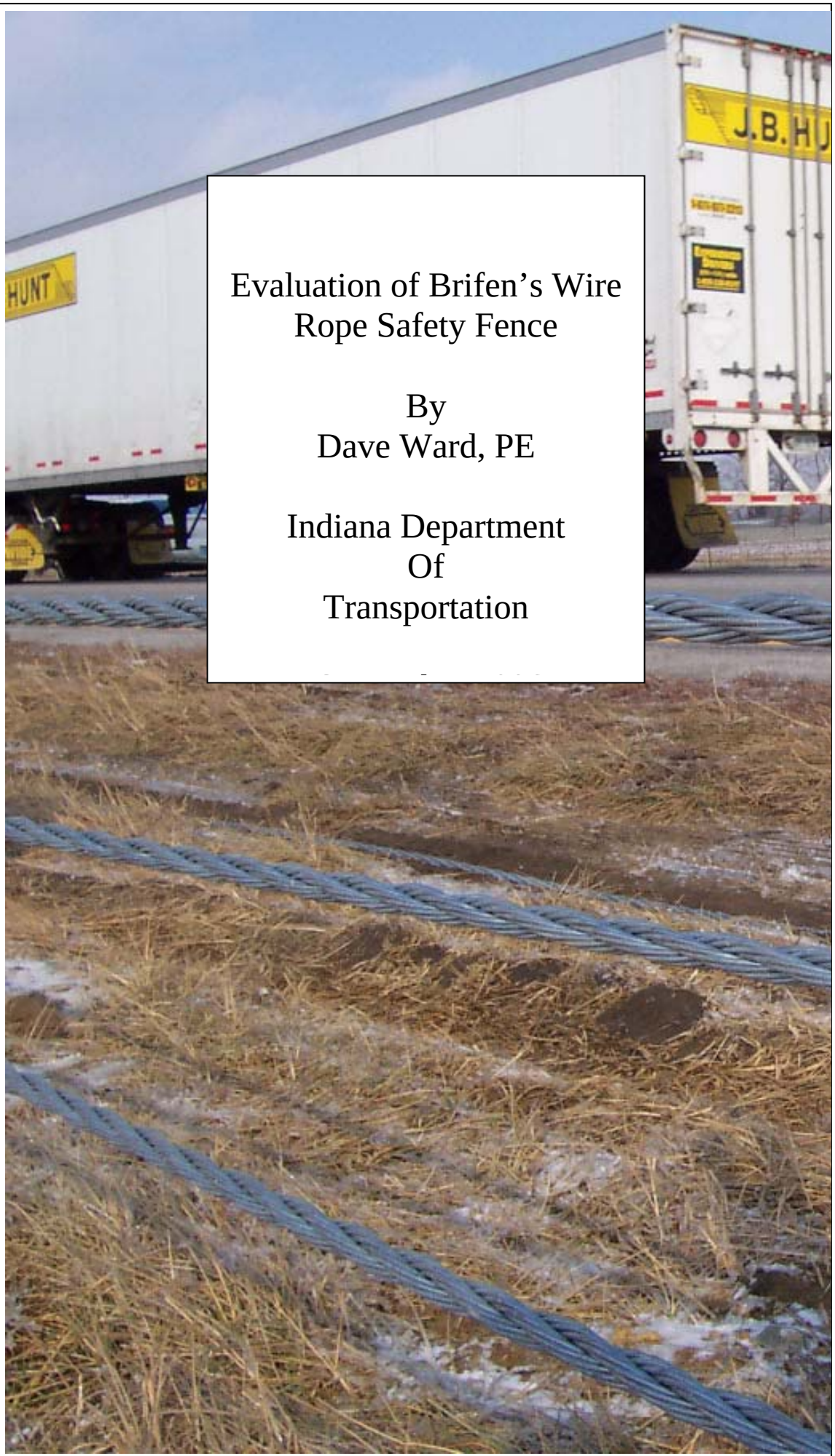

Evaluation of Brifen's Wire Rope Safety Fence

By
Dave Ward, PE

Indiana Department
Of
Transportation

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16. Abstract

This research project evaluated a safety median barrier known as Wire Rope Safety Fence (WRSF) manufactured by Brifen US Inc. of Oklahoma City, Oklahoma. This safety product has been used extensively throughout the world and within the United States for various applications. It is a unique cable design that weaves wire ropes around a post instead of passing it through them. It absorbs the impact from a vehicle by transferring the impact to adjoining posts via high tension wire ropes. A 13 mile section of I-65 just north of Indianapolis was chosen for evaluation. This section had a history of cross median accidents with fatalities. To date the WRSF has been hit over 70 times. The performance of the WRSF has been impressive. There have been no cross median accidents and no injuries. The initial cost of WRSF was cheaper than other median barriers and it is easier to repair. The only problem with WRSF has been foundation failures. The soft soil conditions of the median were not considered in the design of the WRSF. Future WRSF installations will be based on geotechnical investigations of the soil at the site. This study recommends that WRSF be approved for use for appropriate highway applications. It is also recommends that the current study be terminated as concerns about WRSF have been addressed.

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Brifen Wire Rope Safety Fence

Interim Report

Experimental Feature Project #

Prepared By

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INDOTs
Division of Research and Development

October 2006

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- Randy Large, General Forman with the Frankfort Sub-district, for taking pictures and obtaining police reports rain or shine at any hour of the day
- Joe Wilson, the project supervisor, for providing contract information and acting as a resource for all aspects of the Wire Rope Safety Fence (WRSF) installation and repair
- Todd Shields with the Division of Highway Operations for providing information on the process that led to the WRSF contract and also served as a contact person for various questions regarding the WRSF
- Brifen USA for providing design and safety literature as well as contacts in various DOTs regarding the use and performance of WRSF
- The following INDOT employees for providing design, layout, and general information on WRSF: Ronald Heustis, Shakeel Baig and Brad Steckler
- The Federal Highway Administration for providing support throughout this project and special thanks to Ed Ratulowski who was involved with all aspects of WRSF effort

Table of Contents

Note: Information on I-69 will be sent at a later date under separate cover. The I-69 Contract is still active and there is a substantial amount of work that remains to be done.

INTRODUCTION

Background

This will be considered the final report if recommendations are implemented. This report presents findings on the installation, performance, and costs associated with a safety barrier called Wire Rope Safety Fence (WRSF) manufactured by Brifen, USA Inc. based in Oklahoma City. The findings cover the time period from November 05 to October 06. Although WRSF was new to Indiana, it has been used extensively in other countries and about 25 DOTs in the US. All the users of WRSF have been impressed by its performance. WRSF was developed in the United Kingdom (UK) almost two decades ago. It has been used for many applications, including a very narrow median on a four lane divided highway in Australia in lieu of a concrete barrier with good results (Anthony Schmidt, Australia Highway Engineering, January 2003).

