An Evaluation of TYFO S Fibrwrap

Final Report

Report 2013 – 05

May, 2013

Reporting on Work Plan 1994-R-7

STATE OF VERMONT
AGENCY OF TRANSPORTATION

MATERIALS & RESEARCH SECTION

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Technical Report Documentation Page

1. Report No. 2013-05	2. Government Accession No. - - -	3. Recipient's Catalog No. - - -
4. Title and Subtitle An Evaluation of TYFO S Fibrwrap		5. Report Date May, 2013 6. Performing Organization Code
7. Author(s) Jason P. Tremblay, MS, EI George W. Colgrove III	Devon Sanborn	8. Performing Organization Report No. 2013-05
9. Performing Organization Name and Address Vermont Agency of Transportation Materials and Research Section 1 National Life Drive National Life Building Montpelier, VT 05633-5001		10. Work Unit No. 11. Contract or Grant No. 1994-R-7
12. Sponsoring Agency Name and Address Federal Highway Administration Division Office Federal Building Montpelier, VT 05602		13. Type of Report and Period Covered Product and Material Evaluation 1994 – 2013 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

State Departments of Transportation (DOT's) are continually looking for cost effective products and processes to extend the life of any number of transportation related products. Salt splash and leakage from bridge joints are the cause of a significant amount of spalling, cracking, and deterioration affecting the structural integrity of bridges around the state. This damage applied to bridge columns for example, deteriorates the confining effects necessary to counter compressive forces. A common approach in addressing this problem is encasing the column in an outer diameter of new concrete, usually approximately twelve inches thick. The solution has been effective, but expensive. Rather than employ a standard concrete encasement, in June of 1994 the Vermont Agency of Transportation applied TYFO S Fibrwrap to columns of the first pier of Bridge #60 in Williston while rehabilitating the bridge. Based on performance observations conducted by the Agency, TYFO S Fibrwrap appears to be a viable alternative to concrete encasement as a rehabilitative method for concrete bridge columns.

17. Key Words TYFO, fiberwrap, concrete rehabilitation		18. Distribution Statement No Restrictions.	
19. Security Classif. (of this report) - - -	20. Security Classif. (of this page) - - -	21. No. Pages	22. Price - - -

Form DOT F1700.7 (8-72) **Reproduction of completed pages authorized**

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ABSTRACT

State Departments of Transportation (DOT's) are continually looking for cost effective products and processes to extend the life of any number of transportation related products. Salt splash and leakage from bridge joints are the cause of a significant amount of spalling, cracking, and deterioration affecting the structural integrity of bridges around the state. This damage applied to bridge columns for example, deteriorates the confining effects necessary to counter compressive forces. A common approach in addressing this problem is encasing the column in an outer diameter of new concrete, usually approximately 12 inches thick. The solution has been effective, but expensive. Rather than employ a standard concrete encasement, in June of 1994 the Vermont Agency of Transportation applied TYFO S Fibrwrap to columns of the first pier of Bridge #60 in Williston while rehabilitating the bridge. Based on performance observations conducted by the Agency, TYFO S Fibrwrap appears to be a viable alternative to concrete encasement as a rehabilitative method for concrete bridge columns.

INTRODUCTION

State Departments of Transportation are continually looking for cost effective products and processes to extend the life of transportation related products. Salt splash and leakage from bridge joints take their toll on bridge piers and their columns. Depending on the design of the structure and the frequency of salt applications it is subject to, eventually the bridge pier and its columns will spall and crack. As the outer shell of the bridge column deteriorates its confining effects upon the compressive forces which it restrains is undermined. In the past, the most commonly utilized approach for the alleviation of this problem has been the encasement of the column in an outer diameter of new concrete, usually approximately twelve inches thick. The piers for Bridge #47 that carry VT Route 100 over Interstate 89 in the town of Waterbury were encased in concrete to cure ailing pier columns, shown in Figure 1. The solution has been effective, but also expensive. (1) As in the Waterbury solution, the higher costs were compounded by the requirement of more substantive and costly barriers being necessary due to the reduced horizontal clearance.

