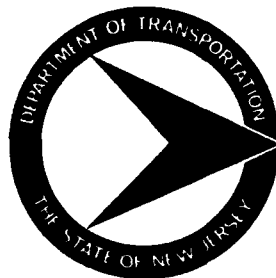


**BRIDGE CONSTRUCTION with UNPAINTED HIGH STRENGTH
LOW-ALLOY STEEL: THE AESTHETIC PROBLEMS**

**BRUCE COSABOOM AND GREGORY MEHALCHICK, CO-AUTHORS,
GEORGE KOZLOV, PROJECT ENGINEER**

**DIVISION OF RESEARCH AND DEVELOPMENT
NEW JERSEY STATE DEPARTMENT OF TRANSPORTATION**

DECEMBER 1978



**Prepared By
New Jersey Department of Transportation
Division of Research and Development
In Cooperation With
U.S. Department of Transportation
Federal Highway Administration**

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. 79-002-7799		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Bridge Construction with Unpainted, High Strength, Low-Alloy Steel: The Aesthetic Problems				5. Report Date December 1978	
				6. Performing Organization Code N/A	
7. Author(s) Bruce Cosaboom & Greg Mehalchick, Authors George Kozlov, Project Engineer				8. Performing Organization Report No. 79-002-7799	
9. Performing Organization Name and Address Bureau of Structures and Materials Division of Research and Development New Jersey Department of Transportation 1035 Parkway Avenue, Trenton, New Jersey				10. Work Unit No. N/A	
				11. Contract or Grant No. HPR	
12. Sponsoring Agency Name and Address Federal Highway Administration Washington, D.C.				13. Type of Report and Period Covered	
				14. Sponsoring Agency Code	
15. Supplementary Notes Project Engineer: George S. Kozlov, New Jersey Department of Transportation					
16. Abstract Use of high-strength, low-alloy steel (ASTM A-242 and A-588) in bridges, as a means of reducing maintenance costs, results in an aesthetic problem of rust staining of abutments and piers. Staining occurs as rust particles, carried by runoff, penetrate into the abutment and pier concrete. The objective of this part of the project is the elimination, easy removal, or camouflaging of staining. There are numerous solutions to the problem. The scope of the project covers the application of a coating to provide an impenetrable layer. Two such products were tested: "Barrier" and "Thompson's Water Seal 101". Following initial testing, it was found only "Barrier" held some promise. Further research, in which "Barrier" was subjected to more severe rust staining, resulted in failure of the product to provide the impenetrable layer. The aesthetic problems are not insurmountable, but various alternatives appear to offer more success than the use of a "penetrant-resistant" coating.					
17. Key Words Steel: Low Alloy, High Strength Abutments: Staining, Painting Staining: Rust, Penetration, Removal Inhibitors: Staining, Rust			18. Distribution Statement		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 23	22. Price

ACKNOWLEDGMENTS

The authors wish to thank all those of the Department who assisted in various ways toward the progress of this research effort. The cooperation of the various product manufacturers and distributors is gratefully acknowledged. The authors also express their appreciation to the Federal Highway Administration for partial funding of the research, without which the work could not continue to a successful end.

NOTICE

"The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State or the Federal Highway Administration, nor do they endorse the use of the product mentioned herein. This report does not constitute a standard, specification, or regulation".

TABLE OF CONTENTS

	Page
I. Summary & Conclusions.....	1
II. Recommendations.....	2
III. Introduction.....	3
A. Background.....	3
B. Objectives.....	4
IV. Study Procedures.....	5
A. Alternate Approaches to the Solution.....	5
B. Products to be Tested.....	6
C. Trial Applications.....	8
D. Post Application Inspections.....	14
V. Results & Discussion.....	16
VI. References.....	23

LIST OF FIGURES

<u>No.</u>	<u>Description</u>	<u>Page</u>
1.	Schematic of Bridge #9 (Areas of application).....	10
2.	Schematic Bridge #10 (Areas of application).....	11
3.	North Abutment (Bridge P1) - Full Scale Barrier Application..	15
4.	North Abutment (Bridge P1) - Two year stains before washing..	19
5.	North Abutment (Bridge P1) - Two year stains after washing with soap solution and soap concentrate.....	20
6.	North Abutment (Bridge P1) - Two year stain and "Barrier" removal with acid solution.....	21