Some Features of WRSF

The Indiana Department of Transportation (INDOT) decided to try this product because of favorable reviews by virtually all users and because the manufacture brought WRSF to the attention of INDOT. Some features of WRSF reported via other DOTs that made it attractive were:

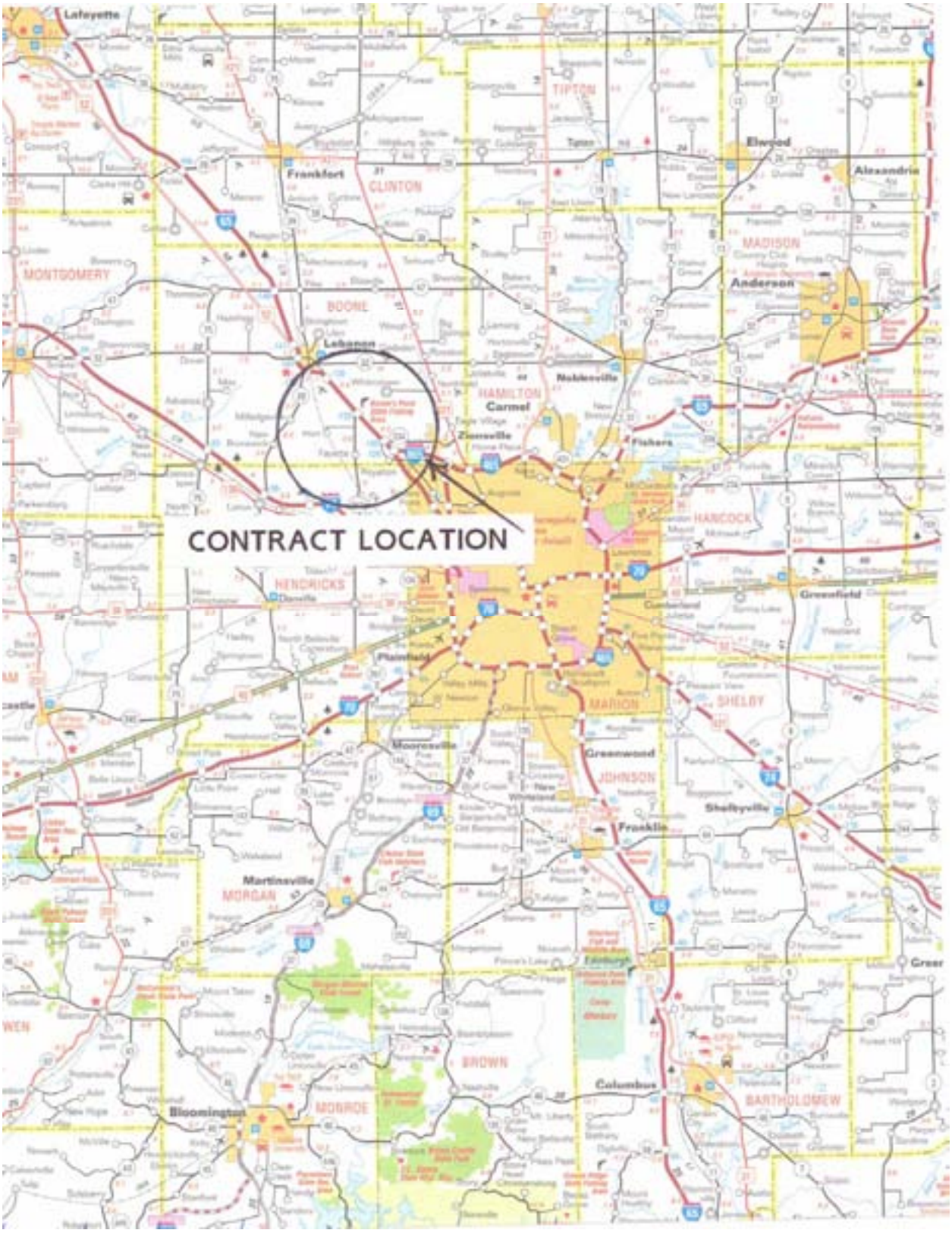
- Controlled impact that absorbs crash energy much better than other barrier systems without deflecting a vehicle back into traffic
- Easy low cost repairs using one or two people and hand tools
- Little or no delay to traffic for installation or repair
- Repair does not require heavy equipment, therefore, the median is not damaged
- WRSF is bi-directional and can absorb hits from both sides
- Complies with NCHRP 350 (TL-4)

- Can stop bigger vehicles

Site Selection

The locations of these contracts were on sections of I-65 and I-69 just north of Indianapolis. Both locations had a history of crossover accidents, with fatalities. The most recent data indicated that I-65 had four recent fatalities. Since WRSF had been shown to be effective in reducing this type of accident, INDOT opted to use it on both contracts. However, since the I-65 and I-69 sections of interstate highway were similar, it was decided to evaluate only one location. I-65 was chosen because of its proximity to a Maintenance Sub-district and INDOT's Office of Research and Development. Personnel from both of these locations would be involved in the evaluation of WRSF. Also this section of interstate did not have any existing median safety barrier. See the map on page 10 for the contract location. Also the contract on I-65 started much earlier than the contract on I-69.

While this report focused on I-65, there is a summary of information from the I-69 that will be forwarded at a later date.


CONTRACT LOCATION
Lafayette
Frankfort
CLINTON
TIPTON
Tipton
Elwood
Alexandria
MADISON
Anderson
MONTGOMERY
BOONE
Lebanon
Noblesville
HAMILTON
Carmel
Zionsville
Fishers
HANCOCK
Greenfield
HENDRICKS
Danville
Plainfield
MARION
SHELBY
Mooresville
Greenwood
JOHNSON
Shelbyville
Franklin
Martinsville
MORGAN
Edinburgh
BROWN
Columbus
BARTHOLOMEW
Bloomington
MONROE

Experimental Features Study

Since the product had not been used in Indiana, it was decide WRSF should be installed and monitored via an Experimental Features Study (EFS). This enables a DOT to use federal funds for new proprietary products provided they are evaluated over a specific time period. As part of the EFS agreement, INDOT would prepare and submit annual reports on various aspects of WRSF including installation, performance, and costs. Interstate maintenance money was used to fund the installation of the WRSF. A copy of the approval letter for the EFS is listed in the Appendix

Study Objectives

This study had five objectives:

- Determine if WRSF performs as well as indicated by the manufacturer and DOTs that have used it
- Determine if there are any problems associated with installing, repairing, and maintaining WRSF
- Determine the costs associated with WRSF
- Compare WRSF to "w" beam guardrail and concrete median barrier which are the primary median barriers used by INDOT
- To determine if WRSF would reduce the frequency and severity of cross-median head-on collisions

HOW THE WRSF SYSTEM WORKS

WRSF is different than other barrier systems. It is designed to absorb the impact of a vehicle by gradually bringing the vehicle to a stop. Three wire ropes are weaved around line posts that are spaced every 10.5 feet. The wire rope does not pass through the posts like most other cable systems. The wire ropes are held in place by small plastic pegs inserted into holes on both sides of the line posts. Another wire rope sets in a slot on the top of the line posts. All wire ropes are put under high tension. As a vehicle impacts the

WRSF, the line posts by design bend over. This dissipates some of the crash energy. High friction between the posts and the wire rope begin to "capture" the vehicle and absorb the rest of a vehicle's momentum. The wire rope transfers the impact to adjoining posts, and the vehicle comes to a gradual stop and is not deflected back into traffic.

LAYOUT AND SITE INFORMATION

Site Conditions

The WRSF location that was selected for evaluation was a north/south 13 mile section of I-65 just north of I-865 in Boone County. The site had the following conditions: a speed limit of 70 mph, 7 interchanges, 28 ramps, poor drainage in the median, 60 foot grass median with a slope of 1/6 or flatter, 12' lanes with an inside shoulder of 4 feet, and an average daily traffic (ADT) of about 60,000 vehicles of which 30% were trucks.

