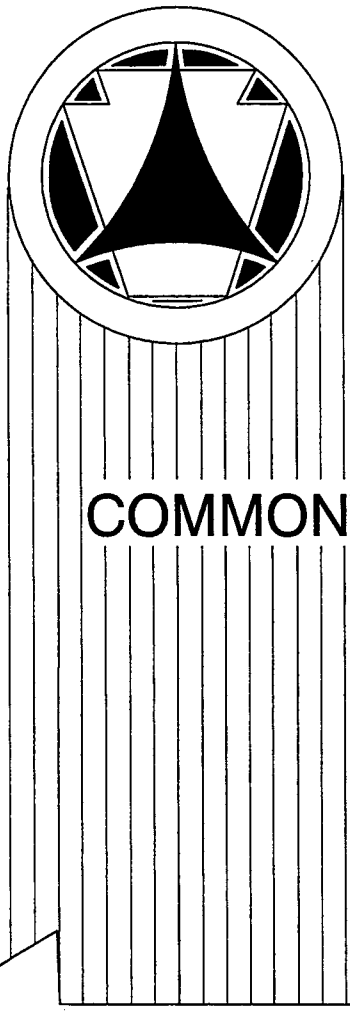

COMMONWEALTH OF PENNSYLVANIA

Department of Transportation

RESEARCH PROJECT NO. 93-052

FIBER COLUMN WRAP SEISMIC RETROFIT SYSTEM

FINAL REPORT

NOVEMBER 1998

Prepared by: Robin Sukley & Carrie Howrylak

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF CONSTRUCTION AND MATERIALS
ENGINEERING TECHNOLOGY AND INFORMATION DIVISION

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. Agency Use Only *(Leave Blank)*	2. Report Date	3. Report Type and Dates Covered
	November 1998	Final Report August 1993 to July 1998

4. Title and Subtitle
Evaluation of Fiber Column Wrap Seismic Retrofit System

5. Funding Numbers

6. Author(s)
Robin Sukley and Carrie Howrylak

7. Performing Organization Name(s) and Address(es)
Pennsylvania Department of Transportation
Bureau of Construction and Materials
Engineering and Information Technology Division
1118 State Street
Harrisburg, PA 17120

8. Performing Organization Report No.
RP 93-052

9. Sponsoring/Monitoring Agency Name(s) and Address(es)
U.S. Dept of Transportation
FHWA
400 - 7th Street, SW
Washington DC 20590

Pennsylvania Department of Transportation
Bureau of Planning and Research
Division of Research
555 Walnut Street - 6th Floor Forum Place
Harrisburg PA 17101-1900

10. Sponsoring/Monitoring Agency Report Number
FHWA-PA-98-004+93-052

11. Supplementary Notes
Program Manager: Gerald Malasheskie Organization
Project Manager: Robin Sukley

12a. Distribution / Availability Statement
Available form National Technical Information Service,
Springfield, VA

12b. Distribution Code

13. Abstract (Maximum 200 words)

The TYFO-S FIBRWRAP System incorporates high strength composite fibers and epoxy resin to strengthen concrete columns, especially for seismic retrofit projects. The manufacturer, R. J. Watson, Inc., explains that its product is economically and easy to install. The objective of this final report is to evaluate the performance, durability, and cost effectiveness of using the TYFO-S FIBRWRAP System.

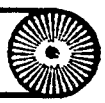
A four span, composite steel, I-Beam and multi-Girder Bridge in Lackawanna County on SR 0084 was selected as a test site for seismic retrofit. The site was constructed in August 1993, and has performed satisfactorily with no deterioration noticeable, although no seismic activity has been recorded in the test site area. The TYFO-S FIBRWRAP System is recommended for further r use by the Department as a standard special provision.

14. Subject Terms	15. No. of Pages
Sesmic, Column, Tyfo – S Fiberwrap	31
	16. Price Code

17. Security Classification of Report	18. Security classification of this Page	19. Security Classification of Abstract	20. Limitation of Abstract
None	None	None	

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18



METRIC CONVERSION FACTORS

TO CONVERT FROM	TO	MULTIPLY BY
Length		
foot (ft)	meter (m)	0.3048
inch (in)	millimeter (mm)	25.4
yard (yd)	meter (m)	0.9144
mile (statute)	kilometer (km)	1.609
Area		
square foot (ft^2)	square meter (m^2)	0.0929
square inch (in^2)	square centimeter (cm^2)	6.451
square yard (yd^2)	square meter (m^2)	0.8361
Volume		
cubic foot (ft^3)	cubic meter (m^3)	0.02832
cubic yard (yd^3)	cubic meter (m^3)	
gallon (U.S. liquid)**	cubic meter (m^3)	0.003785
gallon (Can. liquid)**	cubic meter (m^3)	0.004546
ounce (U.S. liquid)	cubic centimeter (cm^3)	29.57
Mass		
ounce-mass (avdp)	gram (g)	28.35
pound-mass (avdp)	kilogram (kg)	0.4536
ton (metric)	kilogram (kg)	1000
ton (short, 2000 lbm)	kilogram (kg)	907.2
Density		
pound-mass/cubic foot	kilogram/cubic meter (kg/m^3)	16.02
pound- mass/cubic yard	kilogram/cubic meter (kg/m^3)	0.5933
pound-mass/gallon(U.S.)**	kilogram/cubic meter (kg/m^3)	119.8
pound-mass/gallon(Can.)**	kilogram/cubic meter (kg/m^3)	99.78
Temperature		
degree Celsius (°C)	Kelvin (°K)	$t^{oK}=(t^{oC}+273.15)$
degree Fahrenheit (°F)	Kelvin (°K)	$t^{oK}=(t^{oF}+459.67)/1.8$
degree Fahrenheit (°F)	degree Celsius (°C)	$t^{oC}=(t^{oF}-32)/1.8$

*The reference source for information on SI units and more exact conversion factors is the "Metric Practice Guide" ASTM E 380.

**One U.S. gallon equals 0.8327 Canadian gallon.

FIBER COLUMN WRAP SEISMIC RETROFIT SYSTEM

FINAL REPORT

BY

ROBIN SUKLEY AND CARRIE HOWRYLAK

RESEARCH PROJECT NO. 93-052

CONDUCTED BY
PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF CONSTRUCTION AND MATERIALS
ENGINEERING TECHNOLOGY & INFORMATION DIVISION

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November 1998

ABSTRACT

The ***TYFO-S FIBRWRAP*** System incorporates high strength composite fibers and epoxy resin for the seismic retrofitting of concrete columns to increase their ability to withstand loading under seismic activity, and to offer an alternative to steel jackets. The manufacturer, R.J. Watson, Inc. claims that its product is economical and easy to install. The objective of this research final report is to evaluate the performance, durability, and cost effectiveness of using the ***TYFO-S FIBRWRAP*** System for seismic retrofitting.

A four-span, Composite Steel I-Beam and multi-Girder Bridge in District 4-0 on SR 0084 was selected as a test site for seismic retrofitting. The site was constructed in August of 1993, and has shown satisfactory performance, with no noticeable deterioration, although no seismic activity has been recorded at the test site during the evaluation period.

Testing performed by University of California on load deflection response indicated that, based on comparison of horizontal and lateral load cycles of the high strength fiber and steel jacket retrofit columns have almost identical behavior in terms of hysterisis loop width and strength. The high strength fiber retrofit column performed exceptionally well in reducing the tendency for splice-lap tensile bond failure, and in increasing the ductility capacity of the column.