Figure 1 Example of a Mass Concrete Encasement of Pier Columns.

In June 1994, Bridge #60 in Williston underwent rehabilitation to repair damage from salt intrusion in the columns and piers. Rather than employ a standard concrete encasement, the Agency evaluated a fiber reinforced polymeric (FRP) encasement that has tensile strengths fifty times greater than concrete. TYFO S Fibrwrap was applied to the columns of Pier #1 of Bridge #60. The columns are located close to the travel lanes and become coated with salt impregnated slush cast by high-speed traffic. The TYFO S Fibrwrap was selected in order to prevent further contamination from the salt spray, along with providing structural reinforcement for the patched concrete members. (2)

PROJECT LOCATION AND SUMMARY

The project is located at Bridge #60 along Interstate 89 in the town of Williston, Vermont. The bridge carries Oak Hill Road and spans about 400’ over four lanes of I-89 traffic as shown in Figure 2. The bridge is supported by five piers, with three columns per pier. The three columns of pier number one are the experimental columns being evaluated. The remaining columns underneath Bridge #60 were repaired with standard treatment concrete encasements. These were utilized as evaluation controls.

Figure 2 TYFO Fiber Wrap Project Location

Installation of the TYFO S System began June 6, 1994. The columns were excavated to a depth of 2 feet beneath the existing ground surface. This exposed the columns to an elevation, which was 7.6 feet above the top surface of the footings. Cracks and spalling were then repaired with AA Concrete. The entire surface of the columns was then broom cleaned, and an epoxy-paint mixture was applied to the repaired areas as a primer treatment.

The glass fabric was taken from a roll, drawn through rollers under tension and saturated with the previously mixed two-part epoxy. The resin-suffused fabric was measured as it passed through the rollers and pre-cut to the proper length for wrapping around the column three times in one continuous strip. This material was then placed onto a spindle for ease of the wrapping application. The wrapping was done manually, utilizing an adjustable spindle. All wrinkles were eliminated as the columns were wrapped, shown in Figure 3.

Figure 3: TYFO S Fibrwrap spindle application (1994)

The height of each FRP application was 4.5 feet. The wraps were butt jointed against one another other as they were applied from the bottom of the column to the top. The width of the top strip of fabric was cut as necessary to accommodate the variable heights of the columns. After the entire column was wrapped, six inches width of the treated glass fabric were prepared to cover the joints with a one-layer thickness so that the negative visual impact of the seams was minimized, shown in Figure 4. After the initial three-layer wrap was complete, a single layer wrap was applied for aesthetic considerations as well as for additional strength. The layering is shown in Figure 5. The treated columns were then left for twenty-four hours, allowing a tack free cure of the epoxy, and finally painted the next day. This gives the columns a smooth, apparently seam free, and aesthetically pleasing appearance. The manufacturer claims that the final product is a spall and crack free, structurally reinforced column, with a tough outer shell that has a high corrosion resistance. (1)

MATERIAL DESCRIPTION

The TYFO S Fibrwrap system employs a fiberglass fabric impregnated with a two-part epoxy resin. The fabric is wrapped with tension rollers around a concrete structure and then painted. The distributor, R.J. Watson, Inc., claims that the resulting column wrap is resistant to salt, soil, and UV radiation and offers increased shear and flexural strength. (3)

In addition to cost effectiveness, the manufacturer of TYFO S Fibrwrap, FYFE Company, claims another benefit. With TYFO S Fibrwrap System, increased flexural and shear strengths for earthquake protection can be realized. (1)

Figure 4 Applying the six inch strip to seal the butt joint (1994).