Layout

INDOT did the layout design in-house using accident data from the I-65 location and criteria from Brifen, the manufacturer. The original layout placed the WRSF in the center of the median. However, a field check revealed that the median had poor drainage. Therefore it was decided to install the WRSF 12' off the 4' median shoulder or 16' off the edge of the passing lane. This set back would help eliminate incidental hits of vehicles that stray from the passing lane on to the shoulder, but would stop vehicles before they crossed into the opposing traffic. The 16' offset from the passing lane was based on the maximum deflection that could be expected from a backside hit (8 feet) plus four feet more as an added margin of safety. The layout was expected to provide a safe economical solution to the crossover problem.

Median Crossovers

The installation criteria for the WRSF along this stretch of I-65 were the existing median crossovers. They determined where the WRSF began and ended. The ideal protection of median crossovers by errant vehicles would be to overlap the WRSF runs at the crossovers. However, this would require designing and building new crossovers for which the entry and exit locations were offset. In order for a snow plow to cross the median they would have to make extremely tight turns to get from one side to the other. Therefore, the WRSF design required the fence to be on the same side of the median as traffic as you approach the crossover. Because the crossovers dictated which side of the median the fence needed to be on, the next step was to decide where and how to switch sides. One option available was to simply transition the fence from one side of the median to the next in one continuous length of WRSF. This type of transition would be less expensive to install than the method used, but it would make mowing operations more difficult. The method of switching sides chosen was to overlap the WRSF at the existing bridge piers.

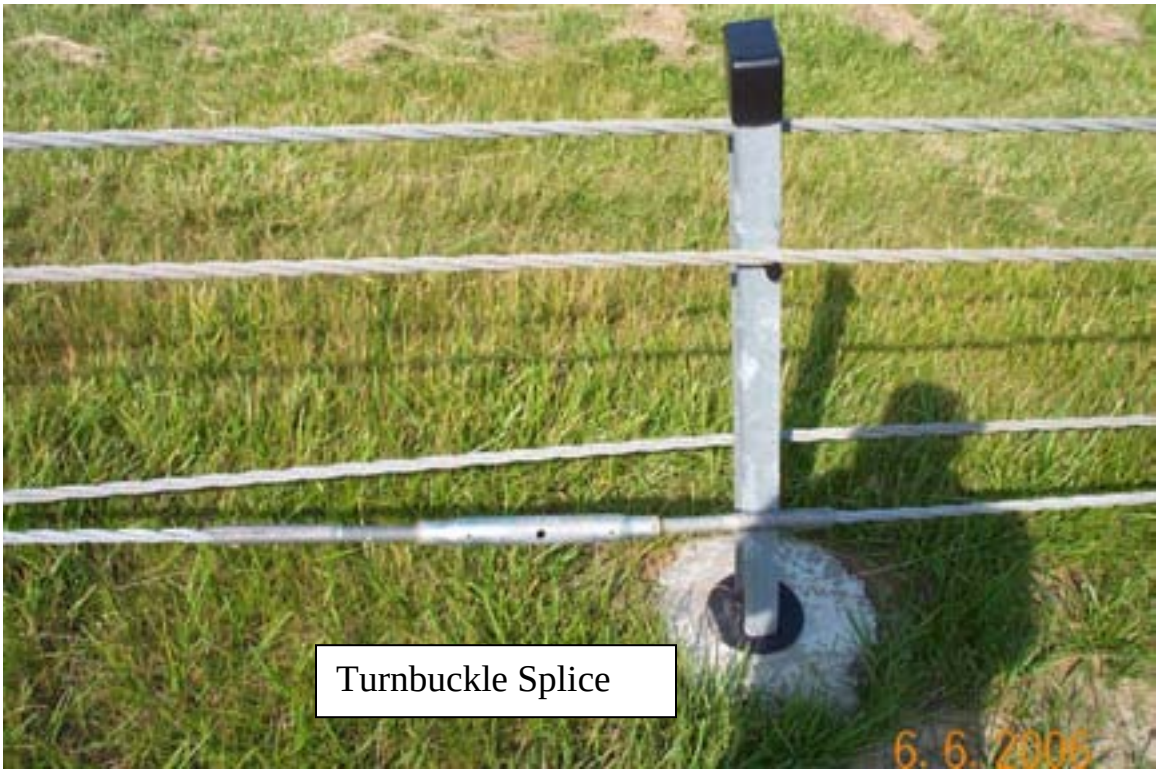
Bidding

INDOT prepared contract plans and proposals for two WRSF projects and let them out for bid in November 05. Only four companies bid on the WRSF contracts. This was probably associated with the uncertainty of bidding on a new product. CTECH based out of Indianapolis was the low bidder on I-65 at $1,625,120.00. The other bids varied but most were about $100,000.00 higher.

WRSF INSTALLATION

Control Points

CTECH began the installation of the WRSF on I-65 in December 05. The first step in the installation was to locate the beginning and end points of each run and offset them 16 feet from the inside edge of the passing lane. This was done using surveying equipment to set the control points for each run. Some of the control points were set for runs that were more than a mile long. These sections would require turnbuckle splicing every 1000 feet See the picture below which shows a typical splice.



Foundations

Using the control points a suspended string line was set over a run so that the depth and position of each foundation could be determined. See page 15 for the foundation layout.

String Line Layout

Line post holes and end terminal foundations were 30 inches deep. Using the string line for reference, the foundation holes were cored to the proper depth every 10.5 feet along the run. The line post foundations were 12 inches in diameter and the end anchors were 48 inches in diameter. A one ton truck with an auger was used for excavating. Waste soil was distributed along the median manually or removed using a Bobcat (small earth mover).

Concrete Placement and Tensioning

After placing socket posts and end terminal assemblies in the cored holes, concrete was placed in the foundation holes. Occasionally it was necessary to use traffic control during the placement of concrete. Concrete beams were cast to determine when wire rope could be weaved on to the line post and tensioned. Once the posts for a WRSF were set the wire ropes were strung and loaded to the proper tension using a pickup truck that pulled them tight. Final tension was achieved by tightening the turnbuckles. After several weeks the ropes were checked by the contractor to make sure they retained proper tension.

Coring

The installations of WRSF began in November 05 when the weather conditions were wet and cold. The contract work began with the layout of the WRSF locations along the median. Once the runs of WRSF were marked and a reference string line was set to the proper line and grade, coring operations began

As the coring operations continued, it was noticed that some of the waste soil appeared to be saturated. This was not a surprise because of the wet weather conditions and poor drainage in the median. The waste soil from coring appeared to be high in silt content. At the time of the coring this observation did not prompt any response from Brifen, the contractor, or INDOT. In retrospect all parties should have discussed this and determined if line posts foundations should have been deeper and reinforced. Later on in the contract this issue resurfaced as a contributing factor for some foundation failures.

WRSF IMPACTS

Reporting Accidents

The reporting procedure for monitoring the WRSF when it was hit by a vehicle involved the local sub-district Operations Manager and local, county and state police departments. Since the sub-district was located approximately 15 miles northeast of the WRSF site collecting information and taking pictures usually took less than an hour. When law enforcement officers were called to the scene of a WRSF accident, they contacted the sub-district manager who then went to the scene, day or night to obtain the police report number and to take pictures. The report number was subsequently used to search the Indiana State Police database to download a completed copy of the report after it had been posted to the database. This process usually took about a week. Pictures were obtained using a digital camera and were then downloaded to a PC and given a file name. The police report number and picture files were referenced to the closest mile marker and this information was emailed to the Principle Investigator (PI) for review.