I. Summary and Conclusions

The excessive staining of concrete abutments and piers, by rust-runoff from unpainted, high strength, low-alloy steel bridge superstructures is documented, and cited as aesthetically unacceptable for the majority of highway bridges in New Jersey. Alternate methods of coping with the stains are discussed in this project. Two methods were attempted. Conclusions are offered as follows:

1. In the opinion of the authors, and based upon the results obtained on NJDOT structures, the use of unpainted, low-alloy, high-strength construction steel in highway bridges will result in unsightly rust-staining of the bridges' abutments and piers. Therefore, when these steels are used in an area visible to the public eye, steps should be taken to prevent and/or cover said staining.

2. On the basis of our limited experience, it appears that the worst rust-staining will occur during the first two or three years following the erection and surface preparation (i.e., sandblasting to achieve uniform appearance) of the structural steel. After that time period, any additional rust run-off would probably present only a minimal maintenance problem.

3. "Thomson's Water Seal 101" and "Barrier" were each promoted as penetrant-sealers of concrete. When properly applied, they were supposed to prevent penetration of paint and/or stains into the "protected" concrete surfaces. On the basis of the results described hereinafter, it is concluded that neither of these products offer any reasonable degree of protection from stains or painted graffiti.

II. Recommendations

The aesthetic problems associated with using unpainted steel are not insurmountable, and for the benefit of its users, the following options are recommended for consideration:

1. To help minimize rust staining of abutments and piers, pier caps and bearing seat areas atop abutments should be designed to collect and channelize run-off.

2. Where staining occurs, painting of the concrete is recommended. It may be necessary to repeat this painting occasionally, but it should be substantially less expensive, and much easier than painting of bridge structural steel. If possible, it may be more economical to postpone the first painting until about two years following the erection and associated grit-blasting of the structural steel.

3. It may be possible to camouflage the stains on abutments and piers by bagging with rust-colored bagging slurry. These abutments and piers subsequently receive rust stains, but a rust-cover camouflage may create a more uniform overall appearance.

4. It may also be advantageous to apply an "impregnable" coating to the surface of concrete abutments, from which graffiti and stains could be sand blasted without marring the appearance of the abutment. Caution is urged in acceptance of such products since the two trial products reported herein were originally promoted as such.

5. The costs involved in maintaining the overall appearance of the bridge structure should be considered when performing a cost-benefit analysis for bridge structures in which unpainted low-alloy steel is proposed as the structural steel.

6. In light of the recommendations outlined above, new or current products or methods of stain reduction, removal or prevention that are or will be marketed or introduced should warrant close inspection and further research. For such reason, this report should constitute an interim (or present state-of-art) rather than final report on the aesthetic problems associated with ASTM A-242 and A-588 steels.

III. Introduction

A. Background - Low-alloy, high strength steels (ASTM A-242 and A-588) have been offered as a substitute to the commonly used plain carbon steel for structural steel in numerous bridges in New Jersey. The advantage of using such steels lies in their self-protecting characteristic, that is, they produce an oxide coating which protects against further oxide deterioration in a manner similar to a coat of paint, thereby decreasing maintenance costs through elimination of periodic painting of the structural steel. However, the use of unpainted structural steels is not without problems. One of these problems, the subject of this report, is the effect of rust-runoff and staining upon the overall aesthetics of the bridge structure. It is realized

that this is a subjective evaluation process. Therefore, to put the analysis presented hereinafter into perspective, it is noted that New Jersey is proportionately much more urbanized and suburbanized than most states, and therefore a fairly conservative approach is taken because of the high degree of public scrutiny upon the highway system.

B. Objectives - The fundamental objective of the research is to determine whether or not A-242 and A-588 steels may safely and appropriately be used in an unpainted mode in highway bridges. However, due to the aesthetic problems associated with said steel, the research is presently divided into two parts:

1. Corrosion tests of unpainted steel
2. Rust staining of abutments and piers

The first part was initially a joint venture between the State of New Jersey and the Bethlehem Steel Corporation, and is now scheduled to continue for eight more years. New Jersey supplied the exposure sites and some personnel; Bethlehem Steel Corporation furnished test materials and their laboratory facilities and personnel. Details of this part of the project are found in the references.