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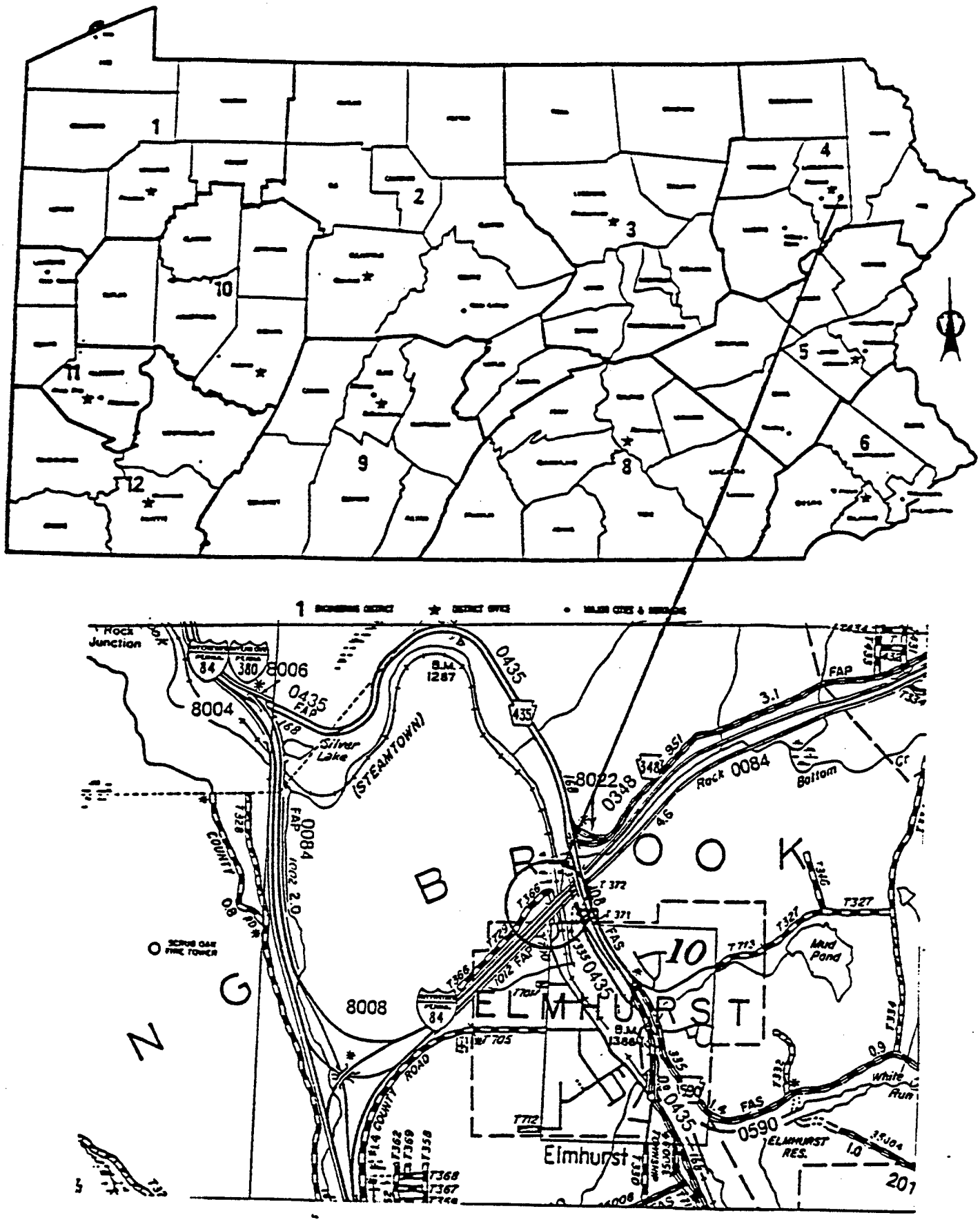


FIGURE 1 LOCATION MAP SR 0084 LACKAWANNA COUNTY

Introduction:

High strength composite fibers are excellent materials for structural engineering purposes. Because of their strength, light weight, and high modulus of elasticity, they are considered appropriate to strengthen bridge components for seismic retrofit.

The ***TYFO-S FIBRWRAP*** System incorporates high strength composite fibers and epoxy resin to strengthen concrete columns, especially for seismic retrofit projects. The manufacturer, R.J. Watson, Inc., explains that its product is economical, and easy to install. The objective of this research project is to evaluate the performance, durability, and cost efficiency of using the ***TYFO-S FIBRWRAP*** System.

A four-span Composite Steel I-Beam and multi-Girder Bridge in District 4-0 was selected as a test site for seismic retrofitting (refer to figure 1). This site was chosen due to its high probability for an earth quake occurrence during the evaluation period. The site was constructed in August of 1993, and has shown satisfactory performance, with no deterioration noticeable.

Tests performed by the University of California on load deflection response, indicate the comparison of horizontal and lateral load cycles of the high-strength fiber, and steel jacket retrofit columns have almost identical behavior in terms of hysterisis loop width and strength (refer to R.J. Watson, Inc. Preliminary Report #1: November, 1990). If one cycles X over an appropriate range, the plot Y versus X gives a closed curve which is referred to as a hysterisis loop. The response Y appears to be lagging the input X. The high-strength fiber retrofit column performed exceptionally well in reducing the tendency for splice-lap tensile bond failure, and increasing the ductility capacity of the column.

Construction Summary:

Prior to application of the strengthening column wrap, the surfaces of the columns (refer to figures 2 through 4) were cleaned using a broom, and bond breakers were placed at the tops of the footings (refer to specification in Appendix 1 for detailed information). The fiber wrap was precut to the desired length, and the wrap was saturated with ***TYFO S*** epoxy using a roller assembly. The fiber wrap was placed on the columns in layers, eight at the top and bottom, and two in the middle, with the joint overlap of approximately six inches. Air pockets that remained between the layers were forced out, and the fiber wrap was cured. Finally, a water-based epoxy paint was applied to the exterior of the columns. For more detailed information, refer to the Construction Report of April, 1997.

Cost Analysis:

The cost of retrofitting the columns with the fiber wrap seismic retrofit system to 1/2 inch thickness was 944 SF @ $60.00/SF = $56640.00.

The cost for 1/8 inch thickness was 1217 SF @ $17.50/SF = $21295.50.

The total cost for this project was: $77935.50.

This cost for retrofitting the columns with the fiber wrap strengthening system seems fairly reasonable in comparison to steel jacketing, which is typically about 20% higher as purported by R.J. Watson.

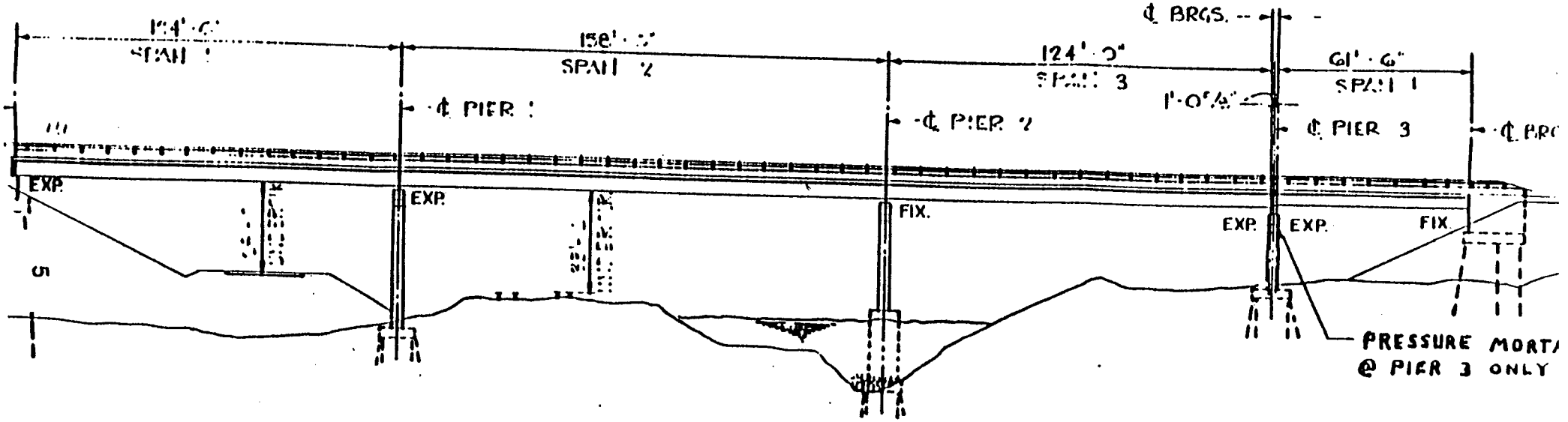
Performance Summary:

Long term performance of the fiber wrap has been satisfactory. Inspections of the site were made approximately every six months, from August, 1993, through May, 1998. No visible delamination from the columns is apparent (refer to final inspection photos 1 through 6). The only problem is the graffiti that has been painted on some of the columns, which is simply a matter of aesthetics, and poses no physical threat to the columns.