Typical Impact

A typical vehicle impact of the WRSF involved about six posts that were bent over at the top of the socket. See the picture below. Some of the wire ropes occasionally passed over the vehicles bumper and ended up on the top half of the vehicle or on the windshield.

This usually was true for smaller vehicles or bullet nose mini vans. For larger vehicles the wire ropes usually tended to stay low on the vehicle and ended up lodged against a quarter panel of the vehicle or bumper. Four vehicles penetrated the WRSF and came to rest partially beyond the wire rope in the grass median. These vehicles passed through the wire ropes with some of the ropes passing over and some passing under the vehicle. None of the wire ropes were severed and no vehicle was in danger of reaching the opposing lanes. Vehicles that hit the WRSF, for the most part, sustained moderate damage of about $5,000.

WRSF Remains Functional

After a vehicle is removed from the WRSF the wire ropes return to their original alignment because they are under high tension. They are no longer attached to the posts that are bent over. Although the posts are bent over, the wire ropes can still "capture" a vehicle. If more than about 10 posts are bent over there is some minor sagging. See the picture on page 19. One hit involved a semi that bent over 31 line posts. Although the wire rope did sag it appeared that it could still stop a smaller vehicle. There were not many hits that bent over more than 15 posts.

Shearing

On a few impacts it was noted that some of the line posts were sheared off at their base (top of the foundation). As a result, removing the posts was more difficult. However, the vast majority of line posts were bent over and not sheared off.

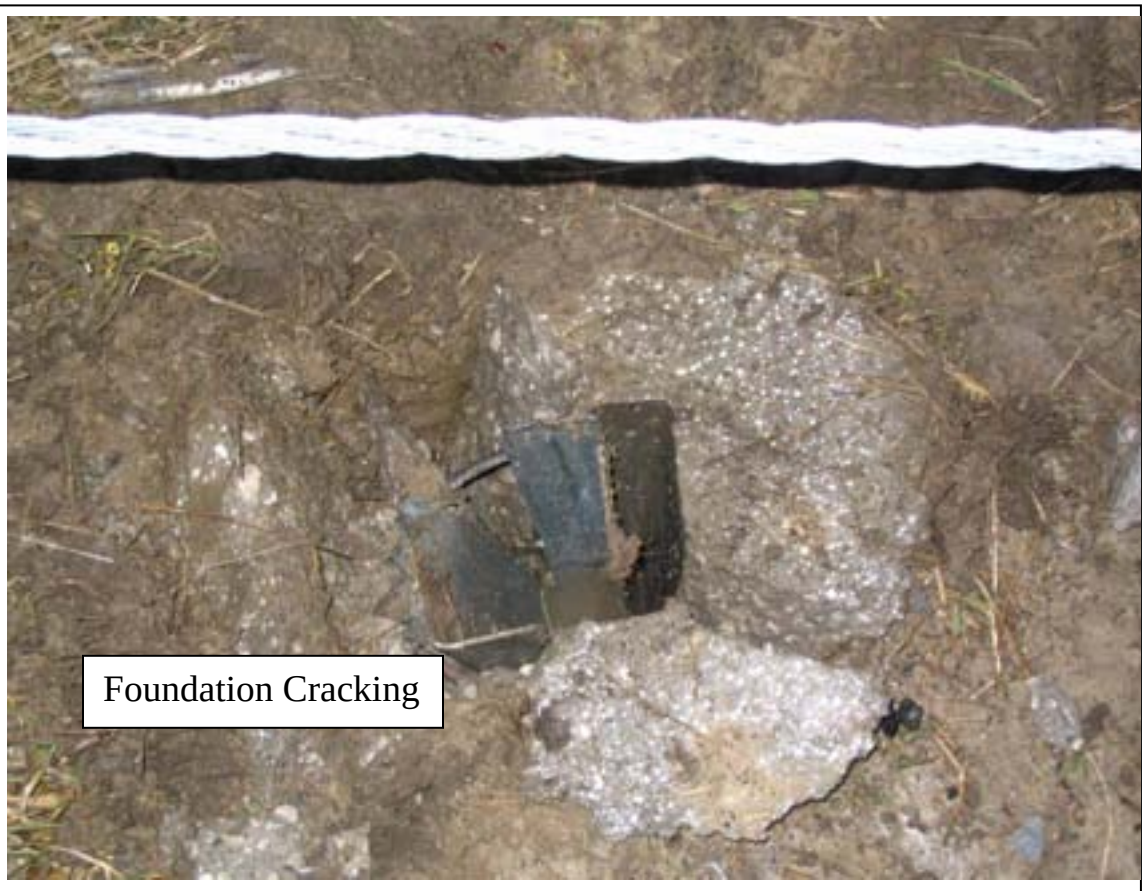
Foundation Failures

Shortly after the installation of WRSF began it was hit in several locations. The WRSF performed as expected in that there were only minor injuries. However, some line post foundations were pulled completely out of the ground. A review of information from other DOTs revealed that the foundations should be cored deep enough to be below the frost line which is 36 inches for Boone County. The line post foundations were only cored to a depth of about 30 inches.

At the time of this report, the WRSF on I-65 has been hit about 69 times. Some of these hits resulted in socket foundations being pulled completely out of the ground. See picture on page 21.


Foundation Pulled Out

This problem was likely due to soft soil and foundations not being cored deep enough. It should be noted that to date that only 13 line foundations have pulled out of the ground, however, there have been a significantly number that were cracked. There is no way to determine how many foundations will exhibit pullout and cracking problems because it only occurs when the WRSF is hit. To date there has been no backside hits to the WRSF. It was also noted that some socket concrete foundations were cracked but had not been pulled out of the ground. See picture below..



Foundation Cracking

After some of the terminal end foundations were put under a load, it was noted that end anchors appeared to be rotating out of the ground. It was suspected that this problem was also due to soil conditions. Brifen indicated that these types of failures have not been a problem on other WRSF installations. However, a report from Iowa reported that they had experienced this problem but it was not widespread.