The second part of the research is being conducted unilaterally by the New Jersey Department of Transportation. The specific objective of this part of the research is to develop procedures which would enable the Department of

Transportation to use the unpainted steel in bridges, and still achieve an aesthetic appearance which would be consistent with current Department of Transportation standards.

IV. Study Procedures

A. Alternate Approaches to the Solution - Basically, there are two approaches to the solution of this problem. One is the outright prevention of unsightly stains. The second is to allow stains to occur, and then to remove or otherwise obscure them. The selection of either approach, or a combination thereof, will depend upon the desired final appearance, and the relative economics involved in acquiring that result.

There appear to be four options available in the handling of rust staining on the concrete structures:

1. Protect all concrete with sheets of polyethylene during the primary staining period. Considering the realities of construction and length of time over which this protection is required (approximately three years) this is not regarded as a viable solution.

2. Allow the staining to occur freely; then paint the affected areas, or camouflage the visible surfaces. This option is, in essence, an exchange of one maintenance problem for another less expensive, and less critical problem from the viewpoint of structural integrity. Although the New Jersey Department of Transportation has not embarked upon this method on a trial basis

for unpainted bridges, many abutments have nonetheless been painted because of graffiti. It may be asserted that in such cases the graffiti may well determine the required painting maintenance, more so than rust stains from unpainted superstructures. Further, it is standard practice in New Jersey, to perform a "bagging" operation on vertical surfaces of piers and abutments. This is a finishing step in the concrete work, and it is done for aesthetic purposes. This step may be delayed until a construction project nears completion. During that time some of the worst staining would occur, and the subsequent bagging operation would partially obscure the stains, thereby allowing the initial painting to be postponed. This, in effect, "saves" one required painting of the concrete.

3. Provide channelization of runoff such that staining is restricted to relatively non-visible areas, or to very small areas that would not substantially detract from the appearance. This is only a partial solution, since experience indicates that some concrete will usually be stained in spite of channelization attempts.

4. Apply a coating to the concrete such that rust run-off does not penetrate and may be removed with minimal washing effort. This is probably the best solution, provided that there is some such coating to effectively achieve this. This approach is the subject of the material hereinafter presented.

B. Products to be Tested - During the beginning of this research program, little consideration was given to the rust staining of abutments and piers. When the experimental Bridge #9

(Route I-78, Section 5V) was constructed with Mayari-R steel, the supporting concrete structures were to have been protected with sheets of polyethylene. However, the contractor failed to provide such protection. The resulting substantial rust staining of the vertical abutment faces, and subsequent attempts to remove the stains, as well as suitable alternatives to otherwise prevent and/or cover up stains on other structures to be built with said steel, initiated this facet of the research project.

In reality, following the erection of Bridge #9, and the subsequent abutment staining by rust run-off, it was intended only to remove the stains with acid solutions. The idea of applying a protective coating to the abutments was promoted by private concerns. Because relatively few bridges in the jurisdiction of the New Jersey Department of Transportation had been constructed of unpainted steel, such coatings for the abutments were relatively untried. And because this research project format made no specific provisions for investigating such coatings, no search for products, nor extensive testing program, was conducted. The two products which were tested, namely "Barrier" and "Thompson's Water Seal 101" were used only because of timely sales promotions.

"Barrier" is a mixture of polyester resins which forms an elastomeric film with various finishes, for example gloss, semi-gloss, when applied by normal painting techniques, i.e., rolling,

brushing, or spraying. When properly applied, it should form a 2 mil protective coating on the surface of the concrete. Surface pores are supposedly sealed by this coating, thereby preventing penetration of stains and graffiti. In addition, its sponsors claim that the stains and graffiti may be removed by nominal washing and scrubbing with a soap-water solution.

"Water Seal 101" is applied via normal painting techniques and is supposed to repel the intrusion of stains by sealing all pores and voids in the surface concrete.

