parts water was poured over the blocks and soil. The tank cover was closed and the solution allowed to percolate through the soil and out the bottom drain where it was collected for re-use. A 100-watt light bulb, enclosed in the tank, was turned on to provide heat to dry the soil. A test cycle was considered complete when the soil was completely dry in the area around the couplings.

The couplings were subjected to numerous cycles of alternate wetting and drying during a six-month period, after which they were inspected. The condition of the couplings in each block was as follows:

Block No. 1. The coupling faces showed heavy corrosion to a depth ranging from 1/32 to 1/8 in., and the first thread in each was corroded. In addition, all threads were corroded in Couplings III and IV, which had received no treatment whatever. The rust inhibitors had provided good protection and the couplings received the hook bolts with ease, again with the exception of Couplings III and IV which required retapping to the same thread size before hook bolts could be screwed into the sleeves.

Block No. 2. All couplings in this block showed corrosion on the end faces to a depth of approximately 1/16 in. and the first thread in each was also corroded. The hook bolts screwed into the couplings with ease, although in Couplings III, IV and VI a small force exerted on a wrench was required, possibly because of pigment from the rust inhibitors having collected in the thread grooves.

Block No. 3. No corrosion was noted on the end faces nor on the internal threads of the couplings and they all received the hook bolt with ease. However, the head on each bolt used to seal the sleeves was heavily corroded, and cleaning was required before a wrench could be applied to remove the bolts.

The condition of the couplings after the six-month inspection is shown in Fig. 1. The experiment failed to show any appreciable difference in the corrosion preventive properties of various rust inhibitors used. With respect to sealing characteristics, the bolt-and-washer systems proved superior. To supplement the information obtained from the experiment it was decided that a section of a regular construction project would be selected in which the hook bolt couplings would be prepared against corrosion with various types of rust inhibitors and plugs.

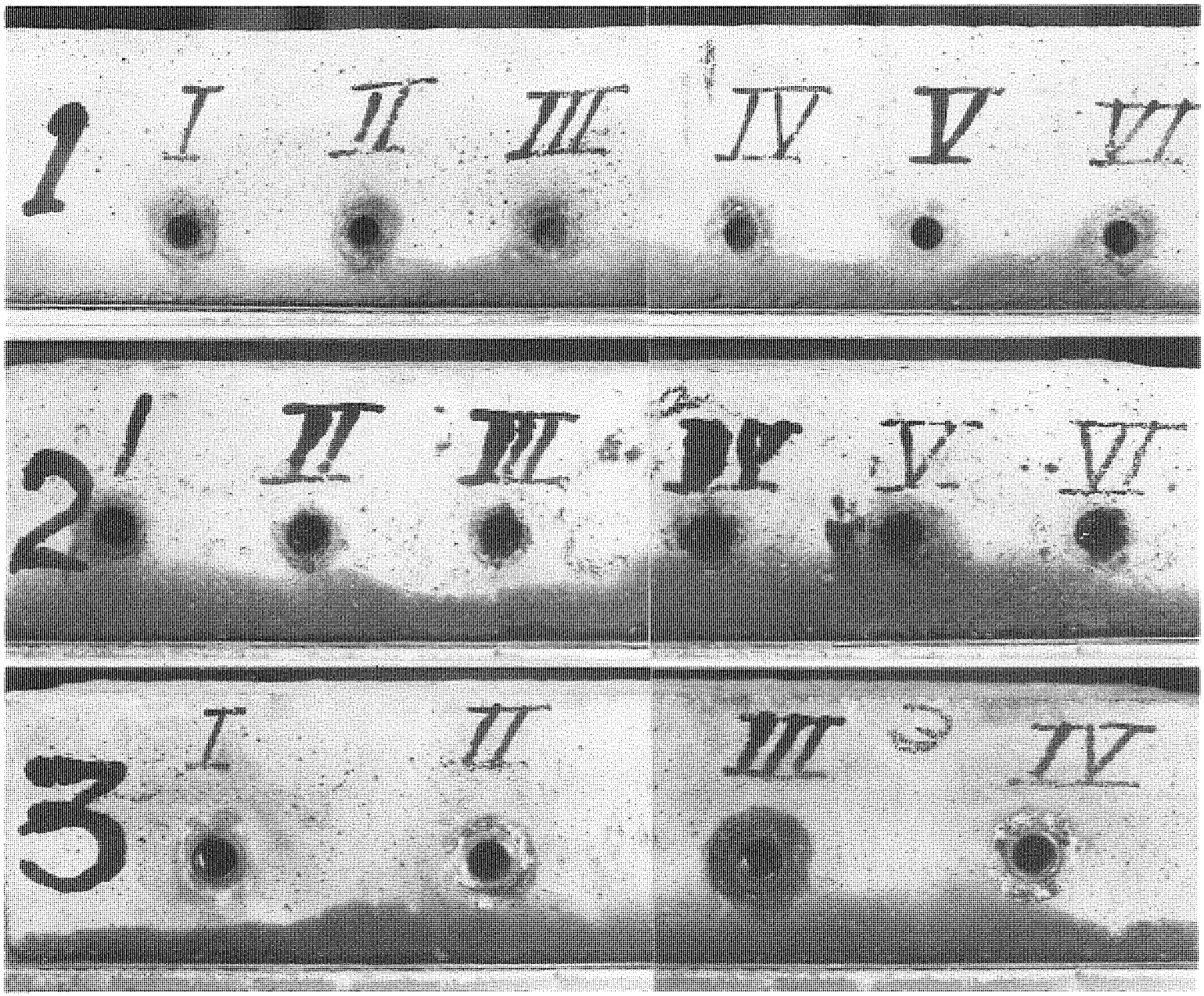

Figure 1. Condition of hook bolt couplings after six months of embedment in corrosive environment Block No. 1 (top), Block No. 2 (center), Block No. 3 (bottom).