Conclusions:

The ***TYFO-S FIBRWRAP*** System has performed adequately for a seismic retrofit system, since its installation 5 years ago, although no seismic activity has been reported at the test site. The system has passed rigorous laboratory tests performed by the University of California, and has shown no signs of delamination. Field construction of the system was rather simple and was completed in a timely manner. The entire project was quickly constructed, Fiberwrap is purportedly less expensive than steel jacketing, and the fiber column wrap has proven to be very durable. The ***TYFO-S FIBRWRAP*** System is therefore, recommended for further use by the Department, by standard special provision, for seismic retrofit. However, there are still questions outstanding on whether trapped moisture in the membrane may cause problems, or the effects of UV light on the wrap when used for other rehabilitation work. To date the surface shows no sign of weathering such as chalking bleaching and no signs of stress resulting from accumulated moisture beneath the wrap.

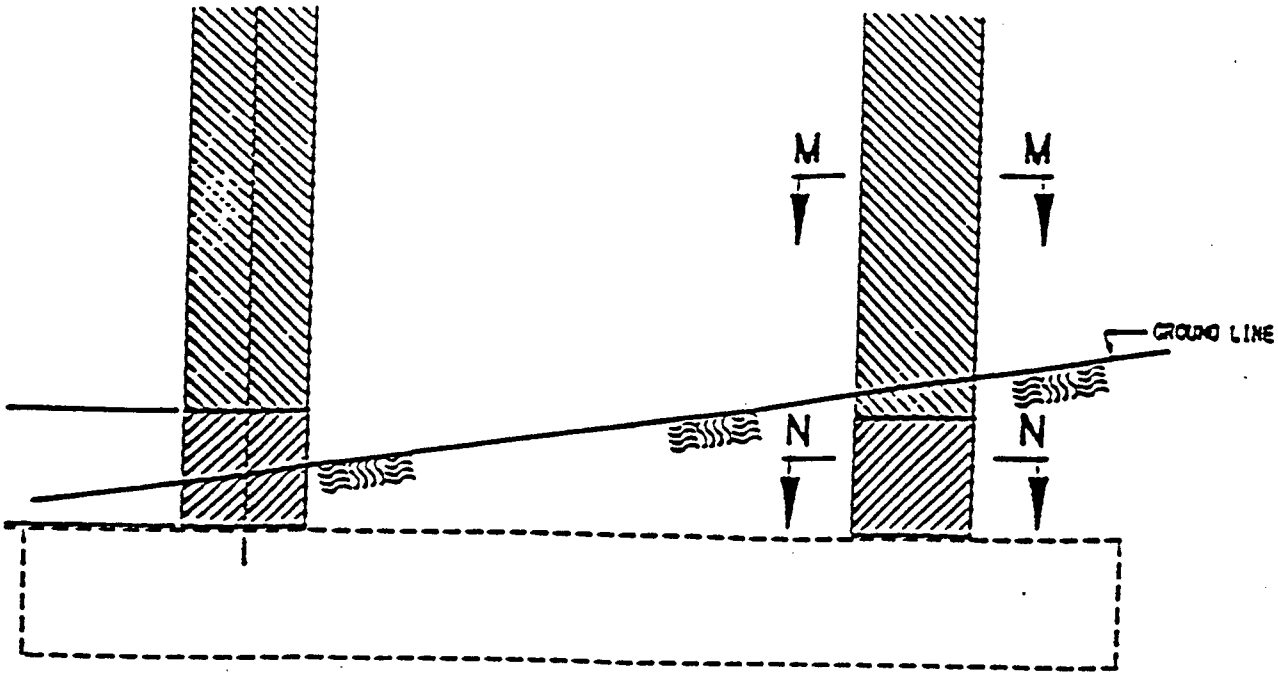
- PLACE HIGH STRENGTH COMPOSITE FIBER COLUMN STRENGTHENING SYSTEM AT ALL PIER COLUMNS.



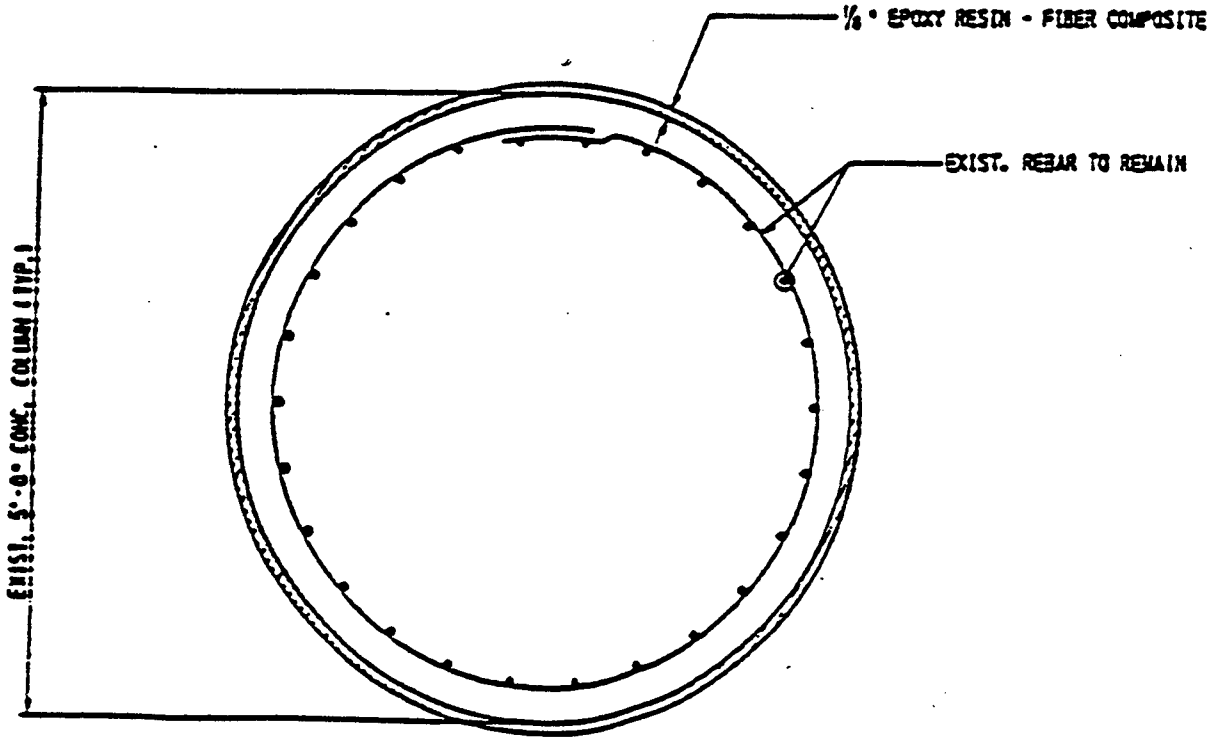
ELEVATION

SCALE : 1" = 30'-0"