C. Trial Applications -

1. Small-Scale Trials

In all, three bridge structures were used for various trials. The aforementioned bridge, designated as Bridge #9, was the first bridge on which partial abutment applications were performed. When it was decided to apply a protective coating to portions of the vertical face of one Bridge #9 abutment, those portions were first washed with a mild phosphoric acid solution to remove as much existing rust staining as possible. Two areas on the abutment face were selected for application during May 1970, with "Barrier".

For the trial application on Bridge #9, one area is a flat-surfaced vertical abutment panel, about 4 feet in width (Figure 1). The upper five feet of the panel were coated with "Barrier" with the next four feet left unprotected. The remaining length of the panel was coated with "Barrier". The second area

is at the southeast corner of the abutment, in a .6-inch wide recess that runs vertically for the full height of the face of the abutment. Whereas the first area is substantially protected beneath the bridge, this area is in an exposed position; thereby undergoing the full effects of weather, including exposure to sunlight. The recess was cleaned from ground level to a height of seven (7) feet. The bottom two feet were left clean and protected. From the 2-foot level up to the 6-foot level "Barrier" was applied with a paint brush. The remaining foot of cleaned concrete was left unprotected. The cleaned and unprotected portions of both areas serve as a basis for comparison with the "protected" areas. Each was selected on the basis that visual inspection revealed they were both subjected to generous supplies of rust run-off. Because this bridge had been constructed 2 years prior, it was suspected that most rust staining may have already occurred and that additional stains may be minimal. As a result, it was decided to perform another trial on a nearby bridge which was under construction, the abutments of which had not yet been stained.

The bridge selected for this second small trial application is Bridge #10, Route I-78, Section 5U (Figure 2). The same product was applied to the west end of the south abutment during July 1970.

"Barrier" was rolled and brushed onto the face and the top surfaces of a 15-foot length of abutment which was totally free of rust stains. The area covered includes a bearing seat surface and a small groove designed to collect and accommodate run-off