Experimental Field Installation

The pavement section selected for the experimental installation was located at Sta. 1084+00, on the I 94 westbound roadway of Construction Project BI 13083, C4 (23 Mile Road east to the Calhoun-Jackson County Line). The hook bolts with 9/16-in. NC thread couplings were embedded in the median edge of the 9-in. uniform slab. Nine separate test treatments were applied to a total of 34 couplings, separated into five groups to be inspected at different dates to ascertain the coupling condition. At the time the couplings were treated, about 4 hr after removal of the paving forms, they were free of rust and other foreign material. The nine treatments involved four different plugs and three corrosion inhibitors, distributed as shown in Fig. 2, as follows:

Plug 1. Threaded, flanged cap screw fabricated from linear polyethylene and having a 1-1/8 in. diam flange for complete coverage of the exposed end of the coupling.

Plug 2. Size 0 neoprene plugs.

Plug 3. Corks of the type initially approved by the Department for this particular application.

Plug 4. Hollow, tapered plastic plugs with shoulders, approved by the Department in 1959 for use on certain projects.

Inhibitor 1. Valvoline tectyl 882, lubricating oil, preservative, medium (Federal Specification MIL-L-3150).

Inhibitor 2. Texaco Type LB - spray.

Inhibitor 3. Graphite grease.

On July 15, 1960, nine months after installation, the nine couplings in Group No. 1 were exposed for examination and at this time it was discovered that the contractor, in the process of placing shoulder material, had allowed a scraper blade or similar piece of equipment to ride along the edge of the pavement damaging the plugs. The plastic cap screws and the corks were broken off flush with the pavement edge, the neoprene plugs were missing, and the hollow, tapered plastic plugs which protrude about 3/64 in. from the pavement edge had been damaged. Thus, it was not possible to evaluate the ability of the plastic cap screws to prevent corrosion of the coupling face. Examination of Group No. 2 on June 6, 1961, and Groups No. 3 and 4 on September 1, 1964, revealed that the plugs in these groups had also been damaged, in the same manner as Group No. 1.

The condition of the plugs, rust inhibitors, and coupling threads is summarized in Table 2. Of the total number of plugs examined, 63 percent were found to be either broken, loose, or missing. Observation

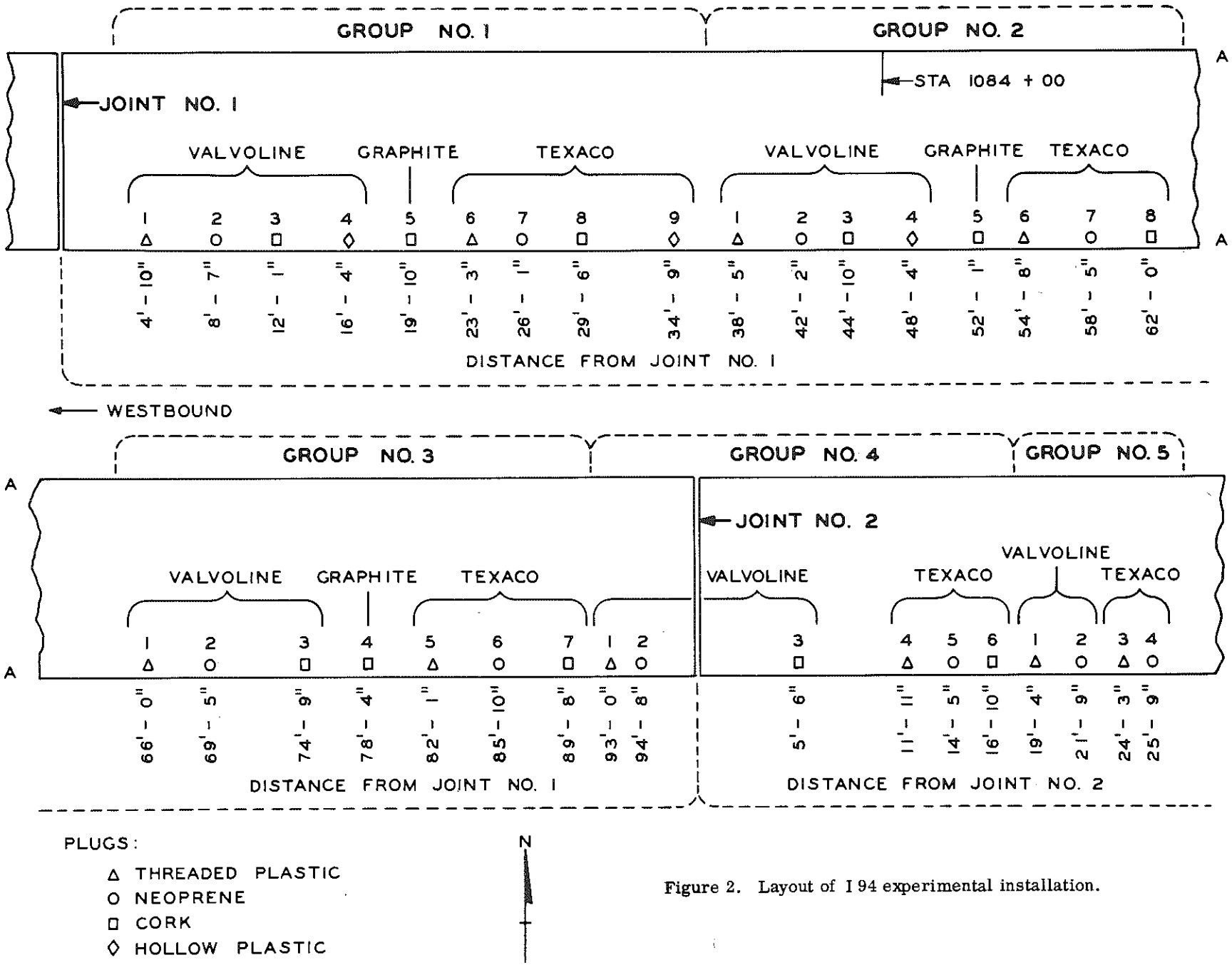

Figure 2. Layout of I 94 experimental installation.

