Second Quarter 2004 Progress Report
Midwest Roadside Safety Facility
Mid-States Regional Pooled Fund
July 23, 2004

YEAR 12

Development of a Guardrail Treatment at Intersecting Roadways-Year 3

Testing is expected late in the third quarter of 2004. The system, augmented by an anchor placed near the center of the radiused section, will utilize a release mechanism similar to the cable terminal currently being tested under Year 14. This anchor will significantly reduce system deflection during impacts on either side of the radiused section and should still allow the system to capture a vehicle impacting on the "nose". The system is approximately ½ constructed.

Portable Aluminum Work Zone Signs

The bogie testing for this project has been completed. A submission to FHWA seeking approval has been sent. Polivka, K.A., Faller, R.K., Holloway, J.C., and Rohde, J.R., ***Safety Performance Evaluation of Minnesota's Aluminum WorkZone Signs***, Final Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-107-01, Project No. SPR-3(017)-Year 11, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, January 29, 2002.

Single-Faced Concrete Barrier

Faller, R.K., Sicking, D.L., Larsen, J., Rohde, J.R., Bielenberg, R.W., and Polivka, K.A.,***TL-5 Development of 42- and 51-IN. Tall Single-Faced, F-Shape Concrete Barriers***, Draft Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-149-04, Project No. SPR-3(017)-Year 12, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, February 18, 2004.

MGS W-Beam to Thrie-Beam Transition Contingency 2000P test and Additional 820C Test

The system is constructed, with testing being delayed for wet weather. Test will be performed early in the Third-Quarter when the soil dries.

Three-Strand Cable Median Barrier

A number of bogie tests have been performed during the quarter. The objective of this effort was to increase the capacity of the connection of the cable to the posts. Increasing the capacity of this connection will make the cables located on the opposite side of the post effective. Full-scale testing of the modified system is anticipated late in the Third or early in the Fourth Quarter.

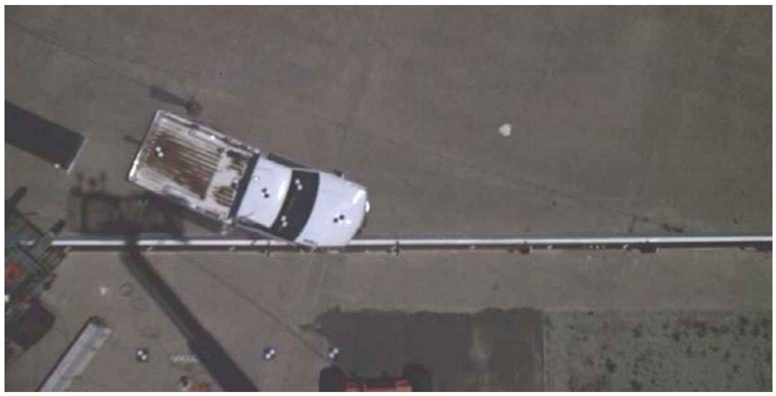
Year 13

Generic W-Beam Guardrail with Curb

Polivka, K.A., Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., Holloway, J.C., Bielenberg, B.W., and Kuipers, B.D., ***Development of the Midwest Guardrail System (MGS) for Standard and Reduced Post Spacing and in Combination with Curbs***, Draft Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-139-04, Project No. SPR-3(017)-Years 10, 11, 12-13, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, February 17, 2004.

Open Railing Mounted on New Jersey Concrete Barrier (2'8")

A second full-scale TL-3 test of a modified rail system, as shown below, was performed on May 28, 2004. As shown, the hood of the vehicle again interacted with the railing elements and the vehicle subsequently rolled. Currently there is not additional funding for further development so our plan is to report on these two tests and look for recommendations during the next year's annual meeting.



Evaluation of Rigid Hazards in Zone of Intrusion

Previous full-scale TL-3 and TL-4 crash tests of a luminaire pole mounted on top of a single-slope concrete barrier have been acceptable. The final test TL-4 in this project of a luminarie pole mounted on the deck behind the barrier is planned for the 4th Quarter of 2004 after completion of the Open Railing tests described above.

Three-Cable Guardrail

This project is on hold pending results of the post bogie testing being performed under the median cable barrier project in Year 12.

Non-proprietary Guardrail System – Additional Test

Polivka, K.A., Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., Holloway, J.C., Bielenberg, B.W., and Kuipers, B.D., ***Development of the Midwest Guardrail System (MGS) for Standard and Reduced Post Spacing and in Combination with Curbs***, Draft Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-139-04, Project No. SPR-3(017)-Years 10, 11, 12-13, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, February 17, 2004.

Kansas Temporary Barrier Redesign and Test

Polivka, K.A., Faller, R.K., Rohde, J.R., Holloway, J.C., Bielenberg, B.W., and Sicking, D.L., ***Development and Evaluation of a Tie-Down System for the Redesigned F-shape Concrete Temporary Barrier***, Final Report to the Midwest States Regional Pooled Fund Program, Transportation Report No. TRP-03-134-03, Project No. SPR-03(017)-Year 13, Sponsoring Agency Code RPRP-03-06, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, NE, August 22, 2003.

System for Stiffening New Guardrail System

Polivka, K.A., Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., Holloway, J.C., Bielenberg, B.W., and Kuipers, B.D., ***Development of the Midwest Guardrail System (MGS) for Standard and Reduced Post Spacing and in Combination with Curbs***, Draft Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-139-04, Project No. SPR-3(017)-Years 10, 11, 12-13, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, February 17, 2004.

YEAR 14

Development of a Four-Strand High-Performance Cable Barrier

Follows work under Year 12.

Evaluation of Transverse Culvert Safety Grate

Additional bogie testing of various configurations is planned for the 4^{th} Quarter. This testing will form the basis of the suspension simulation effort.

Flare Rates for W-Beam Guardrail

The objectives of this research are to evaluate the effect of increased flare rates on impact performance and identify optimal flare rates that minimize total crash costs. A literature review of flare rates, including relevant crash testing and standards, is complete. Additionally, baseline Barrier VII models for the standard W-beam guardrail and for the MGS W-Beam guardrail system have been performed. This effort has resulted in the determination of an impact angle for the initial evaluation of 29.4°. This test is planned for the 4^{th} Quarter.

Approach Slopes for W-Beam Guardrails Systems

No Progress

Concept Development of a Bridge Pier Protection System for Longitudinal Barrier

No Progress

Retest of Cable End Terminal

Further work on this project will be described in Year 15.

OUTSTANDING ISSUES:

Strength Requirements for a Wood Post W-Beam Guardrail System

A final report for this project is anticipated in the 3rd Quarter of 2004.

SUPPLEMENTAL PROJECTS:

Transitions and Deflection Limiting Modifications for the Kansas Type F3 Concrete Temporary Barrier

This project was initiated with two goals. First, it was necessary to develop a tie-down system to limit the deflection of the barrier system when placed on an asphalt concrete surface with some sort of restraint mechanism. Second, it was deemed necessary to transition from free standing barrier to barrier bolted to a bridge deck.

Based on simulation utilizing results of the bogie testing completed last quarter, it was determined that the barrier system appears to meet the deflection objectives of the study utilizing a 2" asphalt pad with the barrier restrained utilizing the three existing holes on the impact face with 1.5" diameter, 3' long A36 pins. We anticipate testing this system in the Third Quarter.

Minnesota Sound Wall Rail

This project was initiated to design and test a railing system for MnDOT's sound wall system in situations where the wall was placed in the clear zone. A glulam rail system was designed and modeled during the 4th Quarter of 2003, details are shown on the following page. Materials for the full-scale 2000P test have been acquired and full-scale testing is anticipated in the 3rd Quarter of 2004.

<u>Pooled Fund Consulting Summary</u>

Midwest Roadside Safety Facility
April 2004-July 2004

This is a brief summary of the consulting problems presented to the Midwest Roadside Safety Facility over the past quarter and the solutions we have proposed.

Problem # 1 – F-shape Temporary Barrier Steel Strap Tie-down Anchors

State Question:

Our bridge section has been talking with Bob Bielenberg about the anchor strap regarding the drop-in anchors. I did not cc Bob because I did not have his email address. Our concern is with the 17 kips pullout and 13.5 kip shear capacity stated being needed for the drop-in anchors. The Red-Head Drop-in Anchor used in the crash test does not provide the capacity stated by your staff as being needed for the strap anchor to work properly. According to the manufacturer's data as well as a test done by an independent testing company the ¾" x 3 3/16" drop-in anchor only provides 9480 lbs and 7680 lbs for ultimate tension and shear capacity, respectively. The values stated by MwRSF for 17kips and 13.5 kips is not possible even if the f'c=6000psi. Our bridge decks are not f'c= 6000 psi and I doubt if your test facility pavement has f'c=6000 psi. In lieu of the drop-in anchor we have been reviewing the concrete screw anchors. Bob Bielenberg told me about these awhile back. We really like the screw anchors as compared to the drop-in anchors.