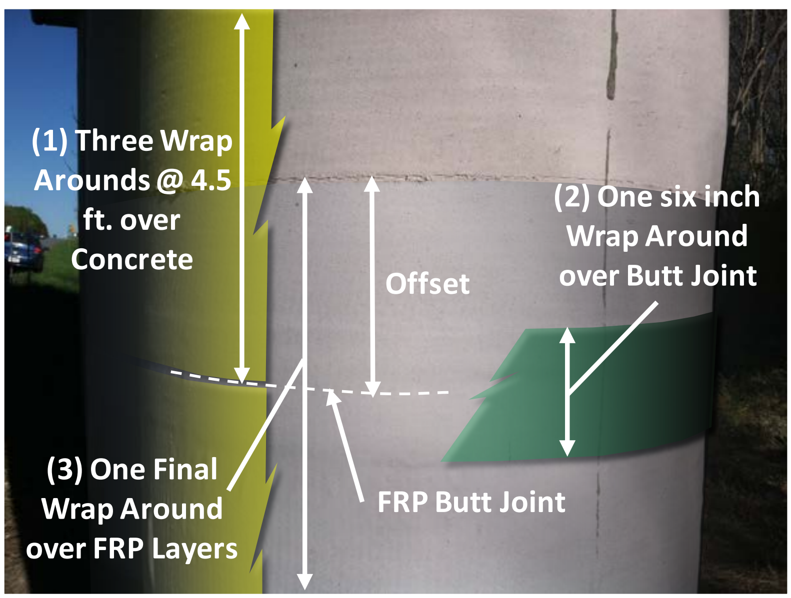

Figure 5 The primary wrap (1) was placed first in three wrap arounds. A 6" strip (2) was then wrapped around to seal the Butt Joint. Finally, a cover wrap (3) was applied at an offset of the Butt Joint covering the other wraps.

PERFORMANCE AND OBSERVATIONS

Periodic site visits were performed to Bridge #60 in Williston to evaluate the effectiveness of the TYFO S Fibrwrap material, as well as to assess the conditions of the concrete columns supporting the bridge. Research and Development personnel inspected the material and site visit reports from each trip were completed. Site visits were conducted on the following dates: June 6, 1996, November 7, 1996, August 22, 1997, July 10, 1998, June 30, 1999, July 30, 2007, July 27, 2010 and a final visit on May 4, 2013. The site visit reports include notes on overall condition and effectiveness, as well as photos documenting any imperfections and visual appearance.

During an inspection in August 1997, apparent bubbles or small bulges in the FRP wrap were discovered, ranging from approximately one to three inches in diameter. A July 1998 inspection showed no change in the size or shape of the air pockets, indicating that they are a result of air being trapped between the Fibrwrap and the concrete at the time of installation and not a result of subsurface activity in the concrete. The status of the bulges was unchanged in the final May 2013 site visit. In June 1999, a separation, approximately one inch wide appeared along a horizontal seam of the bottom wrap of column #1 (Figure 6). This separation had no substantial depth and since the installation of this material involves overlap, there is little concern for salt intrusion. In the final 2013 inspection, the separation did not exhibit any advancement, and appeared to be more of a fray in the FRP fabric that was not smoothed out during installation.

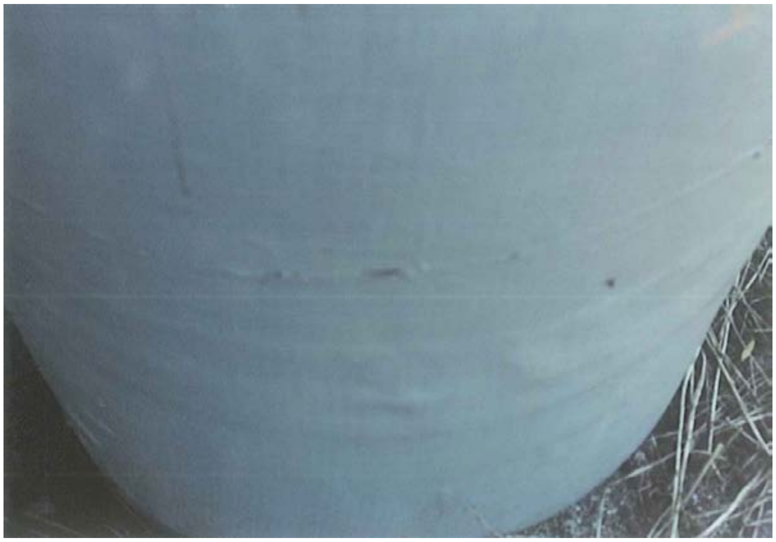

Figure 6 Slight Separation, not substantial in length or depth (1999).