TABLE 2
SUMMARY OF HOOK BOLT FIELD EVALUATION DATA
I 94 Experimental Installation

Rust Inhibitor	Plug Type	Group No.	Plug No.	Survey Date	Condition Ratings		
					Plug	Rust Inhibitor	Threads
Valvoline	Threaded Plastic	1	1	7-15-60	Plug head broken off	Oily, covering threads	Rust free
		2	1	6-6-61	Plug head broken off	Oily, slightly coagulated, threads covered	Rust free
		3	1	9-1-64	Plug head broken off	Oily, slightly coagulated, threads covered	Rust free
		4	1	9-1-64	Plug head broken off	Oily, slightly coagulated, threads covered	Rust free
	Neoprene	1	2	7-15-60	Plug missing	Oil and dirt mixture in threads	Slightly rusted
		2	2	6-6-61	Intact	Oily, slightly coagulated, threads covered	Rust free
		3	2	9-1-64	Broken and loose	Oily, coagulated, threads covered	Rust free
		4	2	9-1-64	Plug missing	Oil and dirt mixture in threads	Slightly rusted
	Cork	1	3	7-15-64	Loose	Oily, slightly coagulated, threads covered	Slightly rusted
		2	3	6-6-61	Intact	Oily, slightly coagulated, threads covered	Rust free
		3	3	9-1-64	Broken and loose	Oily, slightly coagulated, threads covered	Rust free
		4	3	9-1-64	Intact	Oily, slightly coagulated, threads covered	Rust free
	Hollow Plastic	1	4	7-15-60	Flange cracked	Oily, threads covered	Rust free
		2	4	6-6-61	Intact	Oily, slightly coagulated, threads covered	Rust free
Texaco	Threaded Plastic	1	6	7-15-60	Plug head broken off	Oily, threads covered	Rust free
		2	6	6-6-61	Plug head broken off	Dried up	Moderately rusted
		3	5	9-1-64	Plug head broken off	Dried up	Rust free
		4	4	9-1-64	Plug head broken off	Dried up	Rust free
	Neoprene	1	7	7-15-60	Plug missing	Oil and dirt mixture in threads	Slightly rusted
		2	7	6-6-61	Plug missing	Oil and dirt mixture in threads	Moderately rusted
		3	6	9-1-64	Intact	Dried up	Slightly rusted
		4	5	9-1-64	Intact	Oily, threads covered	Rust free
	Cork	1	8	7-15-60	Intact	Oil in coupling threads	Rust free
		2	8	6-6-61	Nearly deteriorated	Dried up	Slightly rusted
		3	7	9-1-64	Intact	Dried up	Rust free
		4	6	9-1-64	Intact	Dried up	Rust free
	Hollow Plastic	1	9	7-15-60	Flange broken	Oil in coupling threads	Rust free
Graphite	Cork	1	5	7-15-60	Loose	Dried up	Slightly rusted
		2	5	6-6-61	Intact	Oily, threads covered	Rust free
		3	4	9-1-64	Broken	Dried up	Rust free

of the ability of the rust inhibitors to protect against corrosion indicated that the Valvoline oil during the five-year test period had retained its protective properties in all couplings. The Texaco oil appeared effective in the 1960 inspection, but in the couplings inspected in 1961 the oil had dried up. This was also the case for the couplings checked in 1964, except for one which still appeared to retain some protection. Of the three couplings protected with graphite grease, the one examined in 1960 showed that the graphite had dried up. The graphite in the coupling inspected in 1961 appeared intact, but had dried up in the one checked in 1964. As shown in Table 2 the threads in most couplings were rust free. Where rust is indicated, it was confined to the first few threads of the coupling. A check of the ease with which the couplings received the hook bolt during the 1964 survey indicated that the hook bolts could be classed as finger free fit. Typical condition of the Valvoline oil and coupling threads is shown in Fig. 3; although these photographs were taken during the 1961 survey, the condition illustrated is also representative of that observed in 1964.

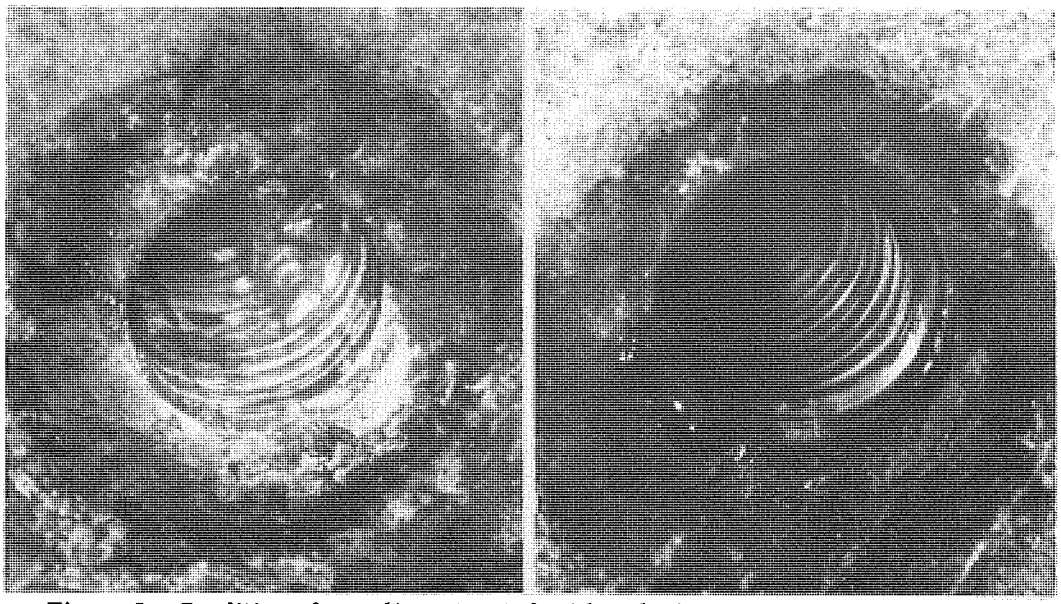

Figure 3. Condition of couplings treated with Valvoline oil. Sealed with hollow plastic plug (right) and cork (left).