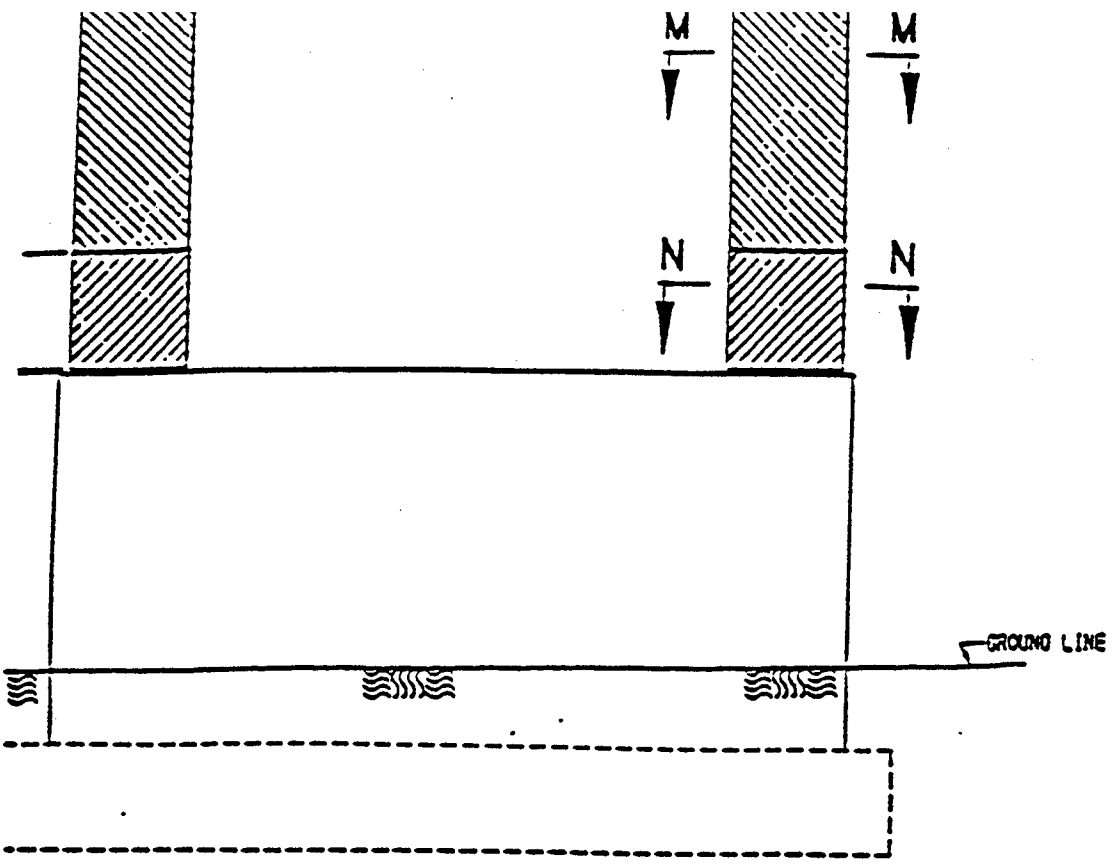
FIGURE 2 BRIDGE PLAN VIEW



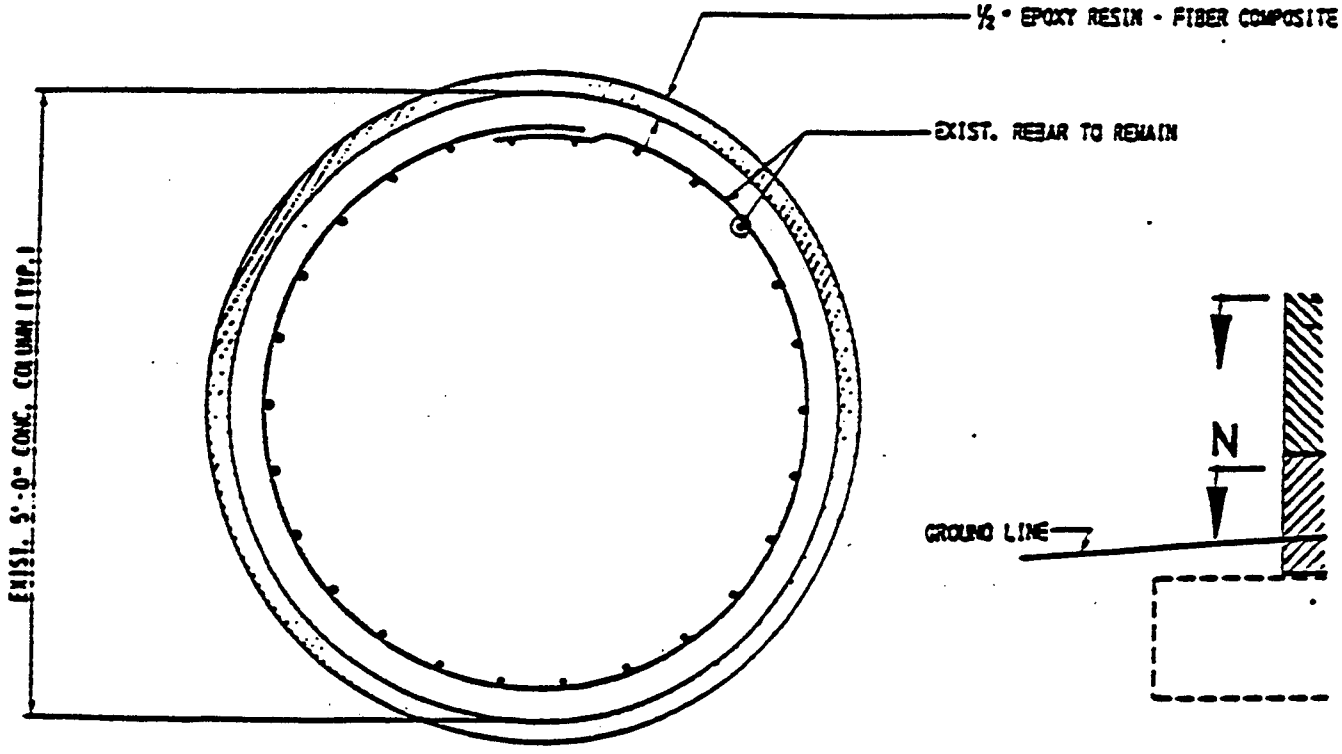
PIER NO. 1 WESTBOUND
LOOKING STATIONS AHEAD
SCALE: 3/8" = 1'-0"



SECTION M-M
FIGURE 3 TYPICAL COLUMN SECTION PIER No.1
SCALE: 1" = 1'-0"



PIER NO. 2 WESTBOUND
LOOKING STATIONS AHEAD
SCALE: 1/8" = 1'-0"