I have attached a PDF file that summarizes the review that we have conducted on the various concrete anchors. KDOT wants to pursue the option of using the concrete screw anchors however we need to know the capacity values needed for the anchors. We also want to minimize the embedment length into the bridge deck. As you can see the screw anchors develop more allowable tension and shear capacity as compared to the drop-in anchor and would like to know if it is acceptable to substitute them for the drop-in anchors. In addition, we would also like to know the actual required capacity. The 17 kips and 13.5 kips values seem high based upon the manufacturer data. Therefore, we do not want to specify values that exceed the recommendations provided by the manufacturer for the drop-in anchor that you used successfully in the crash test. In addition we also want to provide the contractor with several options for anchorage including the drop-in anchor if desired. Note that KDOT will only allow the anchor strap option when we have 2' or more from the edge of the bridge deck to the back of the TCSB. See anchor detail PDF file.

In regards to anchorage for the TCSB I would like to propose the use of the concrete screw anchors in the bolt holes for the TCSB in lieu of the straps. If possible, the size and number of anchors could be optimized based upon the distance from the edge of the bridge deck to the back of the TCSB, shown as "A" in the attached PDF file. Note that KDOT will only use the through bolted option or bolts epoxied (3 bolts per barrier on the traffic side) into the deck when A is less than 2'. An additional part of this research could also look at using smaller diameter bolts (bolted through the bridge deck) in the TCSB with less bolts per barrier when A>2'. This option we allow the bolts to yield or break however the deflection of the barrier would not cause the barrier to topple off of the bridge. Is it possible that this can be done with simulation and design calculations without the need for a crash test? The benefit of this study would be to provide the contractor with more options to anchor the TCSB to the bridge deck, reduce the number of holes in a new bridge deck, as well as reduce the depth that the bolts are embedded into the bridge deck.

Rod Lacy
KDOT
785-296-3897

MwRSF Response:

I have come up with some answers to you questions regarding you questions about anchoring of your F-shape barrier. You basically posed two main issues.

1. With regards to the F-shape strap tie-down developed at MwRSF, you had a question about the anchor strengths we gave as guidelines when compared with the listed anchor strengths supplied by the anchor manufacturers. The basic issue was that only one anchor design on the market could meet the listed anchor capacities listed in our report on the system.

In order to address the issue, I reviewed the listed anchor strengths as compared to the design strengths we used in the design of the strap tie-down. The design criteria we used fro the strap tie down anchors were 17.3 kips in tension and 13.5 kips in shear. We selected the REDHEAD Ramset II 3/4" drop-in anchor for our design based on its publish ultimate loads at the time of 17.3 kips in tension and 13.9 kips in shear in 4,000 psi concrete. We then conducted dynamic testing of the tension capacity of this anchor and got a value of 17.3 kips. This anchor was then used in the development and full-scale testing of the strap tie-down.

Subsequently, the manufacturer's listed ultimate strengths for this anchor and many other similar anchors have reduced significantly from the values that were originally referenced. I have attached a chart showing all of the applicable concrete anchors along with their manufacturers' current listed ultimate strengths and embedment depths. Based on the current published values only the Simpson Titen HD Anchor will meet the tension and shear criteria for the design and have an embedment depth less than 5 inches. Your group had noticed this issue as well and notified us.

I contacted REDHEAD and talked with their design engineers about the reduction in load between their original data and their current numbers. According to REDHEAD, all of their anchor testing was originally conducted in the 70's and early 80's. These are the numbers that have been published for years. In the mid to late nineties, the testing criteria for concrete anchors changed and currently all anchors are tested to the an ICBO standard. The ICBO testing required testing of the anchors at critical edge distances. This reduced the capacity rating of the anchors in the new tests. The anchors themselves have remained unchanged.

Based on the component testing anchor, the full-scale test of the strap tie-down system and the fact that the anchor design has not changed, we believe that the REDHEAD Ramset is still a viable anchor alternative for the strap anchor. I have attached a letter from REDHEAD stating that their anchor design has not changed since we conducted our testing here. Therefore, we currently recommend two anchors designs for the F-shape strap tie-down; 1) the 3/4" dia. x 5" long Titen HD anchor from Simpson or 2) the 3/4" dia. REDHEAD Ramset II drop-in anchor.

We don't believe we can safely recommend any of the other anchors at this time because we have not tested them and their listed strengths are lower than the values used to design the strap tie-down system.

2. You had also asked about the possibility of using a reduced anchorage with your F-shape barrier. You had stated that you typically allow for 2'-4' offsets from the edge of the bridge deck or drop off and you wanted to know if you could use some form of reduced anchor in the holes used for the bolt through tie-down. I have looked at this, and I cannot see any way to do this without significant effort and some testing. The available concrete anchors would not work well with the bolt holes currently in the barrier. In addition, it would be very difficult to predetermine the performance of the anchors used in that application. As such, we are recommending that you use either the strap tie-down or the bolt through tie-down we have developed previously. In addition, we will be testing a tie-down for use on asphalt surfaces some time this summer that should be available to you as well.

If you have any questions, or if I missed something, please let me know.

Thanks

Bob Bielenberg, MSME, EIT
Research Associate Engineer
Midwest Roadside Safety Facility
527 Nebraska Hall
Lincoln NE, 68588-0529
402-472-9064
rbielenberg2@unl.edu

F-shape Temporary Barrier Strap Tie-Down Anchors

Based on the following design criteria:

Tension =	17	kip
Shear =	13.5	kip
Maximum anchor depth	5	inches

Anchor Type	Anchor Diameter (in.)	Embedment depth requried (in.)	Manufacter's ultimate load data 4,000 psi concrete Tension (kips)	Shear (kips)	Strap thickness (in.)	Anchor length (in.)	Actual Embedment (in.)	Applicable (Y/N)
REDHEAD LTD	0.75	4.5000	16.868	20.612	0.5	5.5	5	N
REDHEAD LTD	0.75	5.5000	21.780	25.652	0.5	6.25	5.75	N
PowersFasteners Wedge Bolt	0.75	4.0000	14.800	22.820	0.5	5	4.5	N
PowersFasteners Wedge Bolt	0.75	5.0000	18.705	26.780	0.5	6	5.5	N
Simpson Titen HD	0.75	4.6250	17.426	24.680	0.5	5	4.5	Y
PowersFasteners Drop-In	0.75	3.1875	14.405	15.680	0.5	NA	#VALUE!	N
REDHEAD Ramset II	0.75	3.1875	9.480	10.480	0.5	NA	#VALUE!	N
Simpson Strong Tie Drop-in	0.75	3.0000	10.760	16.000	0.5	NA	#VALUE!	N

= value does not meet design criteria

Notes:
1. According to manufacturer specs, only the Simpson Titen HD meets the design criteria in 4000 psi concrete.
2. Original Ramset II numbers were 17.3 kips tension and 13.9 kips shear in 4000 psi concrete
3. Our testing of the Ramset II showed 17.3 kips in tension pullout.
4. Design cpacities used for strap tiedown listed above.

Discussion with Chris Levine @ Ramset

1. Test methods have changed
- original anchors were tested in 1970's according to an old standard
- new ICBO standard retested all anchors in mid to late 90's
- ICBO testing required that all anchors be tested near a crtical edge distance rather than at the center of a slab as the previous testing had done
- thus, the capacity of the anchors is testing lower.
- Ramset is submitting a letter stating that their anchor design has not changed in years and that if our system worked as tested previously, we can expect similar performance from the current anchors

Figure 1. Concrete Anchors for F-shape Steel Strap Tie-down

ITW Ramset/Red Head
1300 North Michael Drive
Wood Dale, Illinois 60191
Phone: 630.350.0370
Fax: 630.350.7985
www.ramset-redhead.com

ITW Ramset/Red Head

Concrete Fastening Systems

May 13, 2004

Mr. Bob Bielenberg
Midwest Roadside Safety Facility
527 Nebraska Hall
Lincoln, NE 68588

RE: ITW Ramset/Red Head Multi-Set II Drop-In Anchors

Dear Mr. Bielenberg:

This is to certify that the ITW Ramset/Red Head Multi-Set II Drop-In Anchor that is available today is identical the anchor that was available in the 1990's. No design changes have been made to the anchor nor have the installation parameters of the anchor been changed.

Sincerely,

Christopher La Vine
Manager, Product Engineering

Figure 2. REDHEAD Letter Verifying No Change in Ramset II Anchors

Problem #2 – Old Minnesota Bullnose System Steel Post Limits

State Question:

MnDOT asked MwRSF to review the testing of the NCHRP 230 tested Minnesota Bullnose barrier and recommend at what point steel posts can be safely used in the system.