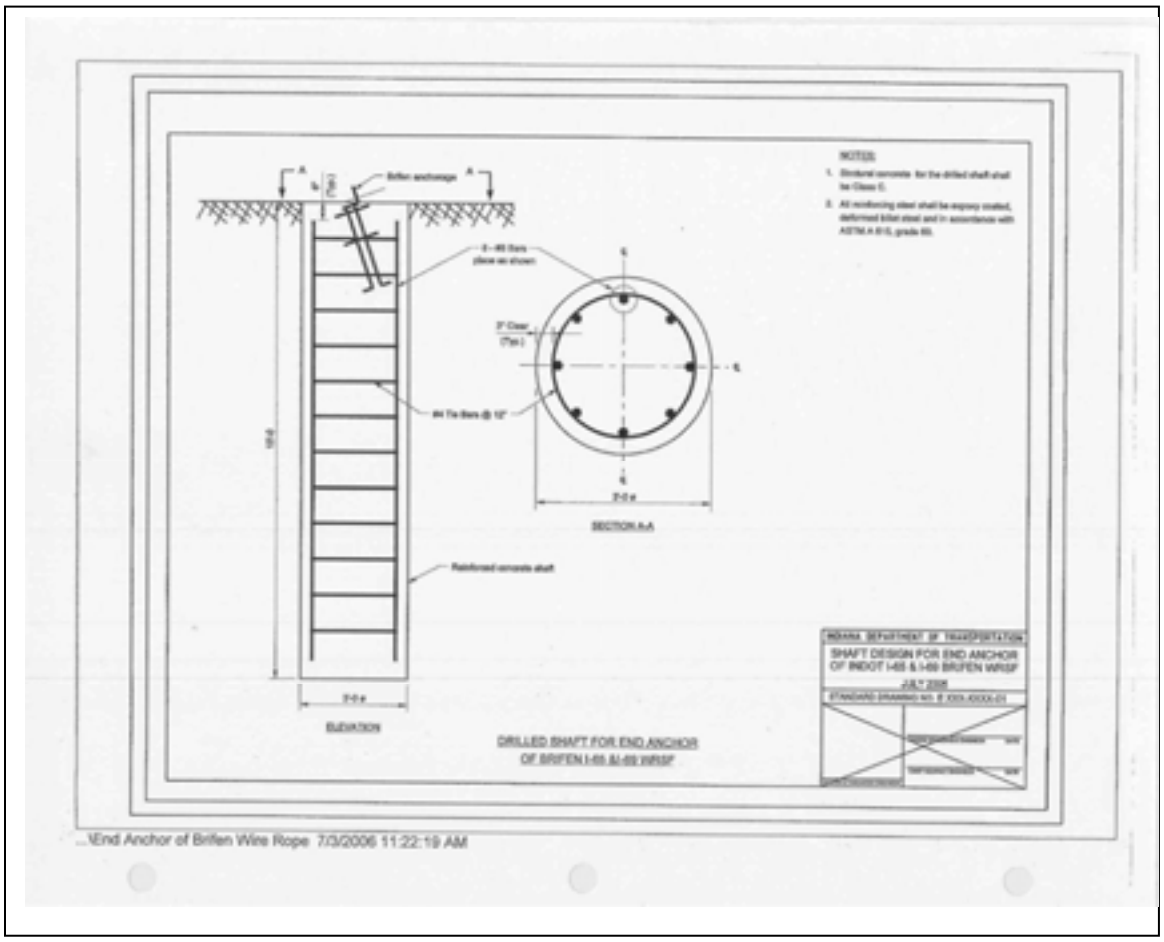
Geotechnical Issues

After several meetings where the foundations problems were discussed, it was decided that INDOT's Geotechnical Section would investigate the foundation problems to determine if soft soil was the cause. The Geotechnical Section took twelve cores in the median spaced out along the 13 mile long contract. The results of their investigation indicated that some locations did have soft soils. Excerpts from the geotechinical investigation are listed below:

- In general, there were 6 to 12 inches of topsoil underlain by silty loam
- Most boring holes were dry after drilling, but there were pockets of water encountered in some of the holes
- There were cave-ins of some boring holes at depths of 1 foot or less
- Although test borings were mostly dry after the completion of drilling, water from the median tended to drain into the boring holes. It was recommended that this be considered in the design of future WRSF installations
- It is recommend that coring be extended to a depth of 36 inches to be at or below the frost line
- Provisions should be made for deeper foundations when soft soils are encountered.

As indicated, several end anchors failed under dead load. As a result of these failures, it was decided to use the results of the geotechnical investigation to design a new end

anchor foundation. The redesigned foundation was substantially deeper than the original but smaller in diameter (36 inches in diameter and 13 feet deep, see the picture below). The redesign also specified that the foundation be steel reinforced throughout its entire depth. Since the new foundation was smaller in diameter, Brifen was asked to verify that the end anchor bracket design would work with a smaller diameter foundation.



NEW FOUNDATION DESIGN

WRSF PERFORMANCE

The performance of the WRSF has been impressive. It has stopped all cross median accidents and kept injuries to a few cuts and bruises. There were at least 16 WRSF hits where the driver drove away since the vehicle had only minor damage. In these instances only a few posts were bent over.

One of the hits on the WRSF involved a car and a semi truck. These vehicles bumped one another while moving to the passing lane to avoid a slow moving vehicle in the travel lane. Both vehicles lost control and hit the WRSF. The semi truck was captured by the WRSF after deflecting it about ten feet and bending over about 20 posts. Neither vehicle had much time to slow down so the hits on the WRSF were at about 60 mph. The car hit the WRSF behind the semi truck. The car sustained only moderate damage. The only damage to the truck was the left fender of the cab. No one was hurt in the accident.

The state police who investigated this accident were convinced that the WRSF prevented a fatal head on collision because both vehicles would have crossed the median into the south bound lanes. The traffic in the north and south bound lanes of I-65 was heavy at the time of the accident. It should be noted that the center of gravity of the truck was probably above the WRSF. It is surprising that the semi truck did not roll onto its side. Even if this had happened, the truck would not have crossed the median into oncoming traffic.

TYPICAL WRSF REPAIR

Replacing Line Posts

Repairing the WRSF was straight forward. Broken or bent line posts were removed using hand tools or a special pry bar available from Brifen. After the posts were removed, a spacer (usually a modified line post) was used to weave the replacement posts back onto the wire ropes and insert them into the sockets (rectangular steel tube

embedded in the foundation) . The plastic plugs to position the wire ropes on the posts were placed and the top wire was set in the top slot. The time to repair a typical WRSF hit of 6 posts for an experienced crew of two was about a half hour or less. Repairs in cold weather sometimes took a little longer because some posts were frozen in the socket. Some DOTs have used torches to thaw out frozen posts.

Checking Tension

The contractor has tested the tension on several wires ropes after the WRSF has been hit. These tests indicate it was unlikely any wire ropes would lose proper tension after a hit. If tension became a concern the suspect wire rope could be tested with a tension meter. If the tension was below the specified value the nearest turnbuckle could be used to increase tension. It should be noted that all repairs to date have not required any adjustment in tension. The only concern regarding tensioning is that a few impacts cut at least one strand of the wire rope. It has not been determined what action will be taken to resolve this issue.

COSTS ASSOCATED WITH WRSF

Contract Cost

The total cost for this 13 mile (appox.) WRSF contract was $1,625,120.00. The unit price for WRSF by the lineal foot including all parts, posts, and foundations was $17.95. The total price for this item was $1,333,685 which was the biggest item of the contract. End anchors cost $2,450.00 each. Traffic control, mobilization, construction engineering, and other incidental items constituted about 18% of the contract.

Additional Contract Costs

There were additional contract costs associated with 3 Extra Work Agreements (EWA). The first EWA was for CTECH to replace bent line posts while the contract was active

and before INDOT maintenance crews made repairs. The second EWA was to replace line posts foundations and sockets. The last EWA was to remove and replace all end anchor foundations with a new design. The costs associated with these EWAs are covered in other sections of the report.