SECTION N-N

FIGURE 4 TYPICAL COLUMN SECTION PIER No.2

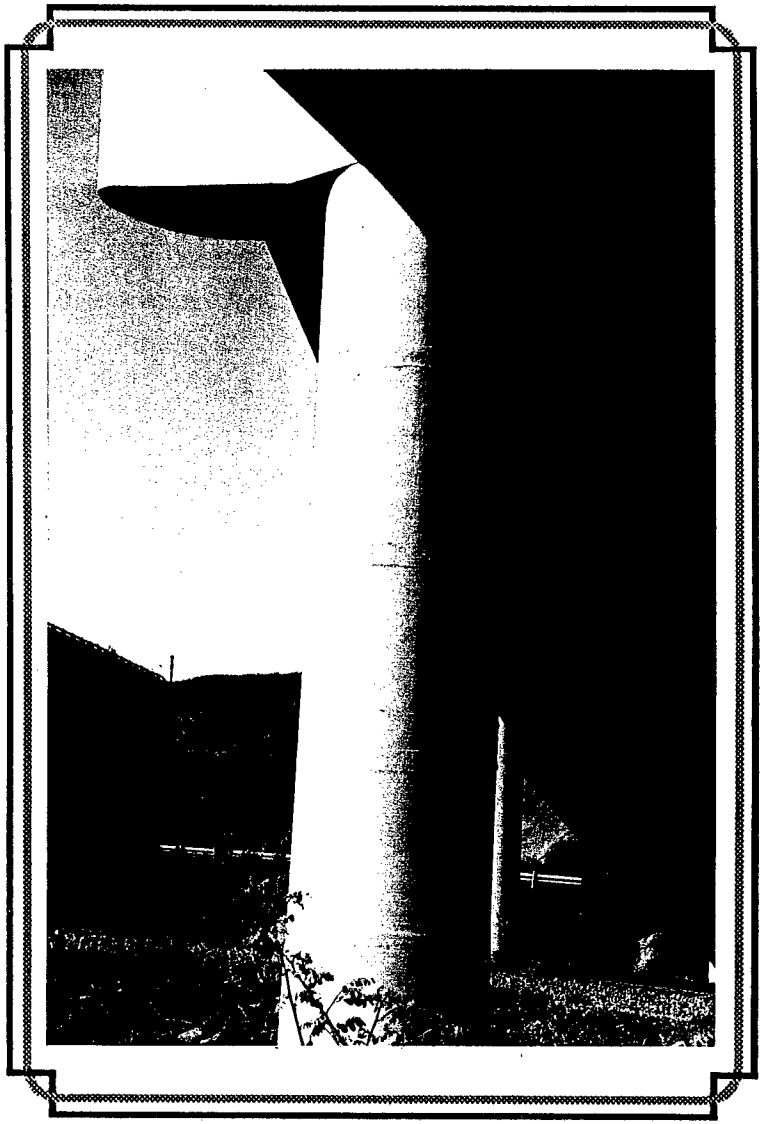


PHOTO NO. 1 ENTIRE COLUMN: MAY 1998
NO DELAMINATION EVIDENT

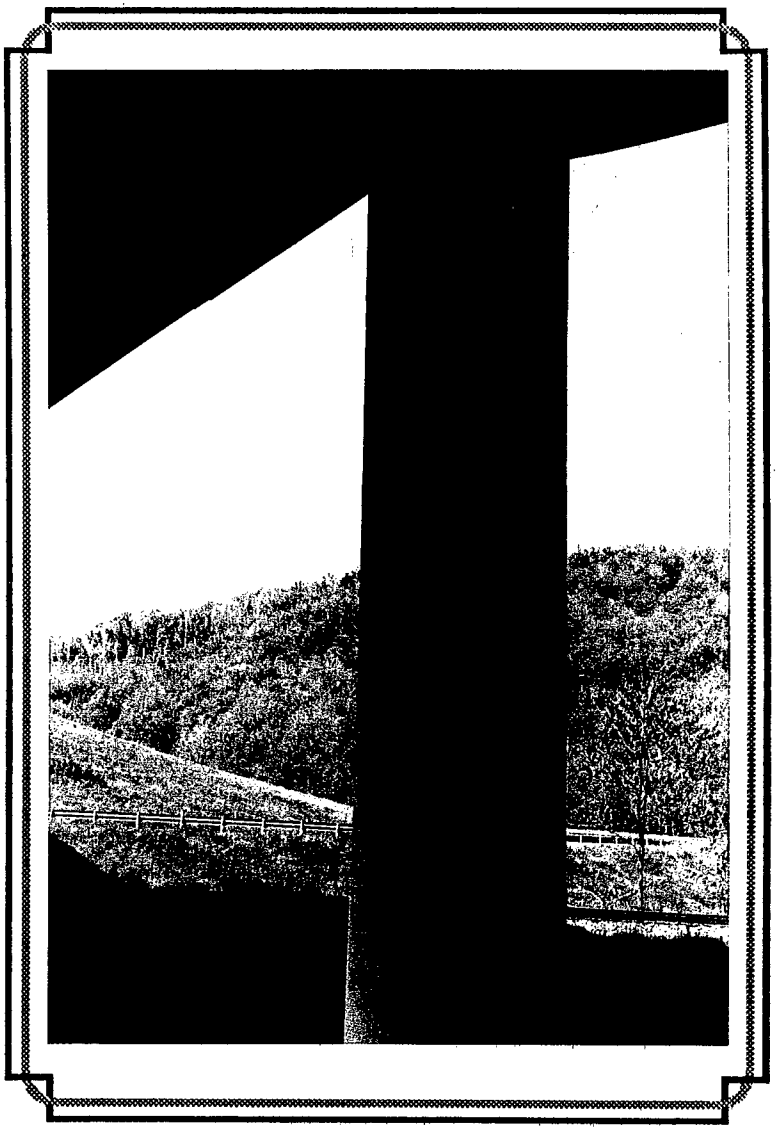


PHOTO NO. 2 BACK OF COLUMN
MAY 1998

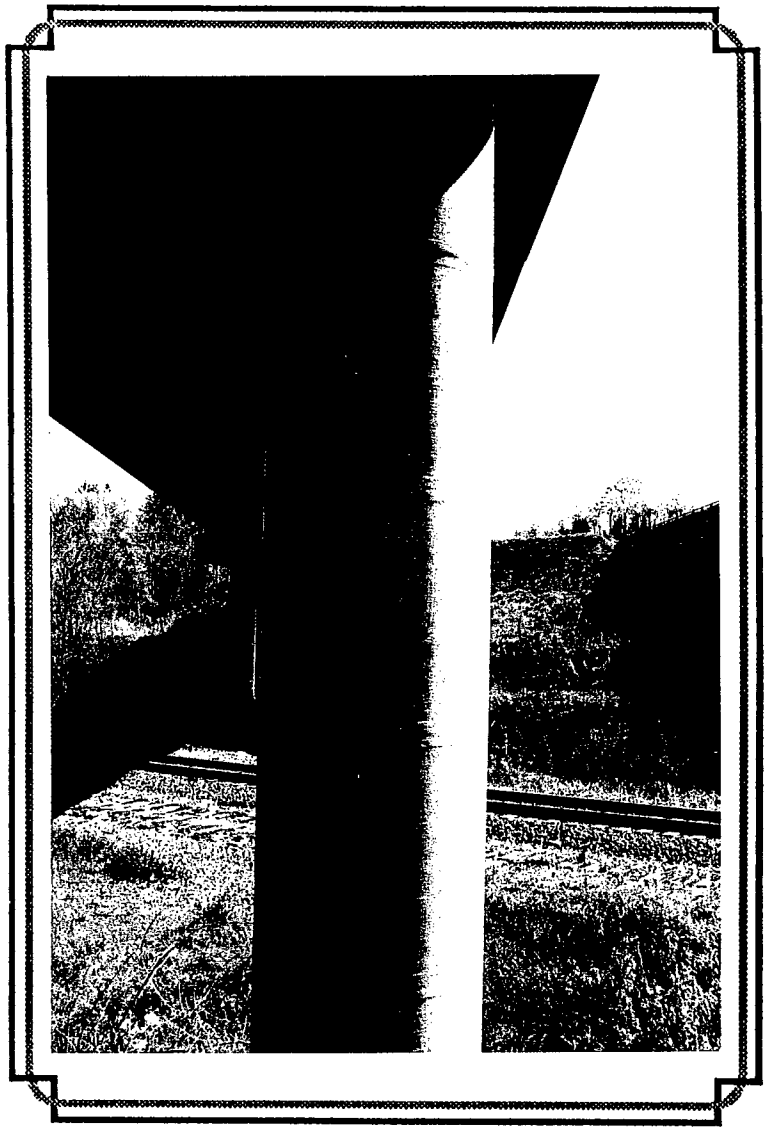


PHOTO NO. 3 ENTIRE COLUMN: MAY 1998
NO DELAMINATION EVIDENT

PHOTO NO. 4 BACK OF COLUMN
MAY 1998

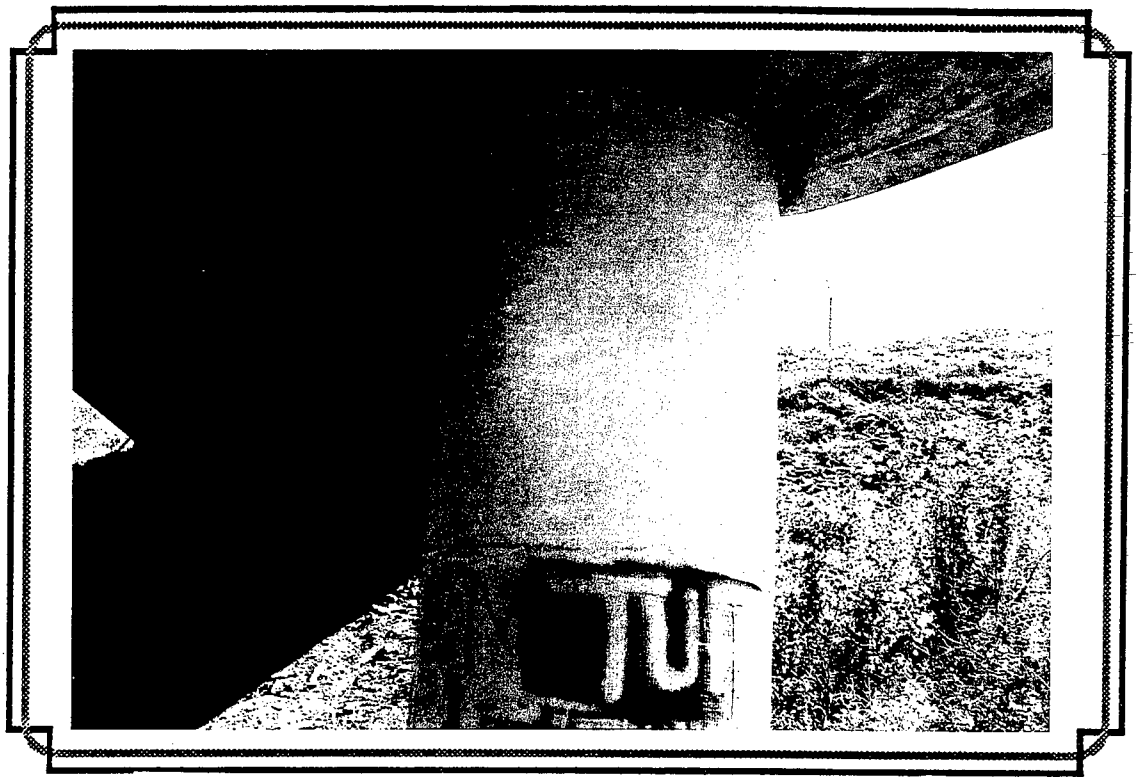


PHOTO NO. 5 FIBER OVERLAP AT TOP: MAY 1998

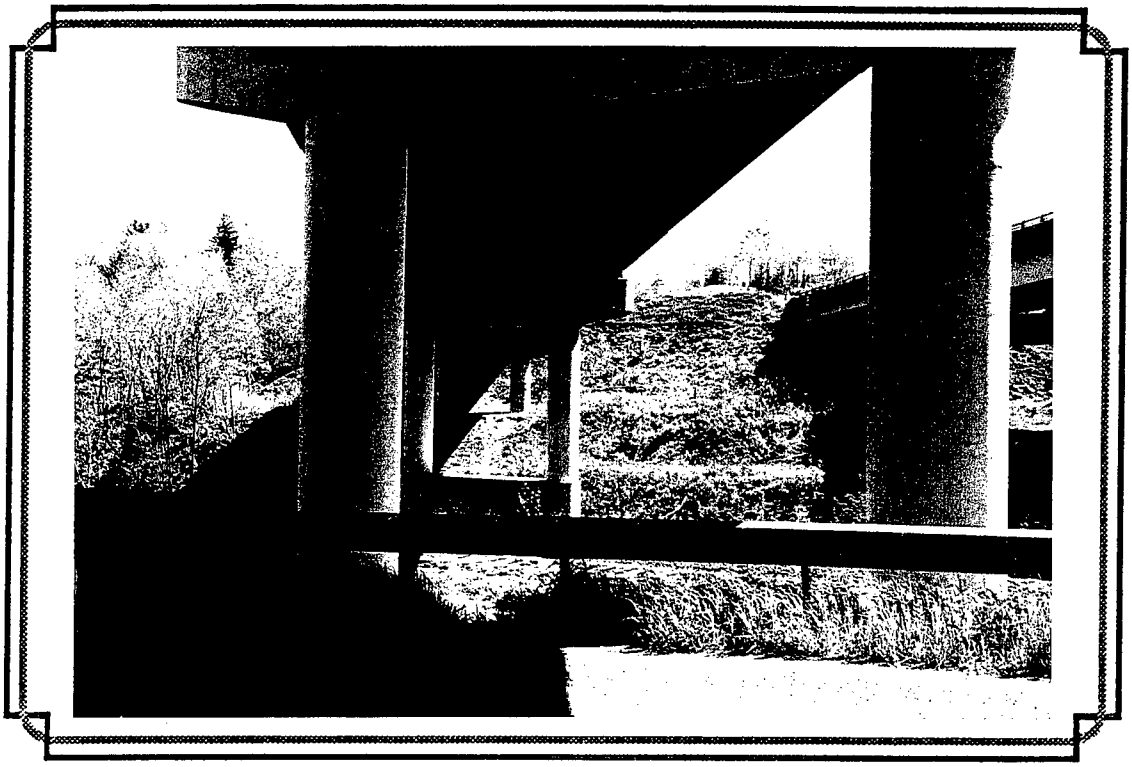


PHOTO NO. 6 VIEW OF COLUMNS: MAY 1998

REFERENCES

R.J. Watson, Inc. Design Specifications, 480 ALT COL CASING, CALTRANS Specification, April 1992.

R.J. Watson, Inc. Preliminary Report #1, November, 1990.

Pennsylvania Department of Transportation. Specifications, "Composite Column Wrap." 1996.

Sukley, R. "Evaluation of Fiber Column Wrap Strengthening System", Pennsylvania Department of Transportation, Construction Report, April 1997.

APPENDIX A
CONSTRUCTION SPECIFICATIONS

ITEM 9001-0016 - COMPOSITE COLUMN WRAP, 1/2 INCH THICK
ITEM 9001-0017 - COMPOSITE COLUMN WRAP, 1/8 INCH THICK

DESCRIPTION - This work is the design and construction of a composite column wrap of the type indicated.

DESIGN - R.J. Watson, Inc., 282 Wood Acres Drive, East Amherst, New York 14051, telephone (716) 688-0094, or a representative is to prepare design calculations and construction drawings for composite column wrap as indicated and directed. R.J. Watson, Inc., or its representative, takes full responsibility of the engineering theory and correctness of the calculations and ensures that all design assumptions are validated in the contract documents either by needed details or construction specifications.

Provide, at no expense to the Department, four (4) sets (one to the District and three sets to the Central Office Bridge Division) of shop drawings (22" x 36"), calculations, and installation methods. Use Department drafting standards. Show a Professional Engineer's seal with valid signature in ink, the date signed, a business name, and address on the first sheet of the design drawings. On the first sheet of the construction drawings, indicate: "I certify that all assumptions made in designing this column casing have been validated either through construction details or special notes and instructions to the installer and contractor." Place the statement above the seal.