MwRSF Response:

Looking at the old test report, in the 4,500 lbs sedan test, six posts on one side of the system plus the center post where fractured. In addition, 3 posts were fractured on the other side of the system. It was also noted that the sedan was not completely stopped by the system, but instead had a low level impact with the concrete piers in the center of the system.

Based on the posts broken in the system and the fact that the car stopped a bit prematurely due to impact with the bridge pier, we are recommending that steel posts not be used for the frist 13 posts in the system. That would mean that the center post and the first six posts on each side of the system need to be wood posts as specified in the tested design.

Problem #3 –Concrete Barriers

State Question:

MnDOT asked,

As you probably know we are trying to increase the thickness of our median concrete barriers from 6" to 8" and add min. amount of reinforcement to match AASHTO's design. However, we are facing some resistance from the designers, they are telling me that we do not have any problem with the non-reinforced 6" F-shape design now why change? On the other hand our bridge department did some strength requirement calculations and they are telling me that our 6" non-reinforced barrier does not have the required strength under NCHRP 350 (~ 54-60 Kips). I appreciate your comments and guidance in this matter.

MwRSF Response:

With regard to the issue of concrete median barriers, I am aware that much discussion has taken place within MnDOT over the last 6 to 12 months. In my opinion, non-reinforced concrete barriers are not my first choice, in that over time, significant cracking can occur due to environmental changes. If impacts later occur in regions where these cracks or even large gaps are located, then vehicle penetrations or snag may occur. Yes, it is possible to design thick, non-reinforced barriers to resist the vehicle loads imparted into them when the barriers have continuity. However, when discontinuities exist, it is uncertain whether vehicle containment and a safe redirection will result.

In my opinion, the issue of barrier width is mostly a non-issue as long as adequate steel reinforcement is provided. A steel reinforced barrier (half-section bridge railing), configured with a 6-in. width, has been shown to meet both the TL-3 and TL-4 safety performance requirements of NCHRP 350. Thus, as long as adequate longitudinal and vertical steel is provided, then narrower widths can be designed to meet the safety standards.

Over the last several years, MwRSF researchers have conducted significant research on an 8-in. wide (top end), steel reinforced, F-shape concrete barrier that could be used in both temporary, free-standing applications as well as in two alternative tied-down applications. This research was all conducted according to the TL-3 safety standards. From this effort, the importance of the steel reinforcement and 8-in. barrier width was shown on more than one occasion, actually 3 to 4 occasions. Had this barrier design been narrower, say 6-in. at the top, and had the same quantity of steel but just placed inward due to the 2-in. decrease in barrier width, we likely would not have safely redirected the pickup truck in multiple crash tests.

In summary, several concrete barrier designs can be optimized to use either the 6 or 8-in. top widths as long as adequate steel reinforcement is provided. However, non-reinforced concrete barriers should not be used unless it can be shown that they will perform in an acceptable manner after being exposed to significant environmental conditions and contain the cracks or gaps within them at the time of testing (i.e., loss of rail continuity).

If you have any questions regarding the information contained herein, please feel free to contact me at your earliest convenience. Thanks again!

Ron Faller
MwRSF

Problem #4 – Concrete Barrier Deflections

State Question:

NDOR asked,

Help My Memory is lacking:
The Iowa/ Kansas Concrete Protection Barrier was crash tested to 350 TL 3 and that the maximum deflections were as follows:

Freestanding = 24"
Strap down = 12"
Bolt down using 3 bolts from the front or traffic side = 6"

Thanks
Phil TenHulzen P.E.
Design Standards Engineer,
Roadway Design Division,
Nebraska Dept. of Roads

MwRSF Response:

Here are the revised numbers obtained in our prior publications.

TL-3

Iowa original F-shape concrete barrier - 1.15 m or 45.3 in.
Simulated F-shape at 85th percentile conditions - approx. 24 in.
Iowa F-shape with tie-down straps - 850 mm at top (33.5 in.) - barrier placed approx. 12 in. from deck edge - recommended that distance could be reduced to 6 in.
Kansas/Iowa F-shape concrete barrier with 3 anchor bolts - 287 mm at top (11.3 in.) - barriers placed approx. 1 in. from deck edge

TL-3 Plus (Heavier truck)

Iowa/Kansas F-shape concrete barrier - approx. 57 in. (p.s. deflection) - more exact analysis still pending

Problem #5 – New York Cable Anchor Modification

State Question:

The Connecticut Department of Transportation entered a research needs statement to the Midwest States Regional Pooled Fund to develop a maintenance friendly modification to the New York State NCHRP 350 approved cable end anchor. MwRSF suggested that this task was small enough to be done through the use of the Pooled Fund consulting agreement.

The NY cable anchorage consists of an end anchor and first post embedded into a concrete foundation. The first post, post no. 1, employs a slip base to disengage the top of the post during an impact on the end of the system. Performance of the system has been satisfactory, but the bottom of post no. 1, which is set in a concrete foundation, tends to get damaged during impacts. Repair of this damage requires full replacement of the concrete anchorage at an approximate cost of $1,100.00. If the system could be modified so only post no. 1 need be replaced, the cost of repair would be reduced to approximately $10.00 - $15.00.

MwRSF Response:

MwRSF has redesigned post no. 1 in the NY cable end anchorage. Instead, setting the base of post no. 1 in concrete, a 4”x3”x39 3/8”x1/4” A500 galvanized steel foundation tube will be cast into the concrete foundation. Post no. 1 remain the same, but will now sit in the foundation tube rather than be cast in the concrete. A ¾” dia. Grade 5 hex bolt will be placed through the foundation tube at the embedment depth of post no. 1. Post no. 1 will rest on this bolt to insure the proper installation height for the post. If damage now occurs to post no. 1, the post can simply be pulled from the foundation tube and a new post no. 1 can be substituted in its place. Drawing for the new end anchorage are attached.