Cost Comparison to other Cable Barrier Systems

Some of the costs per mile for median barriers, including WRSF, that were obtained from an Oklahoma report on WRSF are listed below:

- Three cable generic barriers costs about $50,000 per mile
- Driven post WRSF cost about $68,000 per mile
- WRSF sockets placed in concrete foundations cost about $84,000 per mile
- Double faced "w" beam guardrail costs about $105, 000 per mile
- Concrete median barrier costs about $500,000 per mile

The cost for a lineal foot of WRSF as listed in the Contract Proposal was $17.95 as compared to $19.00 for "w" beam guardrail (average cost from INDOT database). Based on this and information from other DOTs the price to install WRSF is at least comparable to "w" beam guardrail if not cheaper.

The cost associated with a single highway fatality according to the National Safety Council is $1,120,000.00. The total contract price for installing WRSF, excluding other contract items, is $1,333,685. Therefore, if the WRSF saves even one life, it will have almost paid for itself. This does not include the reduction in the severity of injuries and reduced vehicle damage.

Typical Repair Costs

Brifen has tracked the average repair cost for WRSF within the US for repairs made by DOT maintenance crews. A typical repair that replaces 6 line posts cost about $312.00 or

$52 dollars per post. This cost includes all parts and labor. The repair cost charged by CTECH to replace a single line post is substantially higher than $52.00. A single line post cost negotiated via an EWA was $187.50 and a transition post near the end anchors cost $218.30. CTECH explained that this disparity in price was associated with labor costs of having to pay a crew a full day's wages to replace a few posts.

A rough comparison to convert lineal feet to cost by the post can be made by multiplying the space between posts (10.50 feet) by the contract cost per foot ($17.95). This results in a cost per post of $188.50. This is significantly higher than the price per post obtained from Brifen but is close to the EWA negotiated price of $187.50 between CTECH and INDOT. While the price to return and repair a single post would be more expensive than the production price achieved during installation, CTECH's price per post was unexpectedly high. On future WRSF contracts the price to replace posts will be a contract bid item in lieu of EWAs and this should result in a more reasonable cost.

Cost Per Mile

Contacts with other DOTs and Brifen indicated that the installation of WRSF is about $80,000 per mile for a single run down the middle of median. The contract cost for WRSF by the mile including all contract items was about $125,009.23. The disparity between these different costs might reflect uncertainty associated with bidding and installing a new product.

Cost Per Collision

The negotiated contract price via an EWA with CTECH to replace line posts after a typical collision (6 posts) was about $1125.00. The average repair cost of a vehicle was at least $5000. This results in a total cost per collision of $6125 ($1125 + $5000). The total cost of repairing a double faced "w" beam guardrail of the same length is estimated to be about $7,000.00

Estimated Repair Costs Using INDOT Maintenance Crews

One of the main objectives of the EFS was to track the cost of INDOT maintenances crews as they repaired WRSF. At the time of this report, the contract is still active so INDOT maintenance crews have not made any repairs. However, by using INDOT's labor cost including benefits of about $20.00 per hour and post prices from Brifen at $25.00 per post, a reasonable estimation can be made for repairing WRSF. If the repair requires two people for an hour (2 × $40.00) plus a pickup truck ($25.00), this cost would be about $ 105.00. The price for 6 posts (typical hit) based on Brifens estimated cost of $25.00 per post is $150.00. Therefore, the total cost of a typical repair using INDOT maintenance personnel would be about $255.00.

Spare Parts Package

As part of the contract, INDOT paid $15,150.00 for a spare parts package of 200 posts and associated hardware plus a tension meter for maintenance crews to use for repairs once the contract was complete. This is approximately a material cost $76 per post. Information from Brifen indicated that DOTs who purchase posts directly from Brifen pay only about $25.00 per post for quantities greater than 50 posts. This disparity between post prices ($25.00 vs $76.00) may reflect bidding strategies by the contractor or other factors.

At the time of this report the cost of removing and replacing failed end anchors with the new design is being negotiated. The cost for a new line post foundation from CTECH of $ 555.00 was rejected by INDOT.

EXTRA WORK AGREEMENTS (EWA)

First EWA

Even before all the WRSF was installed on the contract, it was hit several times. Since the contract was active, it was expected that the contractor would make the necessary repairs without compensation. However, the contractor indicated it expected to be reimbursed for any repairs made. This became an issue between INDOT and the contractor. To resolve this, several meetings took place to determine who should be responsible for the repairs and how payment would be made. Typically INDOT contract provisions require a contractor to make repairs to contract items without compensation while the contract is active. This typically involves quality issues related to poor workmanship or failed materials. In this case the WRSF was installed according to the plans and there were no material failures.

After several meetings, INDOT and the contractor negotiated payment via an Extra Work Agreement (EWA). Under this agreement CTECH would repair all damaged sections of the WRSF and then would seek compensation from the driver's insurance company. Because law enforcement officers responded to most WRSF accidents and completed an accident report for each one, it was possible to identify each driver's insurance company. INDOT would pay CTECH for hits for which no insurance company could be identified. The EWA cost was by the post because it was assumed the wire rope and sockets did not need to be replaced. The cost to replace bent over line posts was $187.50

Second EWA (proposed)

At the time of this report an EWA is being negotiated to remove and replace all failed end anchors (32) with a new design that is reinforced and deeper. The price to remove end anchors was $ 1300.00 and the cost to install the new foundations was estimated to be about $5000.00. At the time of this report INDOT was deciding as to whether the original end anchors could be left in place.

Third EWA (proposed)

At the time of this report INDOT and CTECH are negotiating a price to replace line post foundations that were pulled out of the ground. There are a total of 13 line posts that need to be replaced. INDOT has rejected the initial price of $555.00 per foundation proposed by CTECH. Some of the line posts are covered by the driver's insurance and CTECH will repair those. At the time of this report there are 6 line post foundations that are not covered by insurance that need to be replaced. When CTECH replaces the line posts foundations covered by insurance they will track their actual cost. They will then use this cost as a basis for an EWA.

PUBLIC, POLICE, MEDIA AND INDOT COMMENTS

Almost immediately after vehicles began hitting the WRSF, there were positive comments made by law enforcement officers, drivers, and the news media. The first comments came from law enforcement officers who investigated the hits on the WRSF. They indicated that there was no doubt that the WRSF was saving lives and that it was reducing injuries. These comments came from veteran police officers who had patrolled this section I-65 for many years and were familiar with the accident history of this section of the road. The more vehicles that hit the WRSF and were safely "captured" the more the police praised the benefits of this safety barrier.

The local media, the general public, and law enforcement officers knew this section of interstate was noted for its cross median accidents. There were many testimonials from these sources lauding the good performance of the WRSF. Most of the drivers that hit the WRSF commented to the investigating officer that they were glad the WRSF was there because it probably saved their life. It is ironic that one of the vehicles hitting the WRSF was an INDOT car. There was only minor damage to the car and the driver was

not injured. This employee spoke to several persons associated with the WRSF project and stated he was lucky that WRSF was installed at this location.

Most of the drivers who hit the WRSF believed that if it hadn't stopped them, they would probably have crossed the median, hit oncoming traffic, and been seriously injured or killed.

There were numerous reports by the news media regarding the benefits of the WRSF. They interviewed several drivers, the state police, contractor employees, and INDOT personnel. It was obvious from the positive coverage that the WRSF was being recognized as an important safety device. On one occasion a semi tractor trailer was stopped by the WRSF and the local news media headlined the accident and pointed out the benefits of the new safety barrier.