The information obtained in the laboratory experiment and the field installation has been used to provide better protection of hook bolt couplings. For example, the graphite treatment with cork or neoprene plug specified in the 1957 edition of the Standard Specifications was eliminated in the 1960 edition, and instead a treatment consisting of an oil similar to the Texaco compound used in the laboratory experiment and

plugs of neoprene or plastic was specified. In the 1963 edition the rust inhibitor specified is the Valvoline oil conforming to Federal Specification MIL-L-3150, which was used for treatment of several couplings in the field installation. The option of using neoprene or plastic plugs remained unchanged.

Field Survey

The field survey of hook bolt couplings installed on regular construction projects was conducted in late October 1964, in cooperation with the Office of Maintenance which furnished men and equipment to expose the couplings and repair the shoulder surface. Three projects selected for inspection (two in Berrien County and one in Livingston County), all programmed for widening in the near future, were as follows:

1. BI 11015, C1; 4.4 miles on I 94, constructed in 1960.
2. BI 11017, C3 and 11016, C1; 3.8 miles on I 94, constructed in 1960.
3. BI 47064, C2; 4.1 miles on I 96, constructed in 1957.

On each project, ten consecutive hook bolt couplings were examined at each of three locations along the length of the project. The condition of the plug and rust inhibitor was noted for each coupling inspected. The usability of the coupling was rated in terms of two condition classes, defined as follows:

Condition 1 - Coupling received hook bolt without cleaning of threads either by finger free fit or by a slight force exerted with a wrench.

Condition 2 - Coupling received hook bolt by finger free fit, only after retapping to same thread size.

The field survey data pertaining to plug, rust inhibitor, and coupling condition for each project are tabulated in Table 3.

Construction Project BI 11015, C1. As shown in Table 3 the couplings on this project were 9/16 NC, treated with graphite and sealed with a hollow tapered plastic plug having a 7/8-in. diam flange. It should be noted that although the plug flange thickness is only 3/64 in., with this slight protrusion from the pavement edge some 30 percent of the plugs examined were either damaged or missing. The graphite in all couplings was dried up and was found to be mixed with sand, except one where the graphite treatment apparently had been omitted at the time of installation.

TABLE 3

SUMMARY OF FIELD EVALUATION DATA ON HOOK BOLT COUPLINGS

Coupling Condition Class 1 = Received bolt without thread cleaning

Coupling Condition Class 2 = Received bolt only after retapping to original thread size

	Coupling, Seal, and Rust Inhibitor	Station Location	Coupling No.	Avg. Condition	Inhibitor Condition	Coupling Condition Class
Construction Project 11015, C1	9/16 in. NC couplings with hollow plastic plugs and graphite rust inhibitor	1143+50 WB	1	Intact	Dried up and mixed with sand	2
			2	Intact	Dried up and mixed with sand	2
			3	Intact	Dried up and mixed with sand	2
			4	Intact	Dried up and mixed with sand	2
			5	Intact	Dried up and mixed with sand	2
			6	Crack in flange	Dried up and mixed with sand	2
			7	Intact	Dried up and mixed with sand	2
			8	Crack in flange	Dried up and mixed with sand	2
			9	Intact	Dried up and mixed with sand	2
			10	Crack in flange	Dried up and mixed with sand	2
		1048+40 WB	1	Intact	Dried up and mixed with sand	2
			2	Intact	Dried up and mixed with sand	2
			3	Intact	Dried up and mixed with sand	2
			4	Intact	Dried up and mixed with sand	2
			5	Crack in flange	Dried up and mixed with sand	2
			6	Intact	Dried up and mixed with sand	2
			7	Missing	Coupling full of sand	2
			8	Intact	Dried up and mixed with sand	2
			9	Missing	Coupling full of sand	2
			10	Crack in flange	Dried up and mixed with sand	2
		998+00 WB	1	Flange missing	Dried up and mixed with sand	2
			2	Flange missing	Dried up and mixed with sand	2
			3	Missing	Coupling full of sand	2
			4	Intact	Dried up and mixed with sand	1
			5	Intact	Dried up and mixed with sand	2
			6	Intact	Dried up and mixed with sand	2
			7	Intact	Dried up and mixed with sand	1
			8	Intact	Dried up and mixed with sand	1
			9	Intact	Dried up and mixed with sand	1
			10	Intact	No rust inhibitor	2
Construction Projects 11017, C3 and 11016, C1	9/16 in. NC couplings with cork plugs and grease rust inhibitor	1501+50 EB	1	Broken off flush with coupling	Clean moist grease	1
			2	Intact - protruding 1/2 in.	Clean moist grease	1
			3	Intact - protruding 1/2 in.	Clean moist grease	1
			4	Intact - protruding 1/2 in.	Clean moist grease	1
			5	Intact - protruding 1/4 in.	Clean moist grease	1
			6	Missing	Coupling full of sand	2
			7	Broken off flush with coupling	Clean moist grease	1
			8	Broken off flush with coupling	Clean moist grease	1
			9	Broken off flush with coupling	Clean moist grease	1
			10	Broken off flush with coupling	Clean moist grease	1
		1542+15 EB	1	Intact	Clean moist grease	1
			2	Broken off flush with coupling	Clean moist grease	1
			3	Broken off flush with coupling	Clean moist grease	1
			4	Broken off flush with coupling	Clean moist grease	1
			5	Intact - protruding 1/8 in.	Clean moist grease	1
			6	Intact - flush with coupling	Clean moist grease	1
			7	Intact - protruding 1/2 in.	Clean moist grease	1
			8	Broken off flush with coupling	Clean moist grease	1
			9	Intact - protruding 1/4 in.	Clean moist grease	1
			10	Broken off flush with coupling	Clean moist grease	1

TABLE 3 (Cont.)