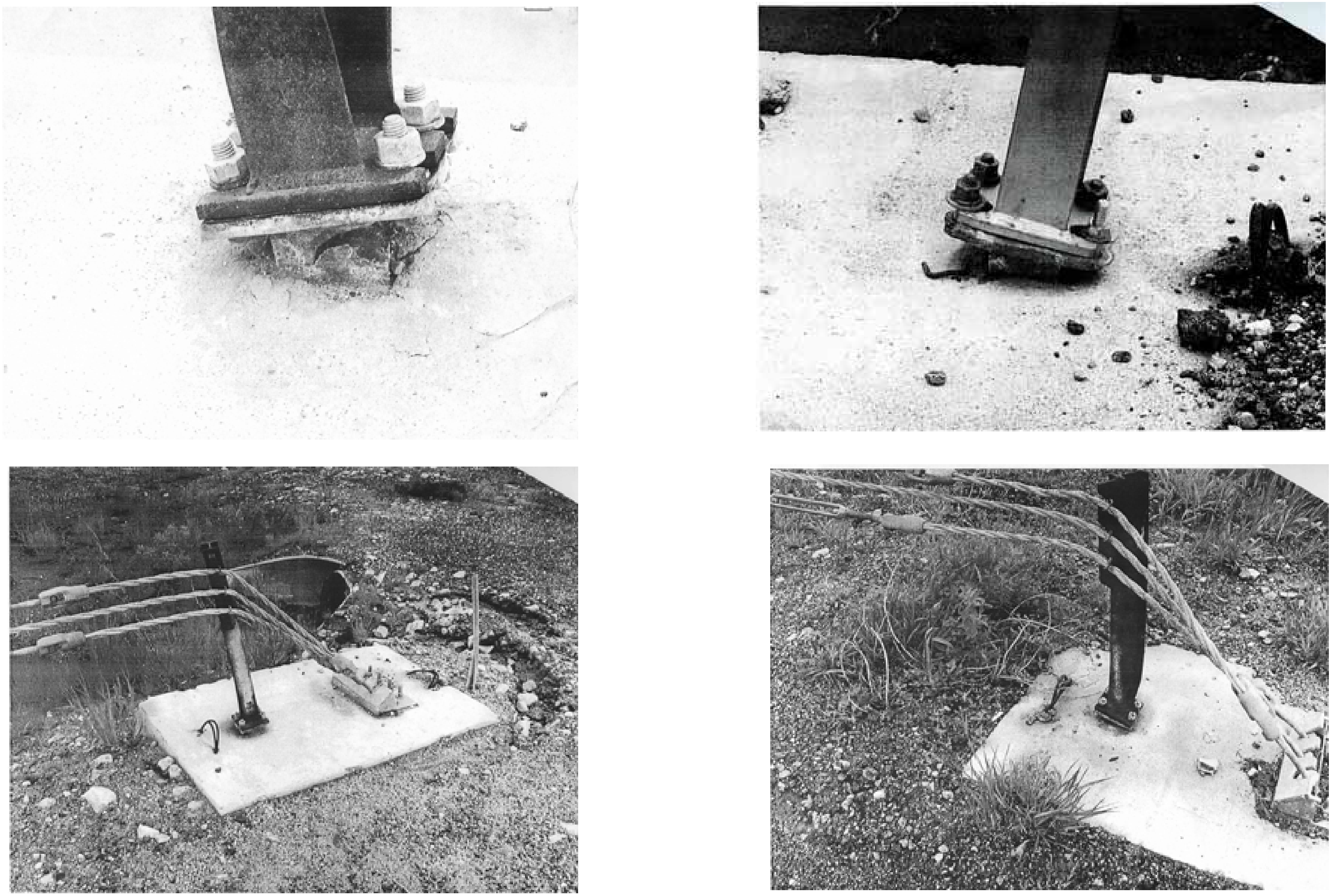


Figure 1. NY Cable Anchorage Damage

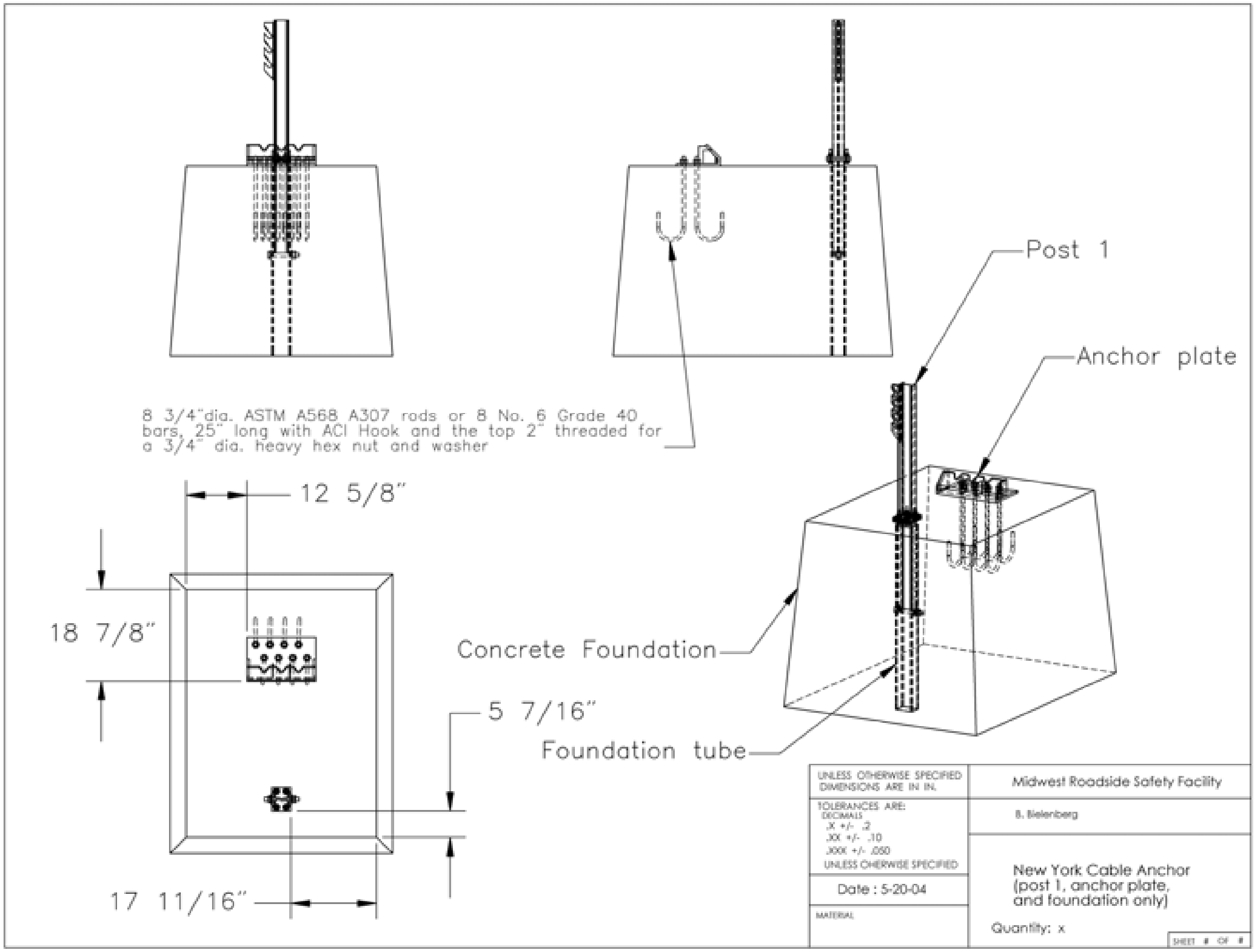


Figure 2. Modified NY Cable Anchorage Details

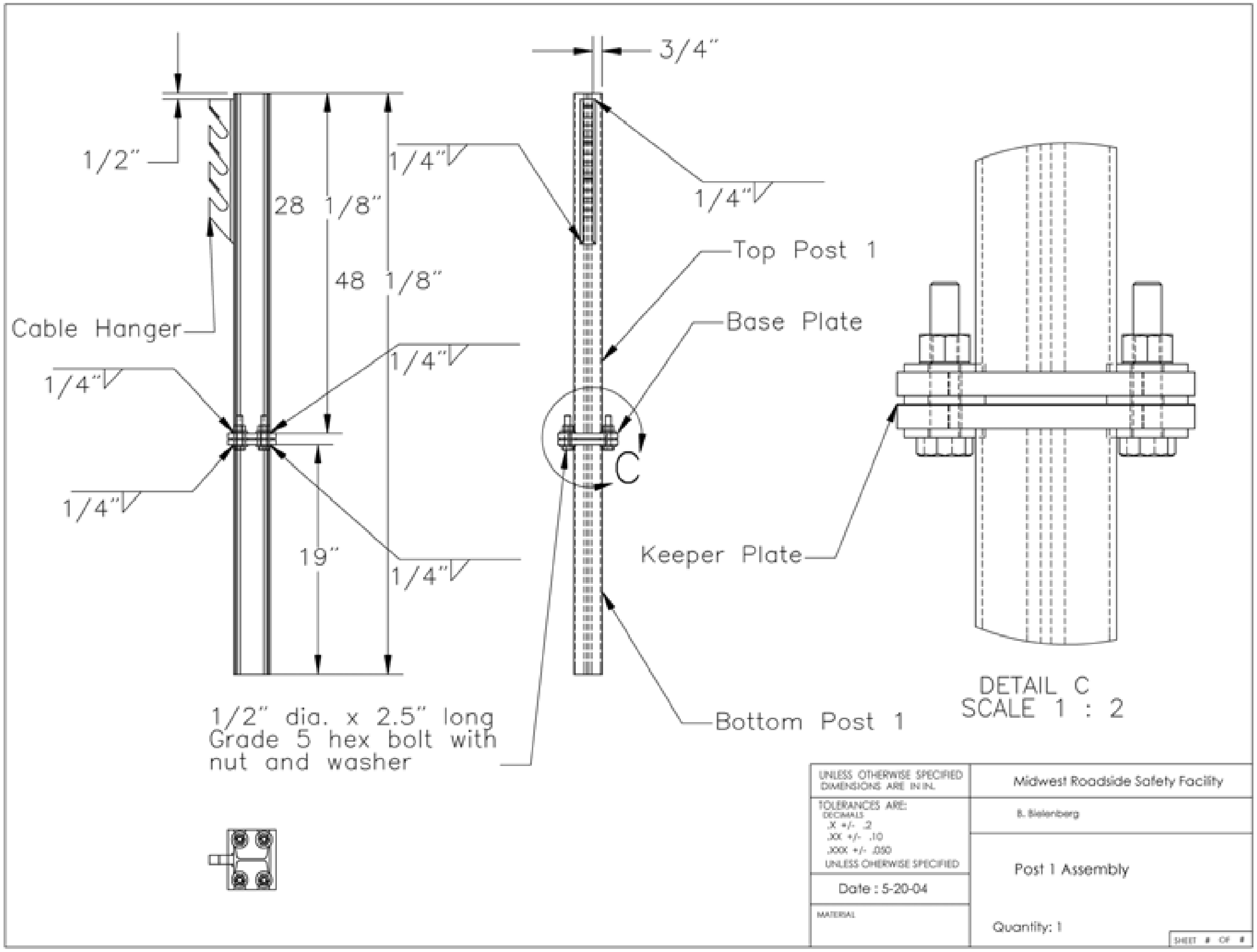