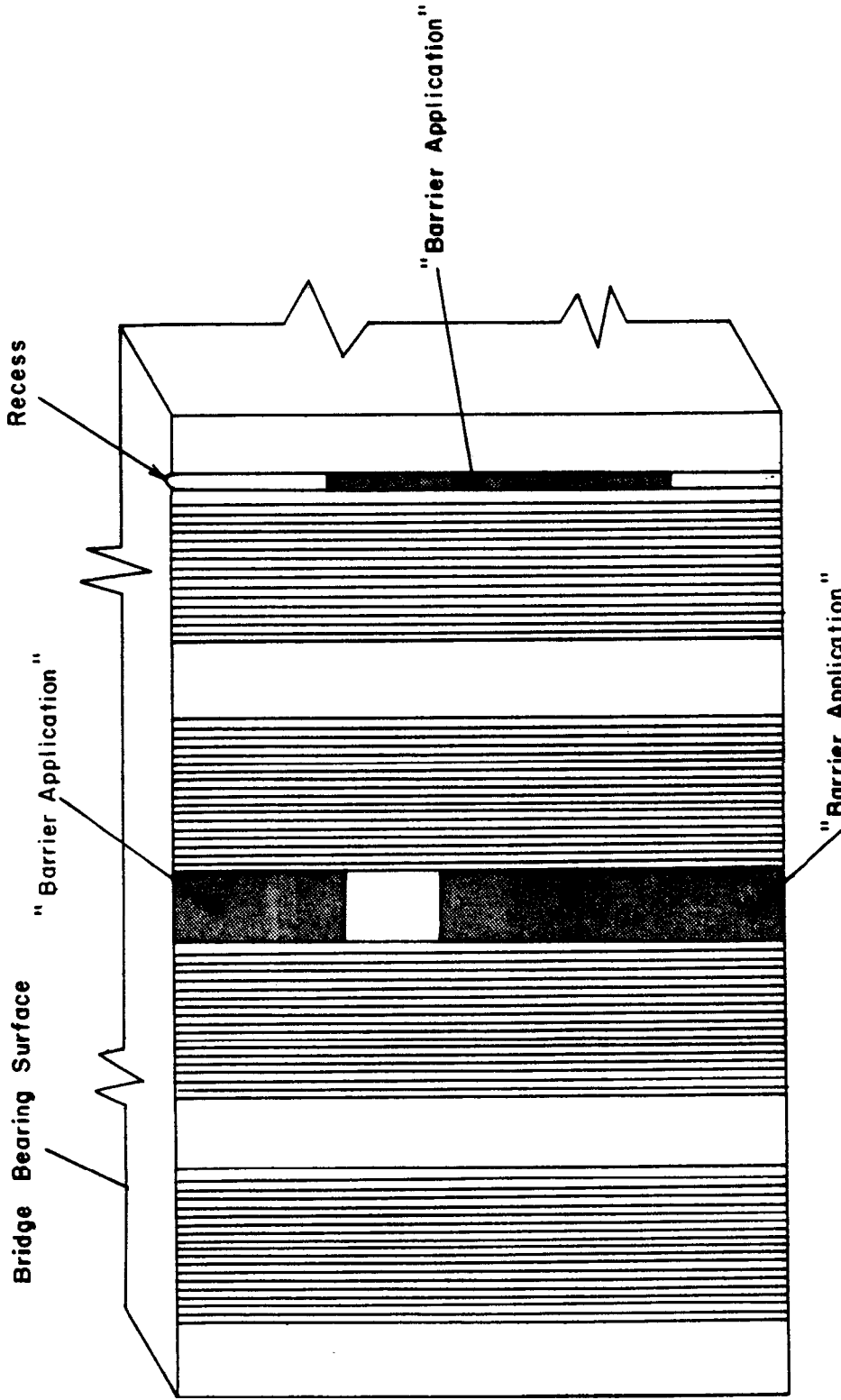


FIG. 1 - SCHEMATIC OF BRIDGE #9 (AREA OF APPLICATION)