In 1997, core samples turned up no signs of distress in the concrete. During the June 1999 inspection, it was discovered that one of the cored holes in column #2 was inadequately filled resulting in a small void in the top section of the hole. By 2013, no distress has resulted from the void. However, as shown in Figure 7, the core hole above is exhibiting leaching rust, which was originally detected in the 2003 inspection. This leaching has advanced by 2013. A core hole location in column #1 showed some signs of rust leaching out around the perimeter of the former hole in 1999. There may have been some moisture trapped within the hole when it was filled, shown in Figure 8.

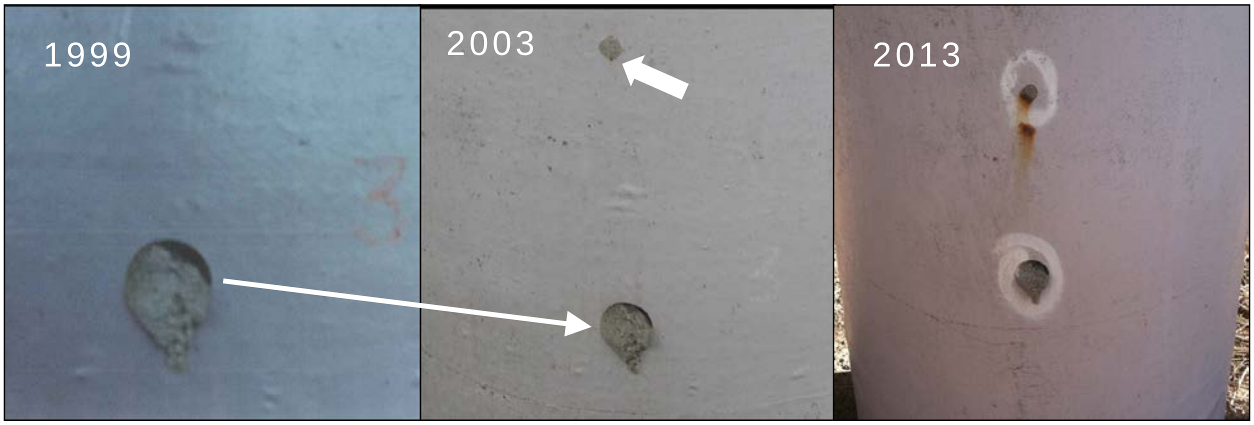

Figure 7 Core hole in Column #2 under pier #1 over 14 years.

Figure 8 Core hole (filled in 1997) in Column #1 under pier #1, over time.

The leaching rust is likely originating from reinforcing in the column the core cut through, and is slowly bleeding between the in situ concrete and the core filler concrete. As it makes its way out the column, it exits the core hole, but also seems to be seeping between the column concrete and the TYFO wrap in an outward spreading pattern. As shown in the previous figures, the core hole in Column #1 shows a lateral leaching pattern, where the Column #2 core hole exhibits a downward leaching pattern. The leaching pattern seems to be confined within a three to four inch radius of the core hole.

By 2013, no other rust spots were detected on the column. Only these two core holes out of ten have exhibited any deterioration. This should not be viewed as a failure of the system, but rather the evaluation process. This suggests that the method of evaluating a CFRP Wrap should be limited to non-destructive methods. J. Levar and H. Hamilton, concluded in a University of Florida study, that "Infrared Thermography can be used effectively for non-destructively evaluating CFRP strengthening systems for concrete." (4)

An observation made in 2013 was with chlorides that were leaching out of the pier cap adjacent to the top of Column #3. The chlorides seem to make the customary route to the column via cracks. Rather than remain and build up on the column as what typically happens with concrete, the chlorides seems to be washing, blowing or flaking off the column with typical environmental diffusion of rain, or air, shown in Figure 9.