Figure 3. Modified NY Cable Anchorage Details

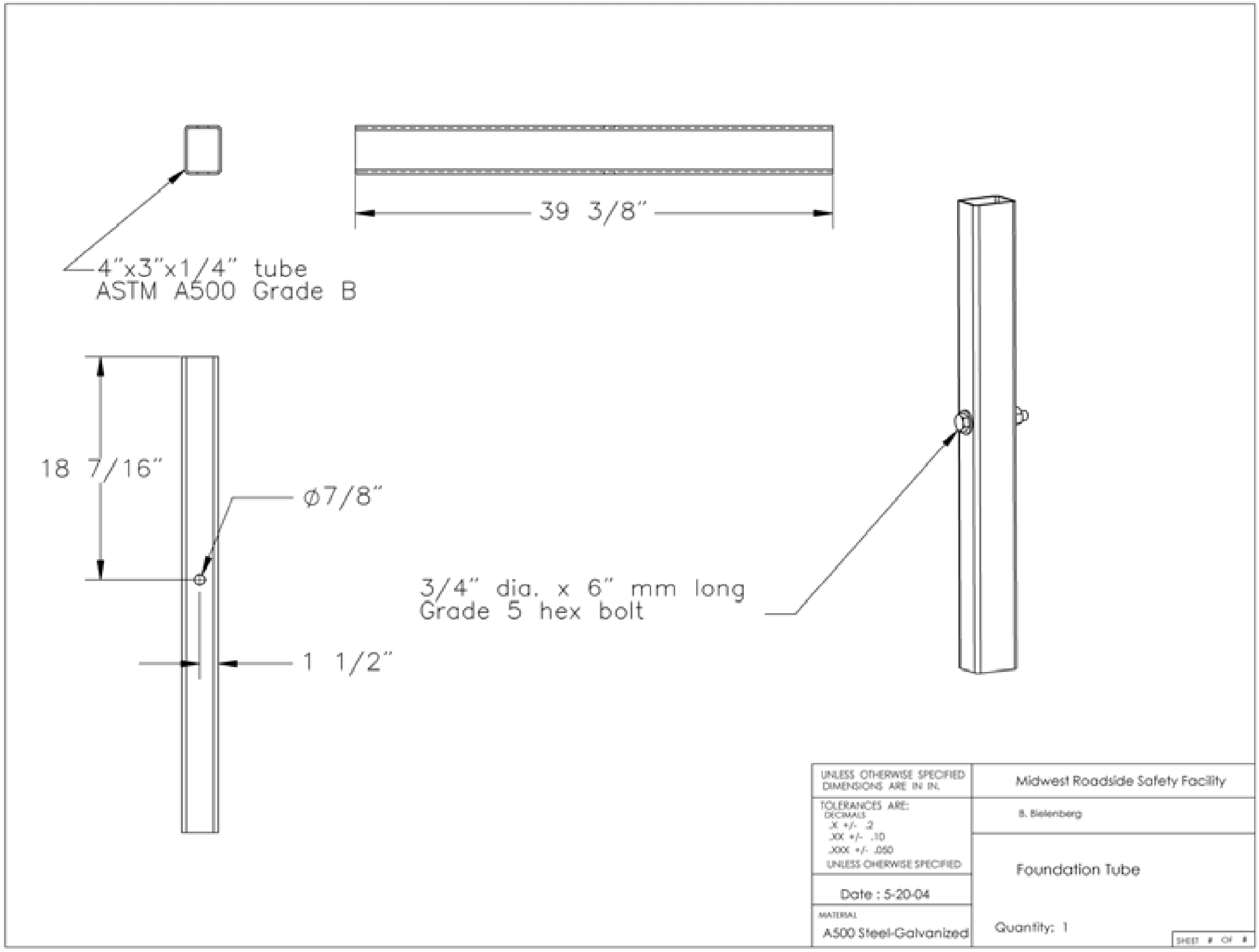


Figure 4. Modified NY Cable Anchorage Details

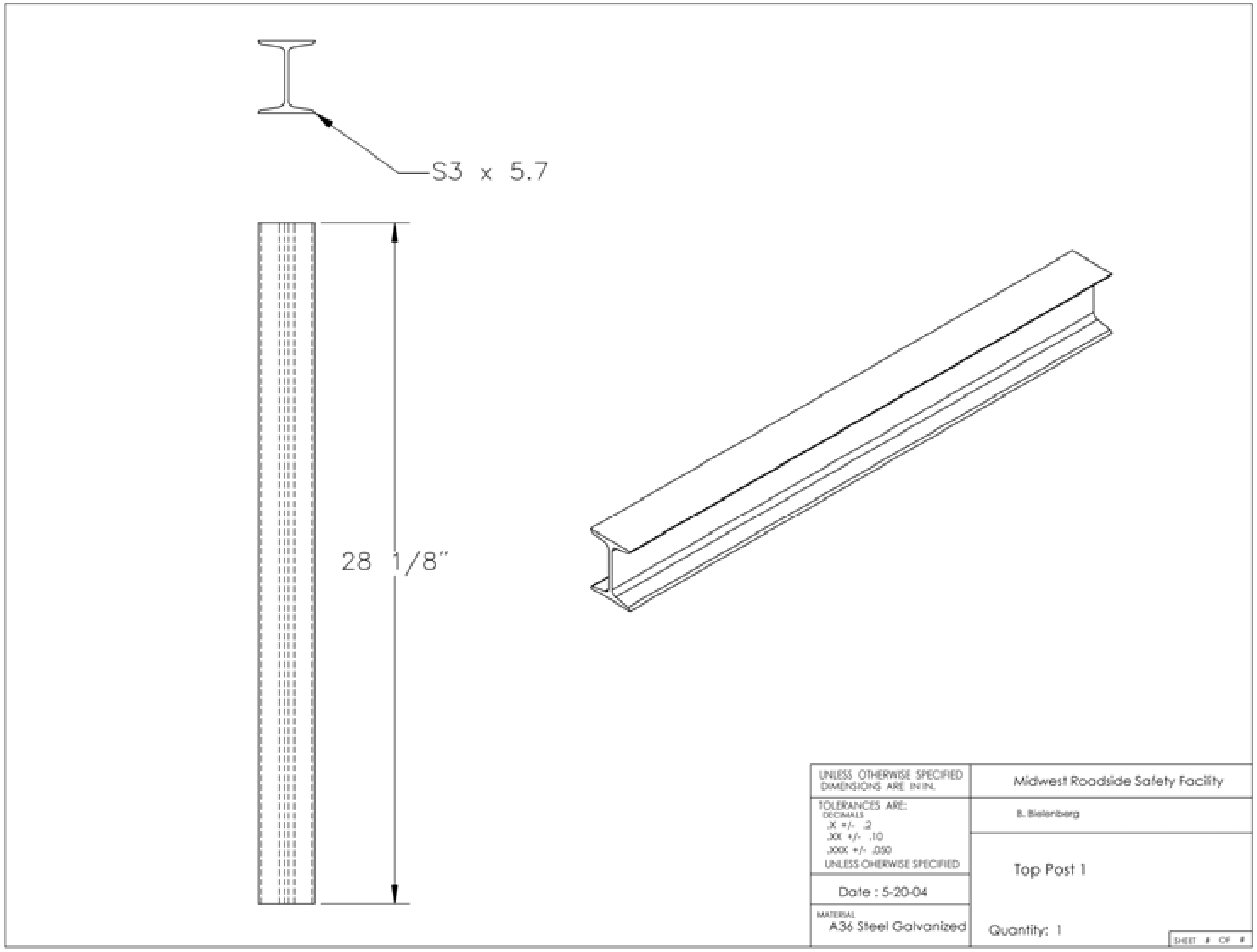


Figure 5. Modified NY Cable Anchorage Details