SUMMARY OF FIELD EVALUATION DATA ON HOOK BOLT COUPLINGS

Coupling Condition Class 1 = Received bolt without thread cleaning

Coupling Condition Class 2 = Received bolt only after retapping to original thread size

	Coupling, Seal, and Rust Inhibitor	Station Location	Coupling No.	Avg. Condition	Inhibitor Condition	Coupling Condition Class
Construction Projects 11017, C3 and 11016, C1	9/16 in. NC couplings with hollow plastic plugs and grease rust inhibitor	1562+80 EB	1	Intact	Clean moist grease	1
			2	Intact	Clean moist grease	1
			3	Intact	Clean moist grease	1
			4	Intact	Clean moist grease	1
			5	Flange cracked	Clean moist grease	1
			6	Intact	Clean moist grease	1
			7	Flange missing	Clean moist grease	1
			8	Intact	Clean moist grease	1
			9	Intact	Clean moist grease	1
			10	Crack in flange	Clean moist grease	1
Construction Project 47064, C2	5/8 in. NC couplings with cork plugs and graphite rust inhibitor	318+00 WB	1	Intact	Dried up	1
			2	Intact	Dried up	1
			3	Intact	Dried up	1
			4	Intact	Dried up	1
			5	Intact	Dried up	1
			6	Intact	Dried up	1
			7	Intact	Dried up	1
			8	Intact	Dried up	1
			9	Intact	Dried up	1
			10	Intact	Dried up	1
		238+80 WB	1	Intact	Dried up	1
			2	Missing	Coupling full of sand	2
			3	Intact	Dried up	1
			4	Intact	Dried up	1
			5	Intact	Dried up	2
			6	Intact	Dried up	2
			7	Intact	Dried up	2
			8	Intact	Dried up	2
			9	Intact	Dried up	1
			10	Intact	Dried up	1
	5/8 in. NC couplings with cork plugs and "Lubriplate" rust inhibitor	146+60 WB	1	Intact	Clean and moist	1
			2	Intact	Clean and moist	1
			3	Intact	Clean and moist	1
			4	Intact	Clean and moist	1
			5	Intact	Clean and moist	1
			6	Intact	Clean and moist	1
			7	Intact	Clean and moist	1
			8	Intact	Clean and moist	1
			9	Intact	Clean and moist	1
			10	Intact	Clean and moist	1

As soon as the plug was removed an attempt was made to screw the proper size hook bolt into the coupling without further cleaning of any kind. In general, all couplings except those where the plug was missing received the hook bolt with ease for the first three to four threads, but then became extremely tight so that full length engagement of the hook bolt threads could not be obtained even by use of a wrench. The rating of the couplings shows that this condition existed in 26 couplings, and only four could be used without retapping to same size. Moisture accumulation was noted in the bottom of the couplings, probably caused by condensation or seepage around the plugs. However, the dried-up graphite apparently had retained enough of its protective properties after four years to prevent corrosion of the threads, because very little rust damage was found. Typical condition of a properly sealed coupling and its threads after retapping to same size is illustrated in Fig. 4.

Construction Projects 11017, C3 and 11016, C1. The survey was confined to the portion of the project west of the I 94-I 196 interchange. In sealing the 9/16 NC couplings two types of plugs had been used--hollow, tapered plastic plugs and corks. The group of 10 couplings where the plastic plug was used had 30-percent damaged plugs. The remaining two groups of 10 each were sealed with corks, with the corks that were found to be intact protruding as much as 1/2 in. from the pavement edge. This condition permitted heavy damage (60 percent), probably inflicted by shoulder construction equipment having broken the corks off flush with the coupling face or pulling them out entirely. An unidentified grease material had been used in treating the couplings. This material appeared to have retained its lubricating properties, as well as protecting the threads from corrosion. It was exceptionally clean and free of sand, except in one case where the plug was missing. As a result 29 of the 30 couplings inspected received the hook bolt without cleaning in a finger free manner, and the remaining one was usable after retapping to the same thread size. Moisture accumulation was most pronounced in the couplings sealed with plastic plugs, probably because the corks (which were noted to be moisture saturated) absorb moisture accumulated in the coupling as well as moisture from the shoulder material. No serious rust damage was noted in any of the couplings after four years. Figs. 5 and 6 illustrate coupling conditions before and after removal of a cork and a plastic plug, respectively.

Construction Project 47064, C2. The protective treatment for the 5/8 NC couplings employed at the time of construction consisted of sealing with corks after inserting graphite into the couplings. In one of the groups of ten couplings, a grease identified as "Lubriplate" had been