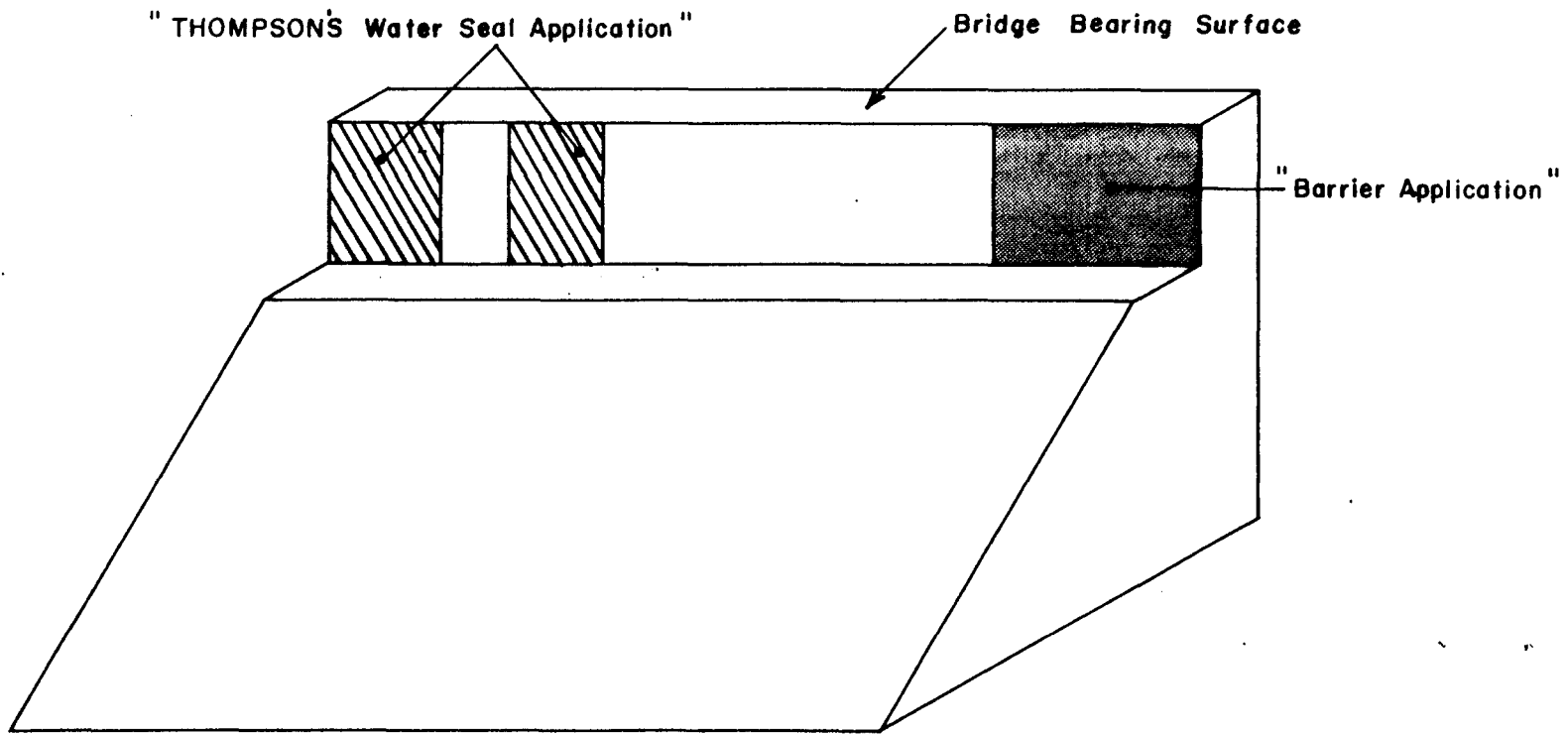


FIG. 2 - SCHEMATIC OF BRIDGE #10 (AREA OF APPLICATION)

from a fascia beam bearing seat. This groove runs around the outside edge of the top surface of the fascia beam bearing seat.

The abutment was bagged just prior to the application of "Barrier", with none of the steel (A-242) superstructures yet in place. The abutments received no special cleaning or washing prior to the actual application of "Barrier" via normal roller and brush painting techniques. In addition to this partial trial application of "Barrier", it was also later decided to apply, on different areas of the abutment, the "Thompson's Water Seal 101", hereinafter referred to as Water Seal.

Water Seal was applied at four (4) locations on the vertical face of the abutment in August 1971; each location was selected due to evidence of encountering rust run-off from the unpainted steel bridge girders. The locations were:

1. Beneath the outer fascia beam at the eastern end of the abutment.
- 2&3. Beneath each of the adjacent fascia beams of the two bridges (omitted from Fig. 2).
4. Beneath an inner beam, where excessive rust run-off was noted.

Prior to application, the areas of concrete were cleaned via wire brushes, with practically all of the rust staining being removed. Then the product was brushed on. The top and bottom

portions of the vertical face were painted, leaving an 8-inch horizontal, unpainted band in between. This band is to serve as a comparison point when later observations are conducted.

During application, the temperature was about 80°F and the concrete was dry. Water Seal was observed to quickly draw into the concrete to the extent that it visually disappeared. Two additional coats were subsequently applied, until the product appeared to be adequately applied. The final appearance of the concrete was somewhat darkened, (as if it was wet) but it did not obtain a gloss similar to abutment treatment with Barrier.

2. Full Scale Trial

On the basis of the advantageous preliminary results obtained from the partial trial applications of "Barrier", it was decided to proceed with a full-scale application of same. On July 6, 1973, prior to placement of the structural steel, an attempt was made to spray coat the abutments and center pier of Bridge P1, I-78, 5AD, representing a full-scale application of "Barrier". Shortly after the spraying commenced, it was noticed that the spray was non-uniform, causing bare spots, running, and dark areas of heavy application. The spraying apparatus then ceased to function altogether and the efforts were terminated for the day. The spray apparatus was not quickly repairable. Therefore, on July 9, "Barrier" was applied to the concrete surfaces with a paint roller. As this technique gave good results on previous trials, a good job was anticipated on this bridge also. Unfortunately, the results did not meet

expectations. Consultation with the state inspector revealed that numerous spots remained uncovered, and the painter was asked to re-paint areas. The entire paint job clearly exhibited non-uniform application with streaking and running of "Barrier" down the surface (illustrated in Fig. 3). Furthermore, the non-uniformity of application shows in practically every stroke of the roller, with one stroke being dark and the next stroke being lighter. Overall coverage, however, is 320 square feet/gallon which is within the manufacturer's 350 sq. ft./gal. minimum requirement.