Figure 9 Chlorides leaching onto column.

Upon the inspections in July of 2010 and in May of 2013, no further imperfections were noted. The Fibrwrap material seems to be performing at a very satisfying level. The concrete columns beneath the surface have shown no signs of distress or decay, and even though there is some surface rust leaching from the core holes, it is not considered to have any structural consequence. The untreated concrete columns under have exhibited further cracking and spalling. The control columns are overall in worse condition then the experimental columns. At this point, nearly nineteen years after installation, the TYFO S Fibrwrap material remains aesthetically pleasing as well as structurally sound. A comparison of a wrapped and unwrapped column is shown in Figure 10 and Figure 11.

COST ANALYSIS

Based on preliminary estimates in 1994, the savings discovered when this treatment was substituted for the originally designed repairs were substantial. The reduced quantities that resulted with the TYFO S replacement, their associated costs and savings are shown in Table 1.

Figure 10: Column #3 under pier #1, 2010 treated with TYFO S Fibrwrap

Figure 11: Column #3 under pier #2, 2010 not treated with TYFO S Fibrwrap

Table 1 Estimated costs of Conventional Construction (1994 dollars)

Item	Description	Quantity	Unit Cost	Savings ($)
204.25	Structure excavation	50.00	$7.00/CY	350.00
204.30	Grnlr Bkfl for Struct.	40.00	$12.00/CY	480.00
501.25	Concrete Cl. B	27.20	$275.00/CY	7,480.00
505.36	Temp. St.Sht. Piling	700.00	$10.00/SY	7,000.00
507.15	Reinforcing Steel	1882.00	$0.75/LB	1,411.50
507.16	Drill & Grout Dowels	60.00	$5.00/LF	300.00
580.14	Repair of Substr. Cl.II	13.00	$350.00/CY	4,550.00
		Total Conventional Costs ($)		**$21,571.50**

It should be noted that the total cost shown above also approximates the cost of repairing the three columns of pier #1 that would have been incurred had the original design been employed. One expense that was not accounted for above, however, is the cost for the reduced quantities of structure excavation and granular backfill that were necessary with the modified design. Another cost not being considered in this comparison is a significant reduction to mobilization costs.

The cost of the rehabilitation alternative is based on the quantities for two items, one of which was substantially increased, and the other of which was added to the contract because of the change, as shown in Table 2.

Table 2 Cost of the FRP Wrap Alternative

Item	Description	Quantity	Unit Cost	Added Cost ($)
580.13(MOD)	Rep. Conc. Substr. Cl. I	495.00	$22.00/SF	10,890.00
580.14(MOD)	Rep. Conc. Substr. Cl. II	10.00	$275.00/SY	2,750.00
			Total Alternate Cost ($)	**$13,640.00**

The items 580.13 (Repair of Concrete Substructures Class I) and 580.14 (Repair of Concrete Substructures Class II) were modified to include surface cleaning and repair of minor scaling and the CFRP wrap. No other items were required.

With the estimated conventional costs of rehabilitating the columns, at each pier location, being over $22,000 and the final costs for employing the TYFO-S wrap totaling $13,640, indicates the cost reduction would be more than $8,400. The savings for this limited application were nearly 35% when costs for the reduced quantities of excavation and granular backfill were included. (1)

If the remaining four piers were rehabilitated at the same time with the CFRP wrap, the total reduced costs would be over $42,000 in 1994 dollars or over $66,000 in 2013 dollars.

SUMMARY AND RECOMMENDATIONS

Based on 19 years of observations, TYFO S Fibrwrap is a proven alternative to concrete encasement as a rehabilitative method for concrete bridge columns. In September 2002, the Agency successfully used a CFRP wrap on similar columns on bridges 43-N and 43-S that carries Interstate 89 over US Route 2, which is still performing well 11 years later. In future applications of this product it is recommended that the same periodic inspections as were done on this project be conducted in order to ensure that the column wrap does not mask serious failures in the structure which would otherwise be readily apparent on exposed concrete. (2) Inspection practices should involve looking into punctures and tears into the CFRP layer where moisture can reach concrete. The inspection practices used this research will be shared with the Bridge Inspection Program.