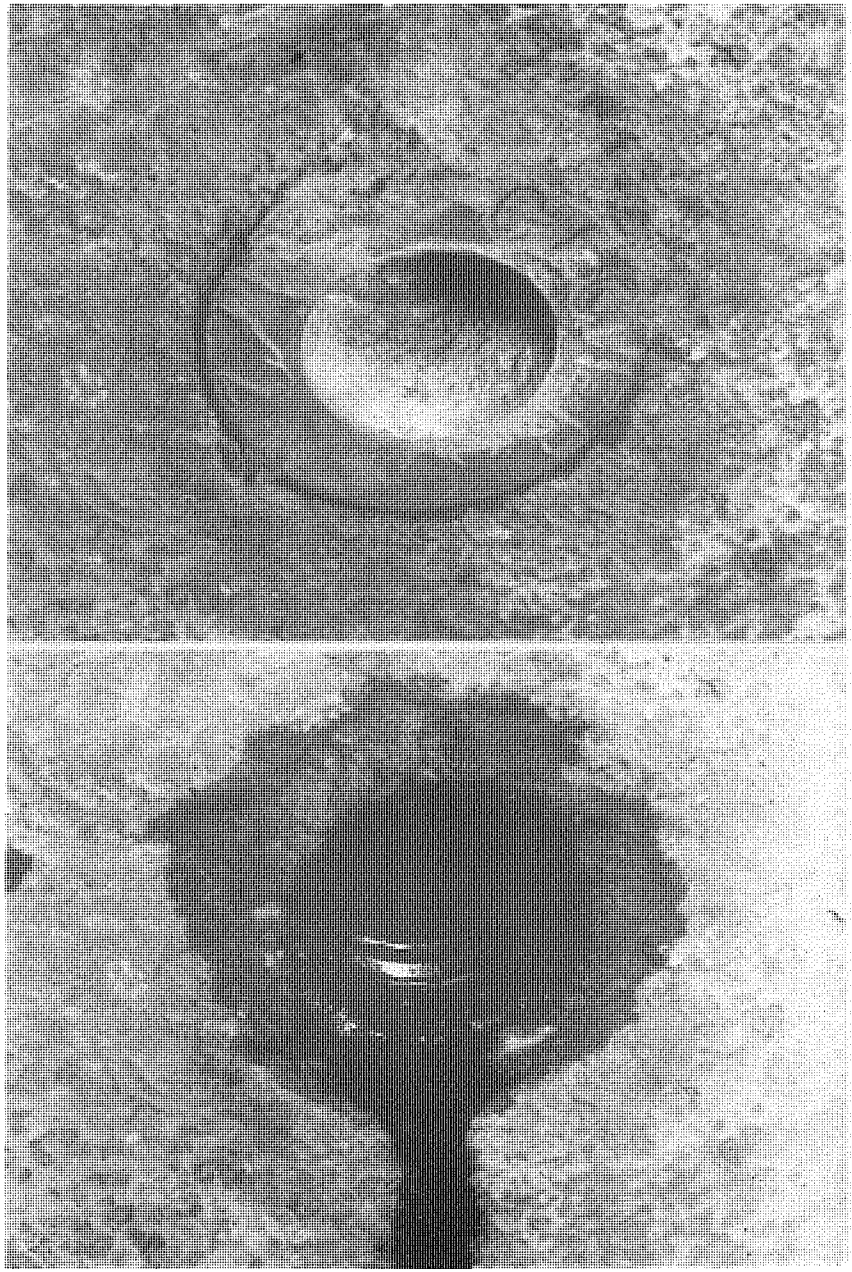

Figure 4. Typical condition of properly sealed coupling, showing sealing plug (top) and threads after retapping (bottom).

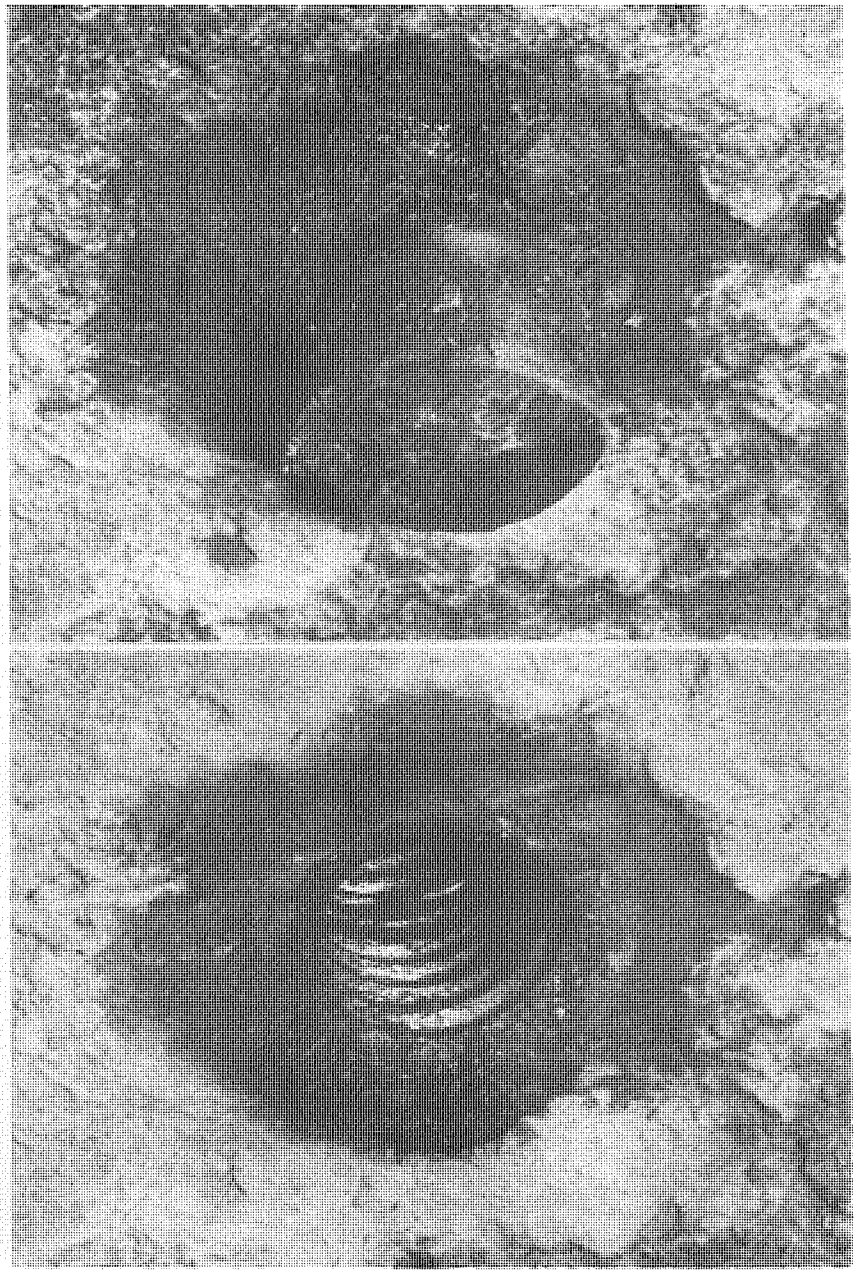

Figure 5. Typical condition of properly sealed coupling, showing sealing plug (top) and exposed threads (bottom).