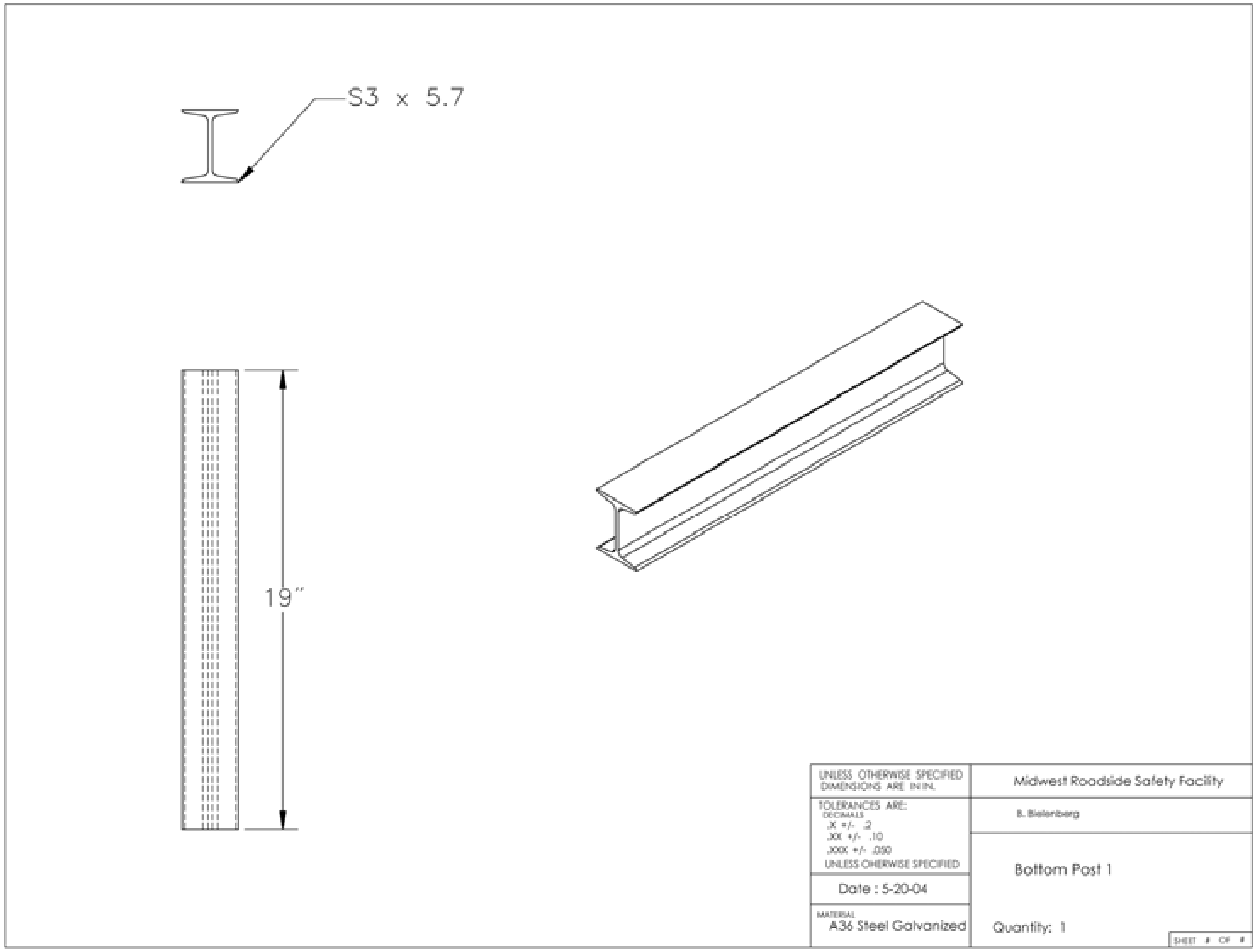


Figure 6. Modified NY Cable Anchorage Details

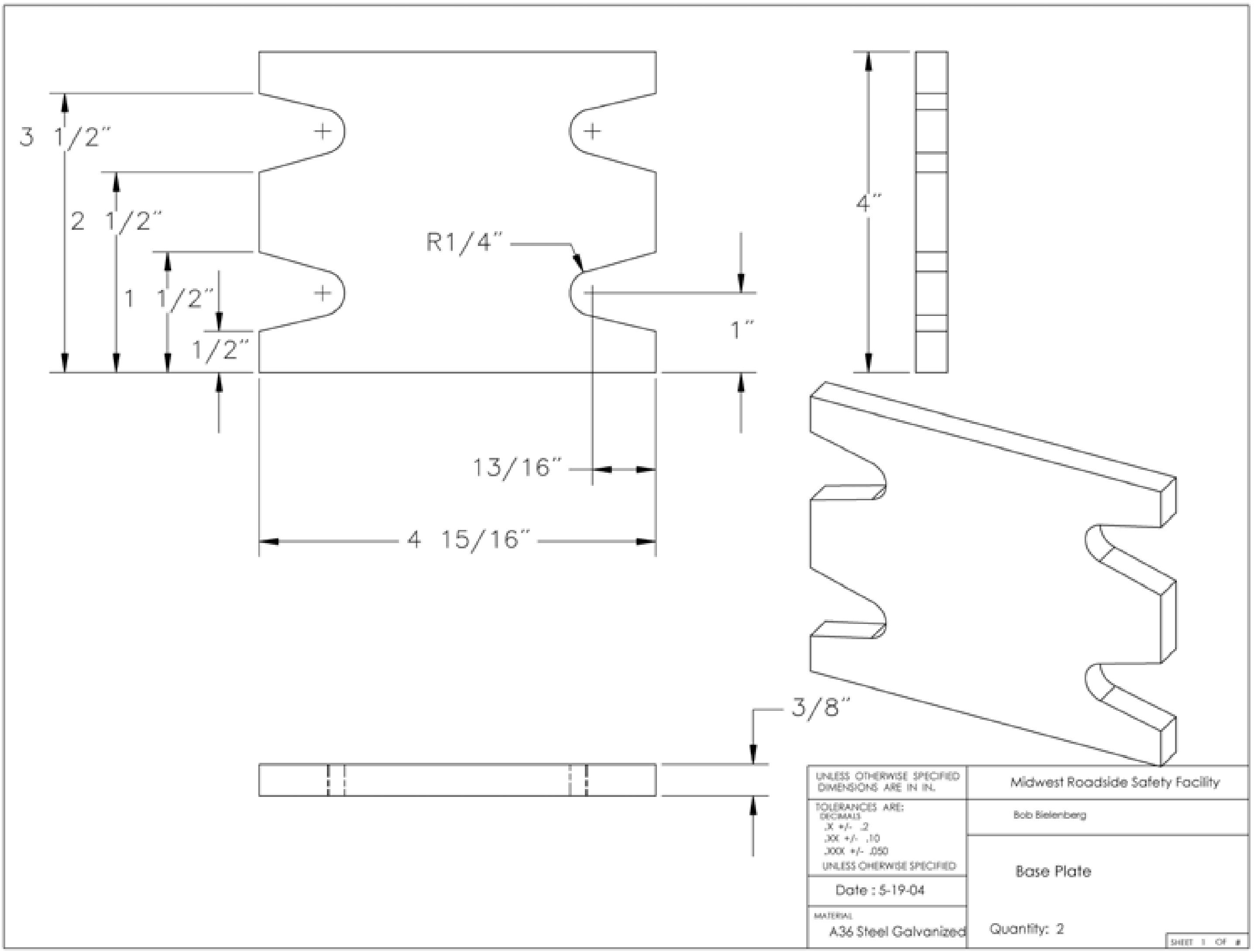


Figure 7. Modified NY Cable Anchorage Details

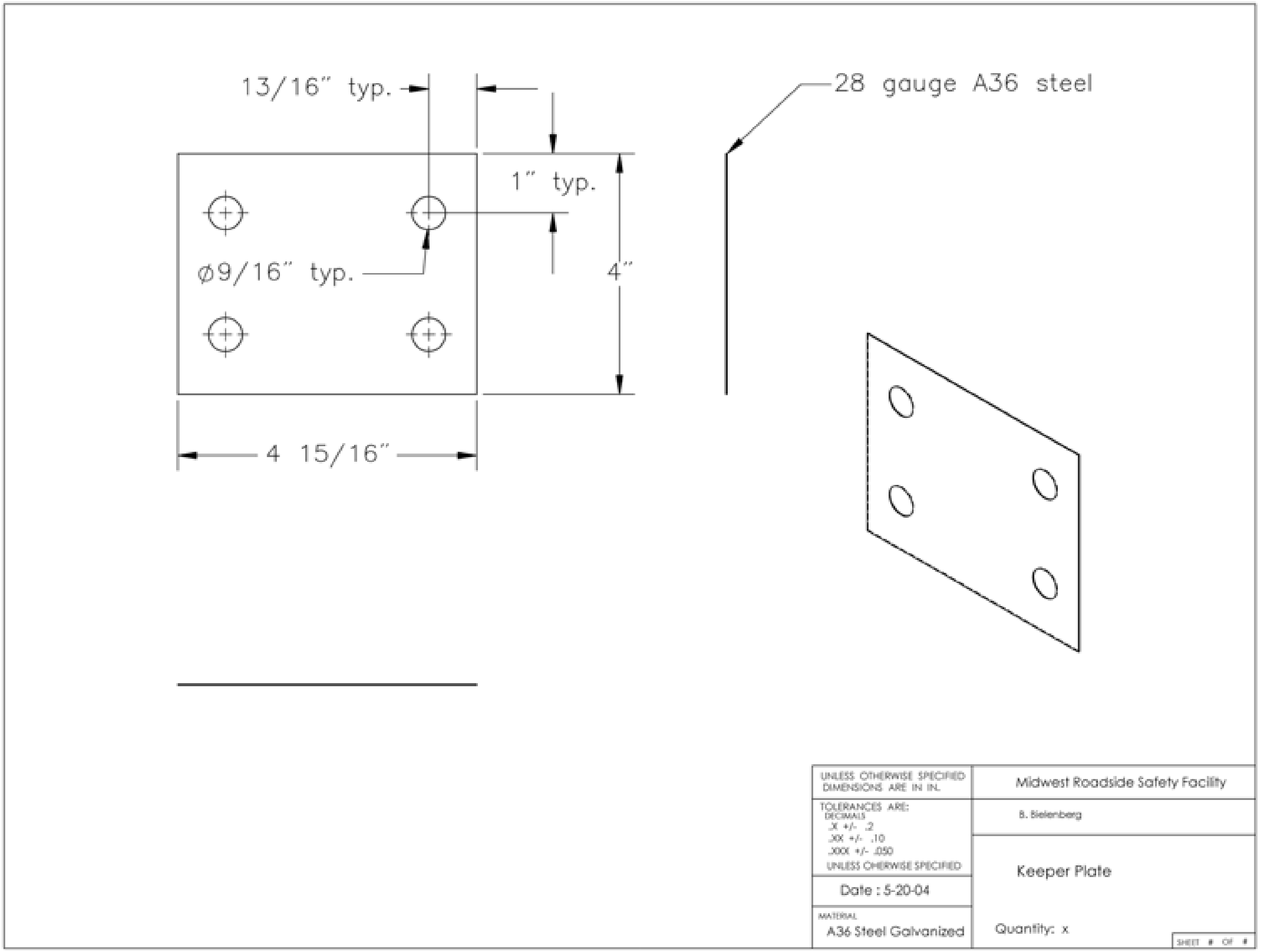