FINDINGS OF THIS REPORT (includes interviews and literature findings)

- Some maintenance crews that were polled expressed concern because of the large number of hits on the WRSF and whether or not they will be able to keep up with repairing them after the contract is completed.
- INDOT plans on doing more WRSF – We plan on installing more cable rail, not necessarily WRSF.

- It has been reported that WRSF has seen more than 800 hits nationally with only minor injuries and no fatalities
- No cross median accidents occurred on I-65 after the WRSF was installed
- At least half of US DOTs and about 30 countries use or have tried Brifen WRSF and have been impressed with its performance
- Of the 10 US DOTS that were contacted all indicated they will continue using WRSF

- WRSF has been used for many applications beyond median barrier
- The contract price per lineal foot for WRSF and "w" beam guardrail is nearly the same. The contract price for WRSF was $17.95 per foot and the typical bid price for "w" beam double faced guardrail is $19.00 per foot.
- The WRSF has been hit 69 times since it was installed. For 16 of those hits the vehicle had minimal damage and was able to drive off.
- The end anchor design (48 inches diameter and 42 inches deep) from Brifen was inadequate for soft soil encountered at several locations of the contract. The new design is substantially deeper than the original design (13 feet deep and is steel reinforced).
- At least one semi truck has been stopped by the WRSF
- No vehicle hitting the WRSF has been directed back into traffic
- No serious injuries have occurred when vehicles have hit the WRSF
- Some vehicles hitting the WRSF had only moderate damage and were able to drive off from the scene
- INDOT maintenance crews may need to repair pullout foundations
- WRSF like other safety barriers is less effective on steep slopes and grading for these locations may be required
- The Indiana Toll Road is installing about 30,000 feet of WRSF

CONCLUSIONS

- Brifen WRSF is an effective safety barrier that prevents crossover median accidents
- WRSF is fairly easy to install and maintain
- Compared to other safety barriers (concrete, "w" beam guardrail) WRSF is more cost effective and is as safe if not safer

RECOMMENDATIONS

- Future bid proposals should contain line items for line post, end anchor and foundation repair/replacement to avoid preparing Extra Work Agreements
- INDOT should determine how mowing around WRSF is going to be managed or plan installing a vegetation barrier along with WRSF
- WRSF is a cost effective safety barrier and INDOT should continue using it to address cross median accidents.
- INDOT should try using WRSF for other applications, such as a safety barrier for bridge piers
- INDOT should not adopt Brifen's WRSF for driven posts as the repair costs appear to out weigh the minimal savings for installation.
- INDOT should consider developing non propriety "generic" specifications based on the performance of Brifen's WRSF design. Other four rope systems are coming online and INDOT needs to track their performance by contacting DOTs that have tried them – There are actually 2 other 3 cable systems (CASS and Gibraltar) that have passed at TL 4
- Line post foundations should be placed below the local frost line on future contracts
- Future designs for foundations should be guided by soil testing from the contract location
- Brifen should test lighter gauge line posts to see if they would put less stress on the line post foundations during a collision without compromising safety.
- The current study should be terminated because all the issues involving WRSF have been addressed

REFERENCES

- "Brifen Wire Rope Safety Fence", Oklahoma DOT, March 2003, by Faria Emamian P.E.
- "Brifen Wire Rope Safety Fence", Iowa DOT, August 2005, by Will Stein P.E.
- "New Cable Barrier is a Star", Colorado DOT, Article by Mindy Crane June 2005
- "Interim Report WRSF", Ohio DOT, by Dirk Gross P.E., July 2005
- The following DOTs were contacted by email or by phone: Texas, Minnesota, Arkansas, and Australia
- Numerous reports, design criteria and sales literature from Brifen USA
    - Several articles on WRSF downloaded from the WEB

APPENDIX

CONTACT INFORMATION

BRIFEN USA, Inc

Lyndal Wiseman Customer Service Manager, phone # 1-405-751-8062, email address lyndal@brifenusa.com , Web site is www.brifen.com

INDOT

Dave Ward Research Engineer, phone # 1-765-463-1521 ext # 249, email address dward@indot.in.gov

CONTRACTOR

CTECH, Brian Barth, Superintendent, phone # 1-317-835-2745, email address bbarth@C-TECHinc.net.

LETTER OF REQUEST

April XX, 2005
(317) 234-0410

Mr. Robert F. Tally, Jr.
Division Administrator
Federal Highway Administration
575 North Pennsylvania Street, Room 254
Indianapolis, IN 46204

Mr. Tally –

The Indiana Department of Transportation is seeking your approval to install a proprietary cable rail system as an experimental feature at select interstate median locations.

Our intent is to install a median barrier on I-69 from Milepost 5 to 9 and 12 to 30, and on I-65 from I-865 (milepost 129) to US 52 (milepost 141). Crash statistics show a significant amount of cross-median type accidents at these locations, including several fatalities. We will use federal hazard elimination safety (HES) funds for both of these projects (reports are on file with the HES committee).

INDOT feels that a tensioned cable system is the best solution to solve these type accidents for the following reasons:

1. A tensioned cable system is designed to maintain its redirective function after being struck.
2. By utilizing the socketed post option, maintenance is much easier than traditional W-Beam guardrail.
3. Installation can be accomplished with minimal grading.
4. The system considered appropriate for these locations offers TL-4 protection.

With your approval, we will install the Brifen Wire Rope Safety Fence, Test Level 4, with socketed posts at these locations. Brifen has passed the TL 4 test and obtained FHWA approval. A copy of this letter is attached. We will let contracts to install the barriers this year.

Once installed, INDOT will evaluate these sections for 2 years. A work plan for evaluation of this product is attached. We will monitor design, constructability, impacts, maintenance and repair costs.

We ask that you approve this request. If you have any questions, please contact me or Todd Shields at 232-5506.

Sincerely,

James M. Poturalski
Chief, Division of Operation Support

attachment

EVALUATION PLAN

Tensioned Median Cable System
Evaluation Plan
Indiana Department of Transportation

INDOT's evaluation plan will include consideration of the following items. Reporting will be done through our Research Section.

1. Design
    a. Necessary site modifications
    b. Comparison of cable design cost to design cost of alternate barriers

2. Installation
    a. Bid price of cable system compared to alternate barriers
    b. Interviews with INDOT project supervisors as to installation issues

3. Maintenance - for each repair or other maintenance
    a. Date of repair
    b. Time of repair
    c. Equipment, Labor and Material needed for repair
    d. Total cost of repair
    e. Interviews with INDOT maintenance personnel as to maintenance issues

4. Accident Statistics – for each hit
    a. Date of hit (approximate if unable to determine exactly)
    b. Location of hit (Reference Post and Offset)
    c. Direction vehicle was traveling
    d. Number of Posts damaged
    e. Condition of driver/passenger (fatal or injury - if available)

U.S. Department
of Transportation
**Federal Highway
Administration**

400 Seventh St., S.W.
Washington, D.C. 20590

March 27, 2005

In Reply Refer To: HSA-10/B-82B

Mr. Derek W. Muir
Group Managing Director
Hill & Smith Ltd.
Springvale Business and Industrial Park
Bilston, Wolverhampton, West Midlands, WV14 0QL

Dear Mr. Muir:

In your March 7 letter, you requested formal Federal Highway Administration's acceptance of your Brifen Wire Rope Safety Fence (WRSF) as an National Cooperative Highway Research Program (NCHRP) Report 350 test level 4 (TL-4) traffic barrier. To support this request, you also submitted reports detailing two tests conducted by MIRA test laboratory, entitled "Vehicle Impact into the Standard Length of a Brifen Safety Fence to the NCHRP Report 350 Test 4-10" and "Vehicle Impact into the Standard Length of a Brifen Safety Fence to the NCHRP Report 350 Level 4-12," and digital videos of the tests themselves.