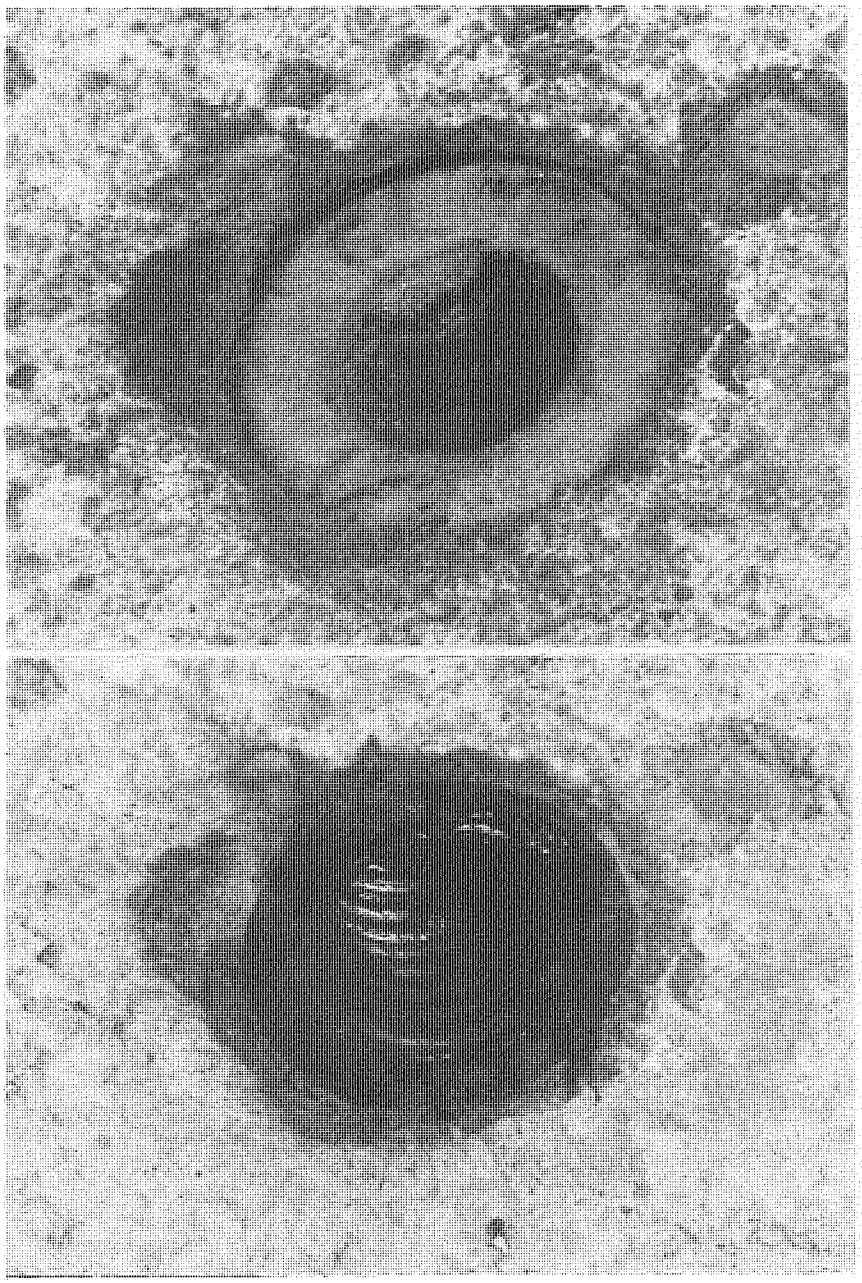

Figure 6. Typical condition of properly sealed coupling, showing sealing plug (top) and exposed threads (bottom).

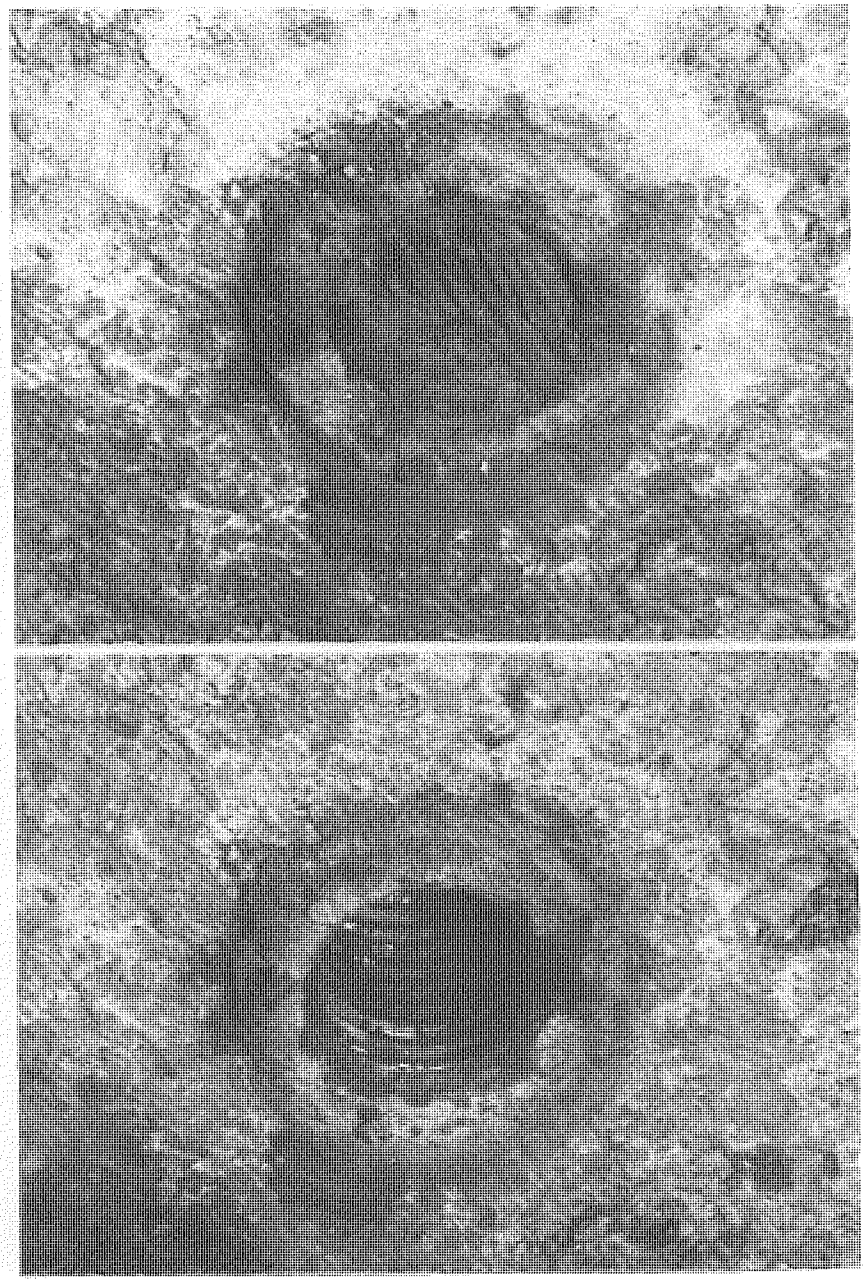

Figure 7. Typical condition of properly sealed coupling, showing sealing plug (top) and exposed threads (bottom).