On the first sheet of the computations show a Professional Engineer's seal (licensed in the Commonwealth of Pennsylvania), signature, and date signed. Also certify that all the assumptions made in designing the column casing have been validated through either the design details on the drawings or in the construction specifications.

In the event that certain design parameters, stresses, or specifications are in conflict, the following order of predominance governs:

1. Design requirements listed in the "Special Drawings and Special Design Requirements" (Part B) of the Special Provisions.
2. PennDOT Design Standards.
3. PennDOT Design Manuals.
4. AASHTO Standard Specifications for Highway Bridges (current edition).

In the event that a clear order of predominance cannot be established, or a difference in the interpretation of the design cannot be resolved, the Chief Bridge Engineer is the arbiter and his decision is final.

On the shop drawings show details of the layer thicknesses, properties of the materials used, joint and end treatments, and all information required for the proper construction of the system at each location including any required revisions or additions to drainage systems or other facilities.

Determine the quality and suitability of alternate primary fibers of the composite column casing including, but not limited to, the following factors: the ability of the systems to confine concrete during seismic loading of the bridge, suitability to the shape and configuration of the column, weatherability, and repairability. Certified tests similar to the tests that have been made on the composite casings are required before approval of the use of alternate primary fibers of the composite column casing.

Base the suitability of the alternate columns upon testing of full scale columns utilizing the alternate casing in question. Testing consists of a minimum of 3 cycles at ductility factors of (+/-) 1, 2, 3, 4, 5, 6, and 7. Stability properties such as ductility serve and loop degradation are to be similar to that of the composite fiber wrap system. Develop analytical formulations such that they accurately represent the performance (ultimate strength, ductility capacity, etc.) of the column with the alternate casing.

Extend existing drainage pipe in a column in accordance with applicable sections of the Specifications.