Figure 8. Modified NY Cable Anchorage Details

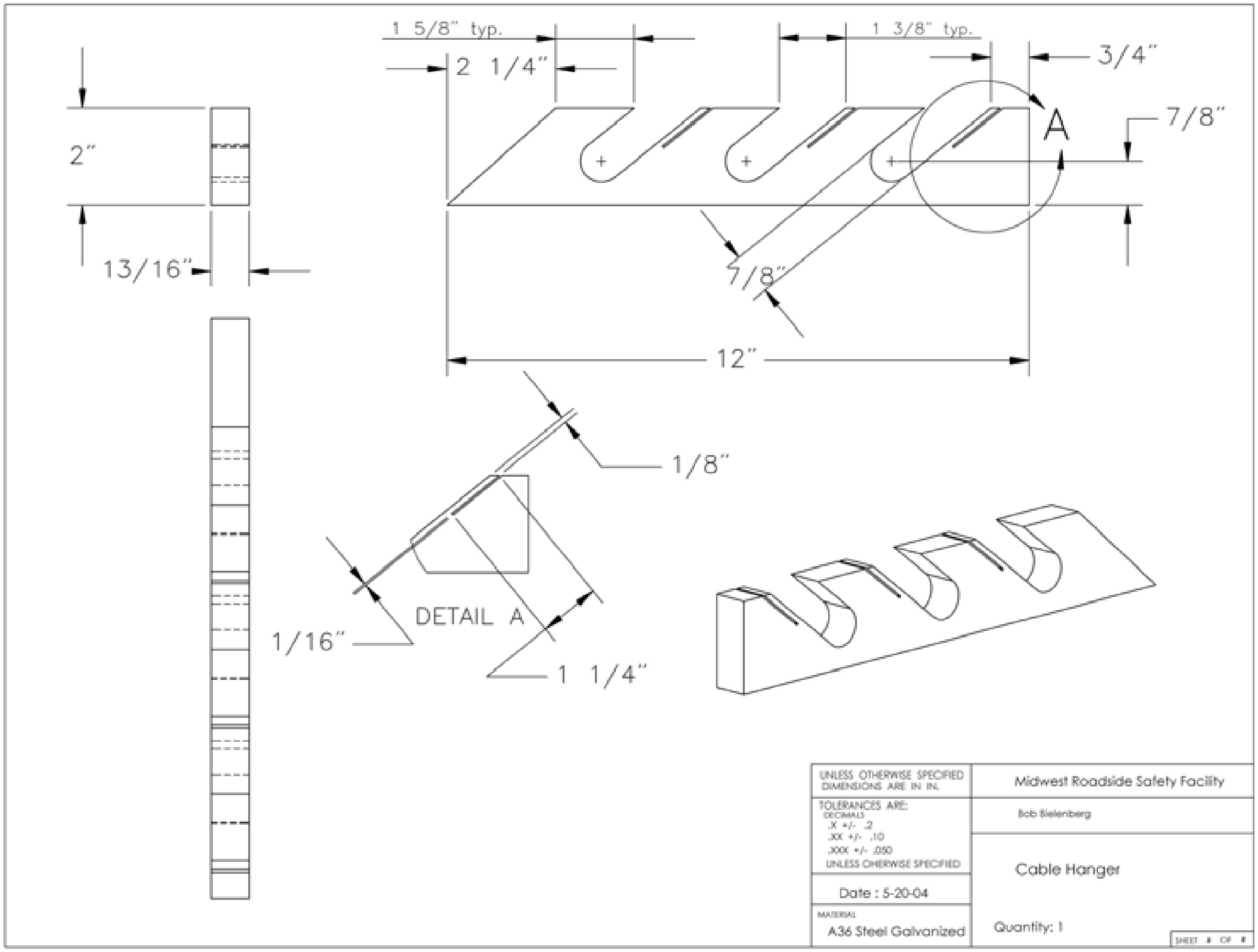


Figure 9. Modified NY Cable Anchorage Details

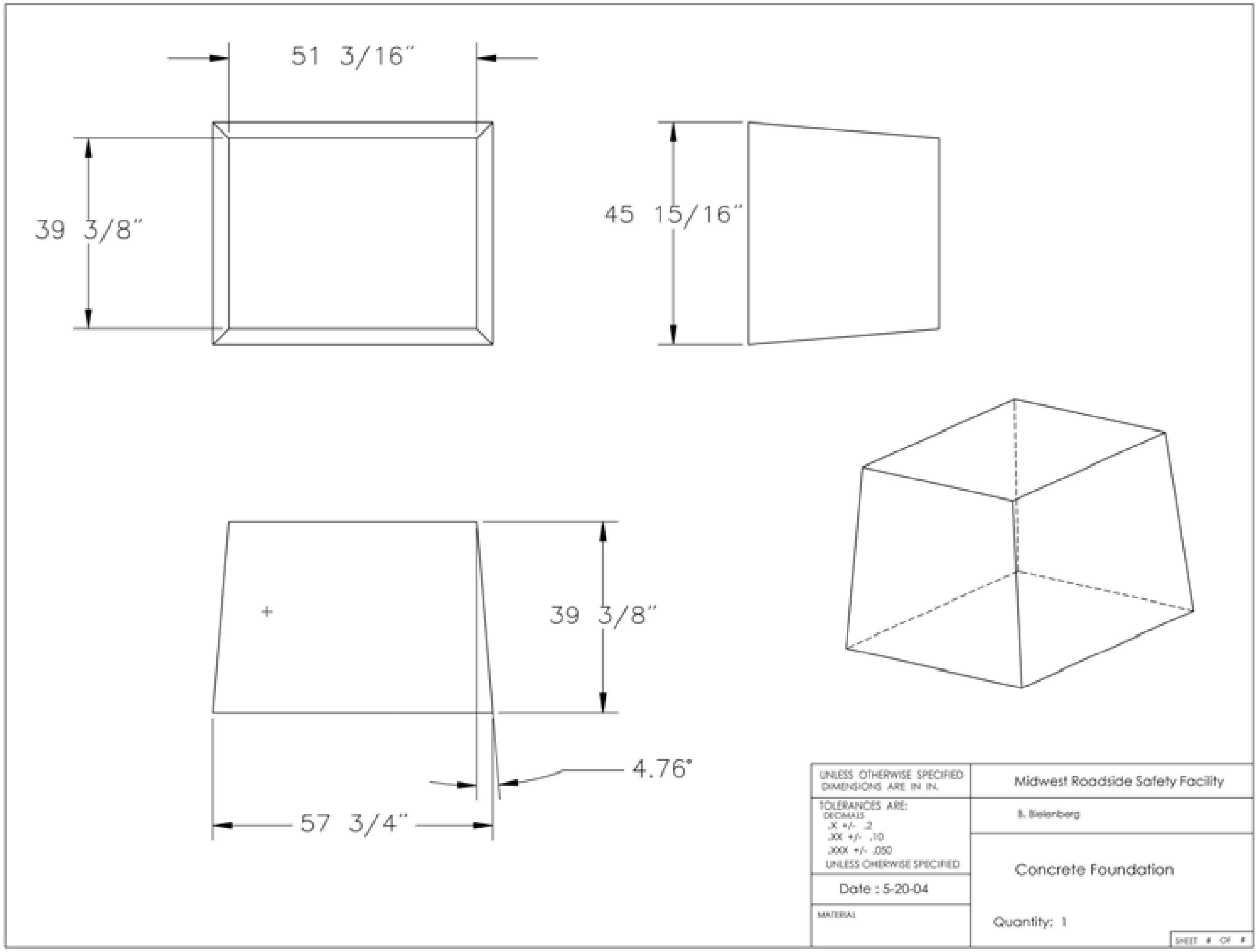