It is mentioned that non-pigmented "Barrier" gives concrete a wet look, and it makes visual discolorations of the concrete surface (such as those due to the wood grain of the formwork, or light and dark areas of concrete) more apparent. These effects are minor when compared to extensive streaks of rust stains that occur.

In all fairness to the product being tested, this paint job has a fairly poor appearance; part of it is due to the finished appearance of the concrete. However, the primary reason for this appearance lies with the "laborers" that applied this product to the concrete.

D. Post Application Inspection -

All of the trial applications received subsequent visual inspections. Usually, about a year after an application, enough rust stains had accumulated on the test areas to make stain

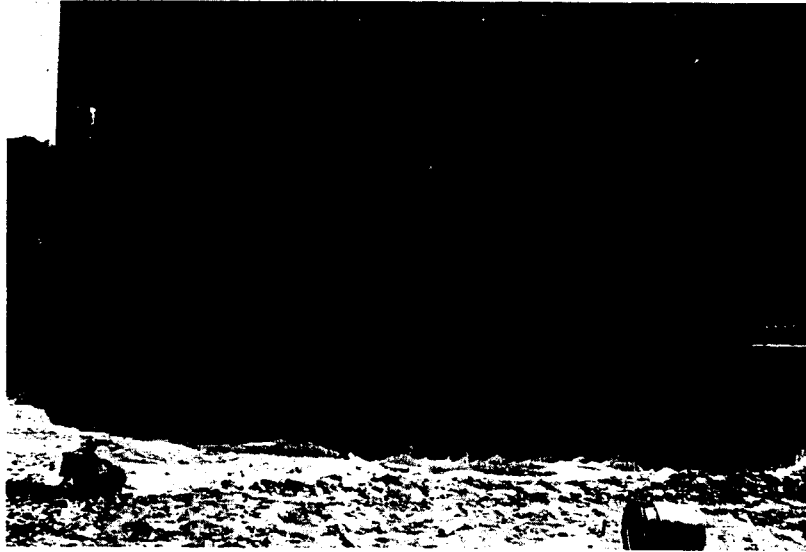


Fig. 3 - North Abutment (Bridge P1):
"Barrier" finished abutment

removal attempts worthwhile. Such attempts began with soap, water and scrub-brush since staining was still light. Depending upon the necessity, progressively stronger means of cleaning were utilized with time and additional, more concentrated stains.

V. Results & Discussion

A. "Thompson's Water Seal #101" -

Shortly after the trial application of "Thompson's Water Seal 101", site inspections revealed that it was virtually impossible to visually observe where the product had been applied. This would seem to be an asset. However, after about one year of exposure to rust run-off, visual observation and cleaning attempts revealed that this product did not prevent the stain either from accumulating upon, or from penetrating, the concrete abutment. There was no visual evidence of this product ever having been applied, nor of its capacity to reduce rust-staining.

B. "Barrier"

1). Bridge #9 Partial Trial Application - The true effectiveness of Barrier in preventing rust stains was obscured due to two causes. First, the application of Barrier to the abutment was an afterthought which occurred primarily because of the extensive rust staining to which the abutment had been subjected. It was not possible to remove all of these stains. And since the "Barrier" was a transparent coating, these stains were visible through the coating, thereby making it difficult to

determine at a later time whether or not any additional stains had occurred in spite of the "Barrier". Second, as of the time of initial abutment cleaning and Barrier application, the worst run-off had already occurred.

Given these circumstances, Bridge #9 could hardly be considered a fair test, although this application did indicate some promise in terms of ease of application, as well as appearance and stain prevention. New stains were washable from the areas where "Barrier" was applied with a soap-water solution.

It should be noted that this coating developed mottled cracking within five years of application. However, this does not give an unsightly appearance since it is only apparent to the discerning eye. On the basis of these preliminary results, it was decided to undertake another application under more-controlled conditions, which led directly to the trial applications on nearby Bridge #10, then currently under construction.