Include on shop drawings any precautions that are necessary to protect the workers and public from the toxicity of unpolymerized epoxy in the air during roughening operations.

Include on shop drawings the supplier's name, safety data sheets, ranges of the properties listed below, and test methods for the materials to be used in the composite column casing. Certify by the responsible manufacturer the properties and test methods used to determine the properties.

Furnish properties and test methods of all components of epoxies, including additives. Properties of Composite to be Furnished (minimum):

Modulus of Elasticity:	2900 - 3200 ksi
Ultimate Strength:	> 60 ksi
Ultimate Strain:	< 0.02 in/in
Creep at Design Strain:	< 0.0003 in/in

Submit to the engineer prior to approval of the shop drawings for composite column casings, four (4) samples not less than 12 inches by 12 inches of the composite to be used. Certify these samples in accordance with Section 106.03(b).

MATERIALS -

Protective coating system - a two component water based epoxy system having the following properties. Certify in accordance with Section 106.03(b)3.

Test Parameter	Property of Part A	Property of Part B
Solids @ 135 C (3 hours)	100 percent	43 to 47 percent
Brookfield Viscosity @ 25 C	N/A	2000 - 3000 CPS
Specific Gravity	1.1400 - 1.1800	1.090 - 1.130
Pot Life Mixed	N/A	No Peel Up 25 Minute Minimum
Component Mix	0.16	0.84

CONSTRUCTION - As indicated on the design contract drawings and approved shop drawings and as follows.

Before beginning construction, submit shop drawings for approval in accordance with Section 105.02(d) showing fabrication details and handling, transportation, and construction procedures.

Mix with components of the epoxy resin in accordance with the manufacturer's written instructions.

Surfaces to receive the composite are to be free from fins, sharp edges and protrusions that will cause voids behind the installed casing or, in the opinion of the Engineer, will damage the fibers.

Offsets at form joints are to be ground flush so that the composite wraps tight without voids between the column and the composite. Fill hollow voids behind the installed casing with cement grout or other material approved by the Engineer. Refinish large surface deformations on buried portions of columns, such as would be on unformed surfaces or a different cross section, as directed by the Engineer.

Place bond breakers (when used) at discontinuities in the wrapped composite such as at drains, conduits, and tops of footings.

Mix the components with a mechanical mixer. Do not use components that have exceeded their shelf life of two years.

Remove free moisture from the contact surfaces of the column at the time of application of the composite. Apply composite wrap when the ambient temperature is between 50 degrees and 120 degrees Fahrenheit. Apply immediately after a batch has been mixed.

Accurately measure epoxy and fiber and deposit smoothly and uniformly at the rates shown on the shop drawings. Place the fibers by hand or machine methods. Gaps up to 1/2 inch wide will be allowed at horizontal joints and a lap of at least 6 inches is required at vertical joints in the composite casing. Cover gaps with a layer of composite.

Adjust the epoxy application rate for the final layer of composite to ensure complete saturation of the fibers and producing a uniform finished surface.

Prepare successive layers of composite materials before polymerization of the epoxy is too complete to achieve full bonding between layers. The application temperature range of 50-120 degrees Fahrenheit accounts for variations above or below this range during curing. The epoxy may take longer to cure below the minimum temperature.

Apply the composite wrap such that the surface of the composite column casing fabricated without grout does not undulate from the dimensions shown on the plans more than 1/2 inch per foot in any direction, or a total displacement of 2 inches at any one point.

Place the fibers of the composite so that the primary fibers are horizontal (+/- 1 inch per foot). Apply the transverse fibers of the composite perpendicular to the primary fibers. Apply one layer of 6 inch wide composite strip at the butt splice region where two composite casings of different thicknesses meet. Provide a smooth transition between casings.

Maintain the epoxy curing temperatures in the temperature range designated for the formulation used.

Inspect the composite casing during and immediately following application of the composite materials.

Release trapped air before the epoxy sets. Embed and adhere each individual layer and ending of composite firmly to the preceding layer of substrate.

Ensure that the cured composite has a uniform thickness and density, continuous bond between layers, lack of porosity and uniform percentage of polymerization.

Apply the composite casing at least 48 hours before grouting.

Repair voids equal to or larger than 144 square inches in size in cured composite or between cured composite and concrete by matrix injection. Individual voids smaller than 144 square inches in size in cured composite or between cured composite and concrete need not be repaired except that for a grouted composite casing.

Maintain a record of the composite casing construction at each column and furnish a copy of the data to the Engineer within 48 hours after painting. Include in the record the following for the casing at each column:

1. Identification of the column and bridge.
2. Date and time of constructing composite.
3. Batch numbers of epoxy used.
4. Quantity of epoxy used.
5. Quantity of fiber used.
6. Temperature and presence of precipitation (if any).
7. Record of samples taken.

Dry all cleaned and roughened surfaces of the composite before receiving the finish paint coat. No primer undercoat is required.

Alternate paint systems may be used providing they show sufficient bond strength to the composite. Supply quantifiable engineering data of the bond strength of the paint system and certify in accordance with Section 106.03(b)3.

MEASUREMENT AND PAYMENT - Square Foot. For the type of composite indicated.

APPENDIX B
DESIGN SPECIFICATIONS

(CALTRANS SPECIFICATION)

.c2.10-1. ALTERNATIVE COLUMN CASING; This work shall consist of furnishing and installing or constructing alternative column casings as shown on the plans or as directed by the Engineer in accordance with the provisions specified in the Standard Specifications and these special provisions.

2

The allowable kinds of casing to be used for installation or construction of alternative column casing will be shown on the plans for each bridge. The kind of casing to be installed or constructed shall be selected by the Contractor from the allowable kinds of casings shown on the plans. The kind of casing shall conform to the requirements in the following subsection, "Alternatives."

3

(Allowable alternatives must be listed on plans for each column to be cased. If different sets of alternatives apply to different columns, the items of work become Alternative column Casing (Type A), (Type B), etc.)

Alternative column casings shown with different combinations of allowable casings will be designated on the plans and in the Engineer's Estimate as Type A, Type B, etc., for each combination of allowable casings.

4

ALTERNATIVES.--The kinds of casings for alternative column casings may include one or more of the following kinds:

4a

Structural Steel Column Casing.--Structural steel column casing consists of a painted and waterproofed structural steel casing with grout filler between the casing and existing column.

4b

Composite Column Casing,--Composite column casing consists of epoxy resin-fiber composite casing with painted exterior surfaces and, where shown on the plane, bladder and grout filler.

5

GENERAL.--Paint formulas or product lists may be obtained from the Transportation Laboratory, P.O. Box 19128, Sacramento, CA 95819, (916) 739-2400.

6

Existing foliage and other materials in the space where the column casing is to be constructed shall be removed and disposed of outside the highway right of way in accordance with the provisions in Section 7-1.13 of the Standard Specifications.

7

(Para. 7: Use only when drains exit columns.)

Existing drainage pipe in a column shall be extended in accordance with the provisions for drainage piping in Section 75-1.03, "Miscellaneous Bridge Metal," one of the Standard Specifications.

8

(Para. 8: Use only when plans show locations of painting bridge names and numbers.)

The same information that is on existing columns shall be painted on their casings in accordance with the provisions in Section 51-1.21, "Bridge Name and Number, Date and Bent Numbers," of the Standard Specifications.

9

WORKING DRAWINGS.--Working drawings for the column casing shall conform to Section 55-1.02, "Drawings," of the Standard Specifications.

10

(Para. 10: Use when there are no flared or tapered columns.)

Working drawings will not be required for the structural steel column casing alternative.

11

(Para. 11 through 14: Use only if composite casing is shown as an alternative on the plans.)

If the Contractor elects to use the composite column casing alternative, complete working drawings shall be submitted for each installation of the column casing. The working drawings shall contain details of the layer thickness, properties of materials used, joint and end treatments, and all information required for the proper construction of the system at each location including any required revisions or additions to drainage systems or other facilities. The working drawings shall be supplemented by samples of the composite with a Certificate of Compliance and, as necessary, with calculations for the particular installation.