used instead of graphite. The corks used for sealing the 5/8 in. couplings were the same size used for 9/16 in. couplings, thus permitting their insertion flush with the pavement edge. Therefore, all plugs except one which was missing were intact and showed no damage whatever. The graphite in the group located at Sta. 318+00 had dried up but was free of sand, and all couplings in this group received the hook bolt without cleaning. In the group at Sta. 238+00 the graphite was in the same condition. However, five of ten couplings, including the one where the plug was missing, required cleaning by retapping to the same thread size before the hook bolt could be engaged for the full thread length. The remaining five couplings needed no cleaning. The last group had been treated with Lubriplate, which was clean and still retained its lubricating properties, and all ten couplings were rated in the Condition 1 class. Very little moisture had accumulated in the couplings, but the corks in most cases were saturated with moisture. No serious rust was noted although these couplings had been embedded for approximately seven years. Plug and thread condition of a coupling treated with Lubriplate are shown in Fig. 7.

Summary of Field Evaluation Survey

In the field survey, conditions of the hook bolt couplings, plugs, and rust inhibitors were as follows:

1. Proper engagement of the hook bolt without prior cleaning of any kind was possible in 65 percent of the couplings.
2. In the remaining 35 percent, cleaning by retapping to original thread size was necessary to obtain proper engagement of the hook bolt.
3. Plugs were missing in 6 percent of the couplings, with an additional 22 percent damaged.
4. The graphite generally was the poorest type of rust inhibitor, as compared to ordinary lubricant greases used in some cases.
5. The condition of the couplings inspected was such that their intended structural efficiency was not impaired.

The necessity for cleaning by retapping to original thread size appeared to be caused in part by the type of rust inhibitor used, but mostly by insufficient care in treating the couplings after embedment. Dried-up graphite pigment lodged in the coupling threads was judged to be responsible for preventing proper engagement of the hook bolt in only a few instances. Sand mixed with the dried-up graphite pigment was the most common cause. Both these conditions were easily corrected by retapping the couplings to the original thread size. A more serious condition existed

where the plugs were missing. To recondition these couplings first it was necessary to clean with a screwdriver or similar tool before retapping, after which the couplings were usable.

Expansion Anchors as Possible Alternates

An alternate method of providing lane-ties when adding an additional lane would be the use of expansion anchors, thus eliminating installation of the pavement-embedded hook bolt and coupling at the time of construction. A study of average unit contract prices, prepared by the Design Office's Estimating Section, revealed that from April 1, 1960 to June 30, 1964, a total of 11,300 expansion anchor units had been installed on projects throughout the State at an average unit cost of $3.02. In contrast, information supplied by a paving contractor concerning the cost of an installed hook bolt and coupling, including labor, rust inhibitor, and plug, showed an estimated average unit cost of $0.42. Based on these prices and on a 40-in. spacing, the cost per mile of roadway would be $665 and $4785 for the hook bolt assembly and expansion anchor unit, respectively.

Conclusions and Recommendations

1. Considering the cost differential between hook bolt and expansion anchor methods and based on the information presented, it is recommended that the practice of installing the hook bolt and coupling assembly at the time of construction be continued on projects where the probability of future widening warrants their installation. Even continuing with present inspection procedures, it would appear feasible from an economic viewpoint to include the hook bolt assemblies in concrete pavement at the time of construction, because initial investment plus cost of retapping some couplings to original thread size would be less costly than providing lane ties by use of expansion anchors.

2. With the present method of corrosion prevention treatment it is felt that the hook bolt assemblies can be maintained in usable condition for a 10-to-15 year period, provided the specified procedures[1] are followed in preparing them for future use.

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[1] Although no inspection of couplings was made on regular construction projects where the rust inhibitors specified in the 1960 and 1963 editions of the Standard Specifications were used, these inhibitors were considered satisfactory in the experimental installation since proper engagement of the hook bolt was obtainable without prior cleaning. Thus it is expected that couplings treated with these inhibitors and properly sealed would eliminate the condition of dried-up inhibitor pigments in the threads.

3. It is concluded that there are three principal causes of failure of the hook bolt coupling component (failure being defined as corrosion or infiltration of foreign material into the interior of the coupling to such an extent that rethreading is required). These causes are:

a. Failure to treat the couplings immediately after paving form removal.

b. Careless application of rust inhibitor and plug.

c. Physical damage, subsequent to treatment, during shoulder construction.

4. Since it is recognized that prevention of physical damage to the coupling treatment during shoulder construction presents a very real, practical difficulty to the contractor, it is recommended that the coupling face be recessed slightly into the slab edge. This might be accomplished by use of a 3/8-in. thick, 11/16-in. ID steel washer placed between the coupling and the paving form when the hook bolt is installed, and then removed when the forms are removed. To facilitate the washer's removal, the face placed against the paving form should have a 1-5/8 in. OD, tapering to a 7/8 in. OD against the coupling. It is felt that this slight recess would allow construction equipment to work against the pavement edge without damaging the coupling face or plug.

5. It is recommended that inspection procedures be tightened to ensure specification conformance. Specifically, the couplings must be treated with the specified rust inhibitor and properly sealed immediately after form removal. Since 100-percent inspection is impractical, it is suggested that each day's pour be inspected according to the following schedule:

Daily Pour Length	Sample Size
1 to 10 sta.	6
10 to 20 sta.	9
20 to 30 sta.	12
30 to 40 sta.	15
40 and over	18

These samples must be randomly selected along the length of the day's pour. If any sample selected fails to meet specifications, all couplings in that pour must be re-treated. Damaged or missing plugs must be replaced before placing shoulder material, and replacement must be preceded by cleaning and retreating, where necessary.