The TL-4 Brifen design consists of four separate cables, the bottom three of which are interwoven between posts with the top cable set in a 101-mm deep x 22-mm wide slot cut into the top of each post. Cable heights measured from ground level are 480 mm, 630 mm, 780 mm, and 930 mm, respectively. The posts, shown in enclosure 1a, are S-shape posts, 100-mm x 55-mm x 4.55-mm thick, manufactured from ASTM A-36 steel that is galvanized after fabrication. Post spacing is 3.2-m. For the tests, 1420-mm long posts were set approximately 400 mm into tubular steel sockets contained in cylindrical concrete footings. Your recommended transition design from the TL-3 system (or from the cable Brifen anchor) to the TL-4 design is shown in enclosure 1b, and consists of transition posts "A" and "B" at which points the two bottom cables are gradually lowered and the two top cables are raised over a 6.4-m distance to match the tested TL-4 cable heights. Since no test was conducted at this location with the single-unit truck, the transition itself can be considered only a TL-3 design.

Test summary sheets for the two tests you conducted are shown in enclosure 2. In the small car test, although successful, several of the concrete footings pulled out of the ground, negating the supposed maintenance benefit of using socketed posts. To reduce the likelihood of this occurrence, you recommended increasing the footing size from its tested 250-mm diameter to a 300-mm diameter, with its depth remaining at 750 mm. Deeper footings can be used in soft or saturated soils to improve system maintainability, the use of which would not need any

additional approval action. If you use driven posts with soil plates with the TL-4 design, these posts must have the same cross-section noted above for the TL-4 system and have the same below-ground geometry as is now specified for the TL-3 barrier, shown for convenience as enclosure 3. If you wish also to utilize steel sockets driven directly into the ground, you will first need to specify the size and depth you recommend, and provide an analysis showing equivalency with the approved designs. Design deflection with the small car was 1.35 m. With the single unit truck, it was reported to be 2.21 m. Presumably, deflection with the pickup truck would be similar to that noted in your earlier TL-3 test and thus may be assumed to be approximately 2.4 m.

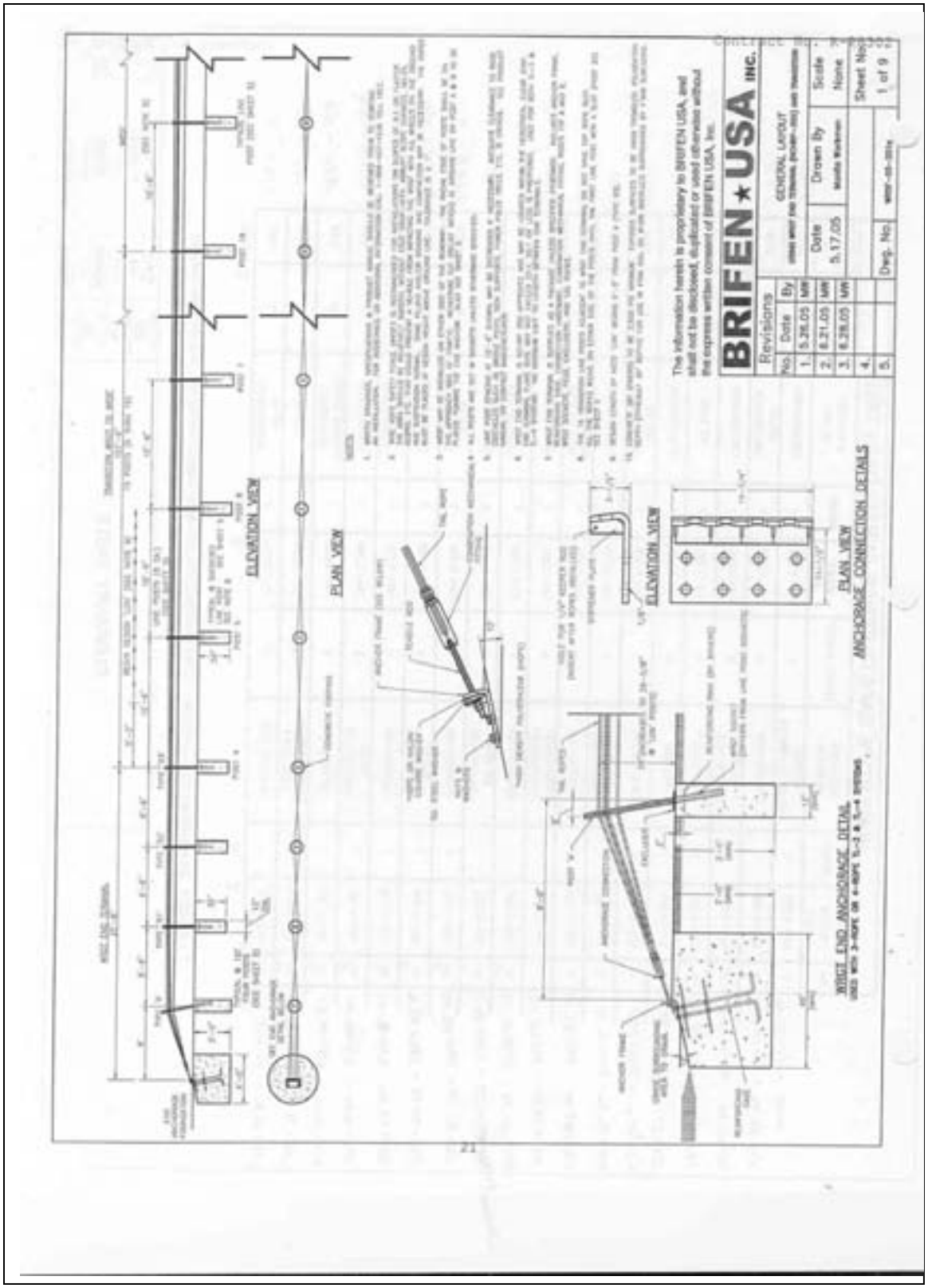
In summary, your Brifen WRSF, as described above, is acceptable as a TL-4 traffic barrier and may be used on the National Highway System when such use is specified by the contracting agency. I understand that all steel components of the TL-4 design, as with the TL-3 WRSF, are manufactured in the United States (U.S.) with U.S. steel and are not subject the Buy America provisions of Title 23, U.S. Code (USC), Section 635.410. However, both designs are proprietary and, as such, their use on Federally-funded projects remains subject to the conditions listed in Title 23 USC, Section 635.411.

Sincerely yours,

/original signed by/

John R. Baxter, P.E.
Director, Office of Safety Design
Office of Safety

3 Enclosures


ELEVATION VIEW
PLAN VIEW
ELEVATION VIEW
PLAN VIEW
ANCHORAGE CONNECTION DETAILS
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Revisions
No. Date By
1. 5.26.05 MW
2. 6.21.05 MW
3. 6.28.05 MW
4.
5.
GENERAL LAYOUT
Date 5.17.05
Drawn By
Scale None
Dwg. No.
Sheet No. 1 of 9