12

Working drawings for composite column casings shall also include the precautions, in any, that are necessary to protect the workmen and the public from toxicity of unpolymerized epoxy in air during surface roughening operations.

13

(Para. 13: Fill in blanks and correct tables as necessary.)

The working drawings for composite column casings shall include the supplier's name, data safety sheets, ranges of the properties listed below, and test methods for the materials to be used in the composite column casing. The properties and test methods used to determine the properties shall be certified to be correct by the responsible manufacturer. The properties and test methods of all components of epoxies, including additives, shall be furnished as indicated below:

MATERIAL	PROPERTIES TO BE FURNISHED
Primary Fibers (parallel to direction of main confining tensile stress)	Tensile Strength, Elongation, Tensile modulus, Coefficient of thermal expansion
Transverse Fibers (perpendicular to direction of main confining tensile stress)	Tensile Strength, Elongation, Tensile modulus, Coefficient of thermal expansion
Epoxy resin	Tensile Strength, Elongation, Tensile modulus, Flexural strength, Flexural modulus, Izod impact strength, Shore hardness D, Coefficient of thermal expansion
Bladder	Tensile Strength, Elongation, Tear resistance, Cold bend flexibility

14

Prior to approval of the working drawings for composite column casings, 4 samples not less than 12 inches by 12 inches of the composite to be used shall be prepared in the presence of the Engineer, unless otherwise directed, and submitted to the Engineer. The samples shall be accompanied by a Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications. The certificate shall state that the materials and fabrication involved in the samples of composite comply in all respects to the specifications and data submitted in obtaining the approval.

73

Epoxy resin shall conform to the requirements in Section 95-1, "Epoxy," of the Standard Specifications, except that no State Specification Number will be required. The components shall be mixed in accordance with the manufacturers written instructions.

74

Surfaces to receive composite shall be free from fins, sharp edges, and protrusions that will cause voids behind the installed casing or, in the opinion of the Engineer, will damage the fibers. Offsets at form joints shall be ground flush so the composite wraps tight without voids between the column and composite. Hollow voids behind the installed casing shall be filled with cement grout or other material approved by the Engineer. Large surface deformations on buried portions of columns, such as would be on unformed surfaces or a different cross section shall be refinished as directed by the Engineer and such refinishing will be measured and paid for in accordance with Section 4-1.03D of the Standard Specifications.

75

A bond breaker shall be placed at discontinuities in the wrapped composite such as at drains, conduits, and top of footings.

76

The components shall be mixed with a mechanical mixer. Components that have exceeded their shelf life shall not be used.

77

The contact surfaces of the column shall have no free moisture at the time of application of the composite. The ambient temperature shall be between 60 degrees and 120 degrees Fahrenheit at the time of application. Application shall begin immediately after a batch has been mixed.

78

Epoxy and fiber shall be measured accurately and deposited smoothly and uniformly at the rates shown on the working drawings. The fibers shall be placed by hand or machine methods, at the Contractor's option. Gaps up to 1/2 inch wide will be allowed at horizontal joints and a lap of at least 6 inches will be required at vertical joints in the composite casing. Gaps shall be covered with a layer of composite.

The epoxy application rate for the layers of composite shall be adjusted to ensure complete saturation of the fibers and a uniformly finished surface.

79

Successive layers of composite materials shall be made before polymerization of the epoxy is too complete to achieve complete bond between layers.

80

The surface of the composite column casing fabricated without grout shall not undulate from the dimensions shown on the plans more than 1/4 per foot in any direction or a total displacement of 1/2 inch at any one point.

81

The surface of the composite column casing fabricated with grout shall not undulate from the dimensions shown on the plans more than 1/2 per foot in any direction or a total displacement of 2 inches at any one point.

82

The surface of the composite shall be placed so the primary fibers are horizontal. The fibers shall not deviate from a horizontal line more that 1 inch per foot. The transverse fibers of the composite shall be perpendicular to the primary fibers.

83

Epoxy curing temperatures shall be maintained in the temperature range designated for the formulation used.

84

The composite casing shall be completely inspected by the contractor during and immediately following application of the composite materials. Entrapped air shall be released or rolled out before the epoxy sets and each individual layer and ending of composite shall be firmly bedded and adhered to the preceding layer or substrate.

85

The cured composite shall have uniform thickness and density, continuous bond between layers, lack of porosity, and uniform percentage of polymerization.

86

Composite casing to be grouted shall be in place for at least 62 hours before grouting.

87

Voids equal to or larger than 100 square inches in size in cured composite, or between cured composite and concrete, shall be repaired by matrix injection. Individual voids smaller than 100 square inches in size in cured composite, or between cured composite and concrete, need not be required except that for a grouted composite casing.

88

The Contractor shall keep a record of the composite casing construction at each column and shall furnish a copy of such data to the Engineer within 48 hours after painting. The record shall include the following for the casing at each column:

Identification of the column and bridge.
Date and time of constructing composite.
Batch numbers of epoxy used.
Quantity of epoxy used.
Quantity of fiber used.
Weather conditions (temperature and humidity to be recorded continuously or at 30 minute intervals).
Record of samples taken.

89

(Para. 89 through 93: Use only when a bladder and grout filler are shown on the plans.)

BLADDER.--Bladder for composite column casings to be grouted shall be an elastomer that is continuos around the column with seams made grout tight and capable of withstanding the grouting pressures. The material for the bladder shall be chemically compatible with the grouting material and the epoxy materials. The size of the bladder shall allow grouting without folds and without splits or seam failure.

90

GROUTING COMPOSITE CASINGS.--Composite column casings shown on the plans to be grouted shall be grouted according to the requirements for grouting structural steel casings elsewhere in this section "Alternative Column Casings," and these requirements.

91

Casings shall withstand the grout pressure shown on the plans and shall be equipped with a bladder lining and equally spaced around the base. Ejection pipes shall be provided at the same horizontal spacing as injection pipes and shall be placed at 25 feet maximum vertical spacing. Injection and ejection pipes shall be fitted with positive mechanical shutoff valves. Suitable alternatives, when satisfactorily demonstrated to the Engineer, may be substituted for mechanical valves. After grouting, the valves shall be closed at the grouting pressure shown on the plans and the closed valves shall not be removed or opened until the grout has set.

92

Grouting equipment and valves shall be capable of grouting at a pressure of at least 400 pounds per square inch. Grouting equipment shall include pressure gauges at injection and ejection pipes having a full-scale reading.

93

The maximum elongation of the composite casing after grouting shall be 1.5 percent when measured around the circumference of the casing.

95

(Para. 95: Alternative thick finish coat may be furnished by Fyfe.)

PREPARING SURFACES AND PAINTING COMPOSITE CASING.--Exposed surfaces, including surfaces below ground, shall be cleaned, including removal of any grout from the grouting operation, and roughened by abrasive blasting using an abrasive that is no larger than 30 mesh. Grouting shall have been completed at least 72 hours before roughening the surfaces of grouted casings. The abrasive shall be of appropriate hardness to toughen the surface without damage to the fiber portion of the composite. The fiber portion of the composite shall not be exposed by the abrasive blasting operation.

96

Dust and residue shall be removed from all roughened surfaces by flushing with clean water before painting.

97

All cleaned and roughened surfaces of the composite casing shall be dry before receiving the same finish paint coats in the same manner as specified for the structural steel column casing in this section, "Alternative Column Casing," except that a mist coat will not be required for the first application. No primer undercoat will be required.

112

MEASUREMENT AND PAYMENT.--The various types of alternative column casing will be measured by the square foot. The quantity to be paid for will be the area of the existing concrete.

113

The contract price paid per square foot for the various types of alternative column casing shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in furnishing and installing or constructing column casings complete in place, including removing and disposing of foliage and other materials, drainage piping, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

115

Full compensation for any additional testing, materials or work required because of the use of an alternative column casing system shall be considered as included in the contract price paid per square foot for the various types of alternative column casing, and no additional compensation will be allowed therefore.

116

Payments of the Contractor will be reduced for inspection expenses for alternative column casings in the same manner as required for welded structural steel in the sixth paragraph of Section 55-4.02, "Payment," of the Standard Specifications.