The installation process should be carefully monitored and specifically designed for each application. With the proper preparation and installation of the product, it is clear that TYFO S Fibrwrap can be a viable alternative to concrete encasement. The bridge rehabilitation project subjected to experimentation on bridge #60 proved very cost effective and produced a sufficient protective barrier as well.

Future installations of an FRP wrap should be inspected using non-destructive evaluation processes such as Infrared Thermography to check for areas of unbonded or debonded FRP wrap and areas of delaminating concrete. From observations made from the repairs made after taking core samples, it is clear that destructive testing methods put the structure at risk of advanced deterioration.

Today when public dollars are being negatively impacted by the struggling economy while also being spread to cover more needs, products like TYFO S Fibrwrap provide a significant and viable alternative to concrete encasement. CFRP products can help with stretching the life of Vermont's Bridges and the dollars used in maintaining them. Based on the observation thus far it appears that this method is a very cost effective way of preserving bridge pier columns and should become standard maintenance and rehabilitation practice.

REFERENCES

1. Brunelle, R. E. *Tyfo S Fibrwrap Column Strengthening & Rehabilitation System, Research Update WP 94-R-7.* Vermont Agency of Transportation, 6-13-94.

2. Companion, Theresa J. *Tyfo S Fiberwrap, Research Update U 1999-4.* Vermont Agency of Transportation, 7-20-1999.

3. Carter, P.L. *Tyfo S Fibrwrap, Research Update U 96-27*. Vermont Agency of Transportation, 11-19-1996.

4. Levar, J. M, Hamilton, H. R., III, (2003). *NDE of CFRP-Concrete Bond using Infrared Thermography*, ACI Materials Journal Vol 100, pp 63-72.

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION

WORK PLAN FOR CATEGORY II EXPERIMENTAL PROJECT

TYFO S COLUMN STRENGTHENING & REHABILITATION SYSTEM
Work Plan No. 94-R-7

OBJECTIVE OF EXPERIMENT:

To evaluate the performance of a proprietary bridge column strengthening and rehabilitation system and its ability to increase structural strength, repair cracks and spalling, and inhibit any further deterioration of the columns.

PROJECT:

Richmond-Williston IR DECK(29)

PROJECT LOCATION:

In the town of Williston, on I89, BR#60.

EXPERIMENTAL WORK LOCATION:

The three columns of pier #1 of BR#60.

MATERIALS TO BE USED:

The column strengthening and rehabilitation system used shall be the TYFO S system, manufactured by R.J.Watson, Inc. of East Amherst, N.Y.

Only the manufacturer of the TYFO S system, or the contractor, under the supervision of the manufacturer or an authorized agent of the manufacturer will be allowed to install it.

EXPERIMENTAL TREATMENT:

The treatment will consist of repair and cleaning of all spalled or cracked areas, patching with an approved grout or cement and wrapping the repaired column with TYFO S epoxy treated fiber until the specified number of layers have been obtained. A protective coating of the epoxy mixed with Aerosil 202 will then be applied. After the epoxy has cured, a two component, water based, epoxy paint system will be applied.

CONTROL SECTION AND TREATMENT:

The remaining columns of BR #60 will be repaired with standard treatments. These will be utilized as evaluation controls.

DURATION OF STUDY:

The study will continue as long as necessary to determine the effectiveness of the system and its anticipated life cycle.

SURVEILLANCE:

Installation surveillance and performance evaluations will be conducted by Vermont Agency of Transportation personnel.

REPORTS:

Reports will be prepared and submitted to the Federal Highway Administration when warranted as the data collection process progresses, and when conclusions can be drawn about the column strengthening and rehabilitation system.

Materials & Research Division
Agency of Transportation

Reviewed By:

R. F. Cauley, P.E.
Materials & Research Engineer
Date:

Approved by Material and Research (RFC)