2). Bridge #10 Partial Trial Application - On Bridge #10, "Barrier" was applied two days after the "bagging" operation, and prior to any staining of the abutment. In spite of this effort to obtain a valid test under controlled conditions, most of the test area was inundated by the indiscriminate application of any epoxy coating directly upon the trial application of "Barrier". The remaining untouched area of "Barrier" on Bridge #10 appears to have received very little rust run-off. For these reasons there are no results to report from this particular trial.

3). Bridge #Pl Full Trial Application - The final trial application served the purpose quite well, although unfortunately the results were all negative. This trial is the aforementioned full-scale trial on Bridge #Pl. It is the opinion of the author that the previously mentioned application problems on Bridge #Pl were a result of faulty equipment, and a nearly total lack of concern or control over the quality of workmanship displayed by the laborers involved. The sloppy final appearance of the concrete abutments and pier is not alone due to the nature of the material being tested. However, aside from this, it is difficult to defend "Barrier" on any other point.

Figure 3 is a photograph of the north abutment before any stains had occurred. After one year, light stains were adequately removed on the north abutment. Subsequent photos show the northern abutment after two year staining; Figure 4 illustrating the "before" condition, Figure 5 showing that there was no heavy stain removal after washing with soap solution and concentrate, and Figure 6 clearly indicating removal of stains and "Barrier" with an acid solution. Regarding the painted graffiti, nothing short of removal of the "Barrier" coating with solvents, would wash off the paint. The use of the solvents allowed the dissolved paint and "Barrier" to penetrate the concrete leaving permanent discoloration. Therefore, it must be stated that the results achieved through the use of "Barrier" were much the same as if the concrete had been left "unprotected".



Fig. 4 - North Abutment (Bridge P1):
Two year stains before washing

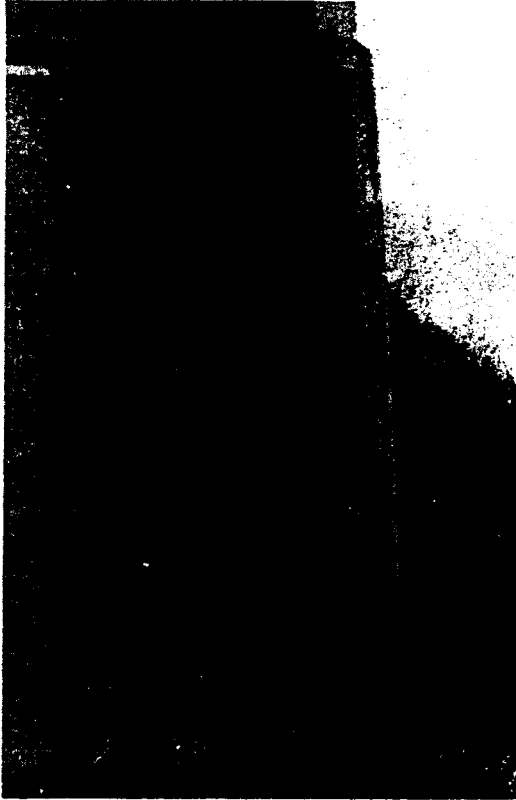


Fig. 5 - North Abutment (Bridge P1):

Two year stains following washing
with a soap-water solution.



Figure 6 - North Abutment (Bridge P1):

Stain and "Barrier" removal
with acid solution.

It is understood that the accompanying black and white figures may not accent the degree of staining and its unappealing appearance. Due to costs, color photos had to be replaced with black and white. If said emphasis is required by the reader, the color photos are available through the authors.

REFERENCES

- (1) "Unpainted Low-Alloy Steels for Use in the Construction of Highway Bridges", by the Division of Research & Development, NJDOT, September 1968.
- (2) "Atmospheric Corrosion Tests of Unpainted Steels for Use in Construction of Highway Bridges", by Bruce Cosaboom and George S. Kozlov for NJDOT and James Zoccola for Bethlehem Steel Corporation, HPR #287.
- (3) "Bridge Construction of ASTM A-242 Unpainted Steel - A four Year Progress Report:, NJDOT interdepartmental report.
- (4) "Bridge Construction with Unpainted, High-Strength Low-Alloy Steel - Eight Year Progress Report", Interim Report by Bruce Cosaboom, Gregory Mehalchick for NJDOT and James Zoccola, Bethlehem Steel Corporation, February 1979.