Figure 10. Modified NY Cable Anchorage Details

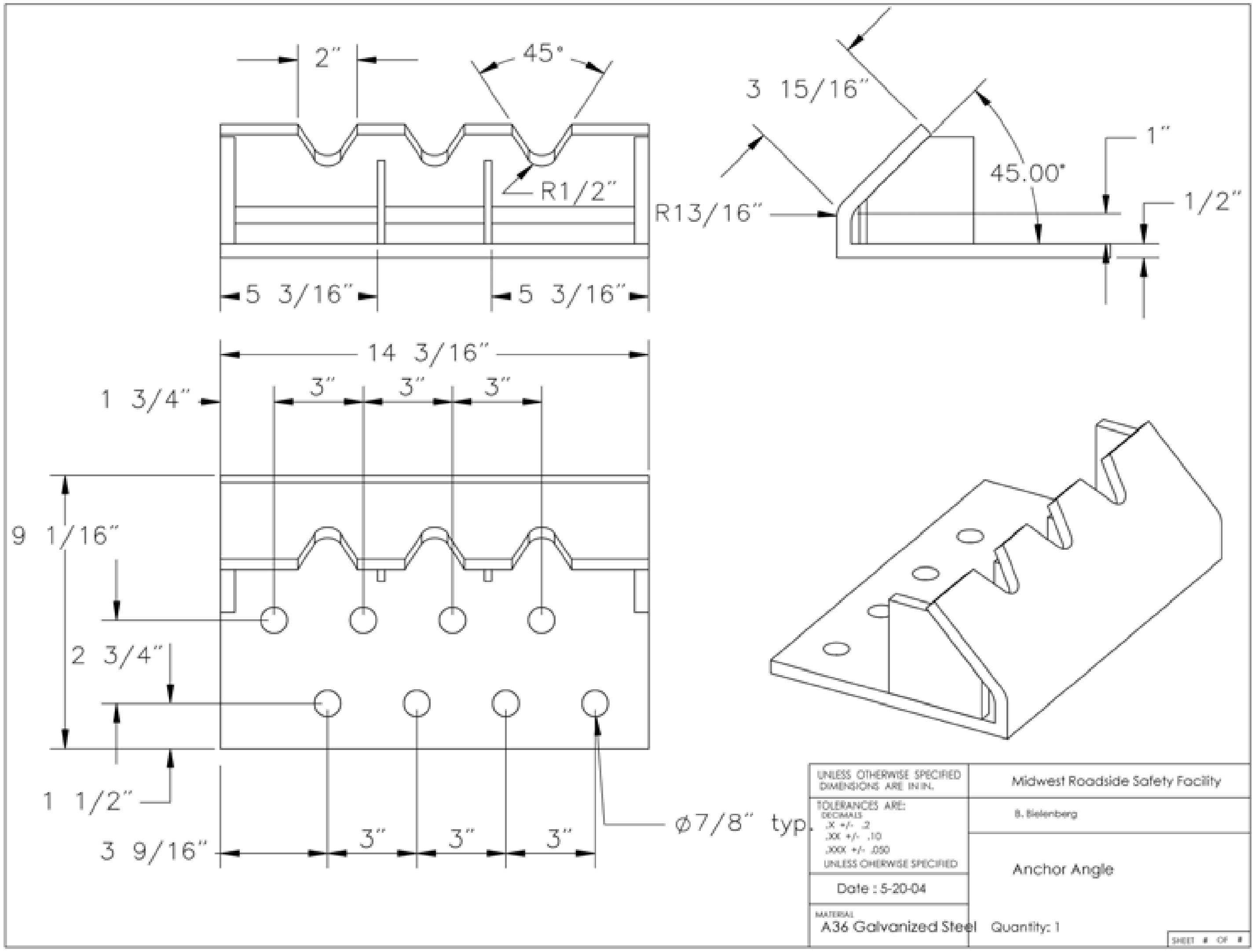


Figure 11. Modified NY Cable Anchorage Details

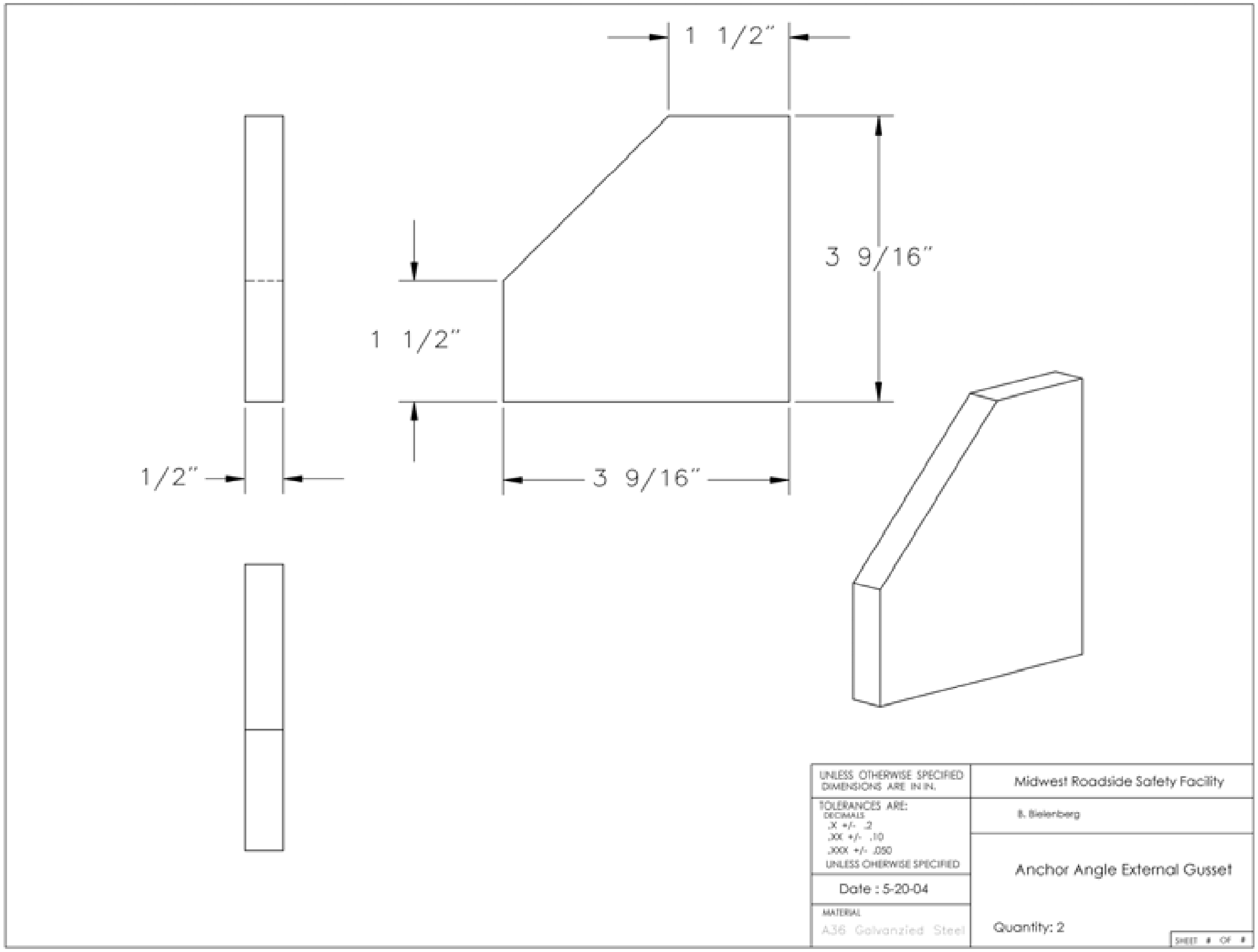


Figure 12. Modified NY Cable Anchorage Details

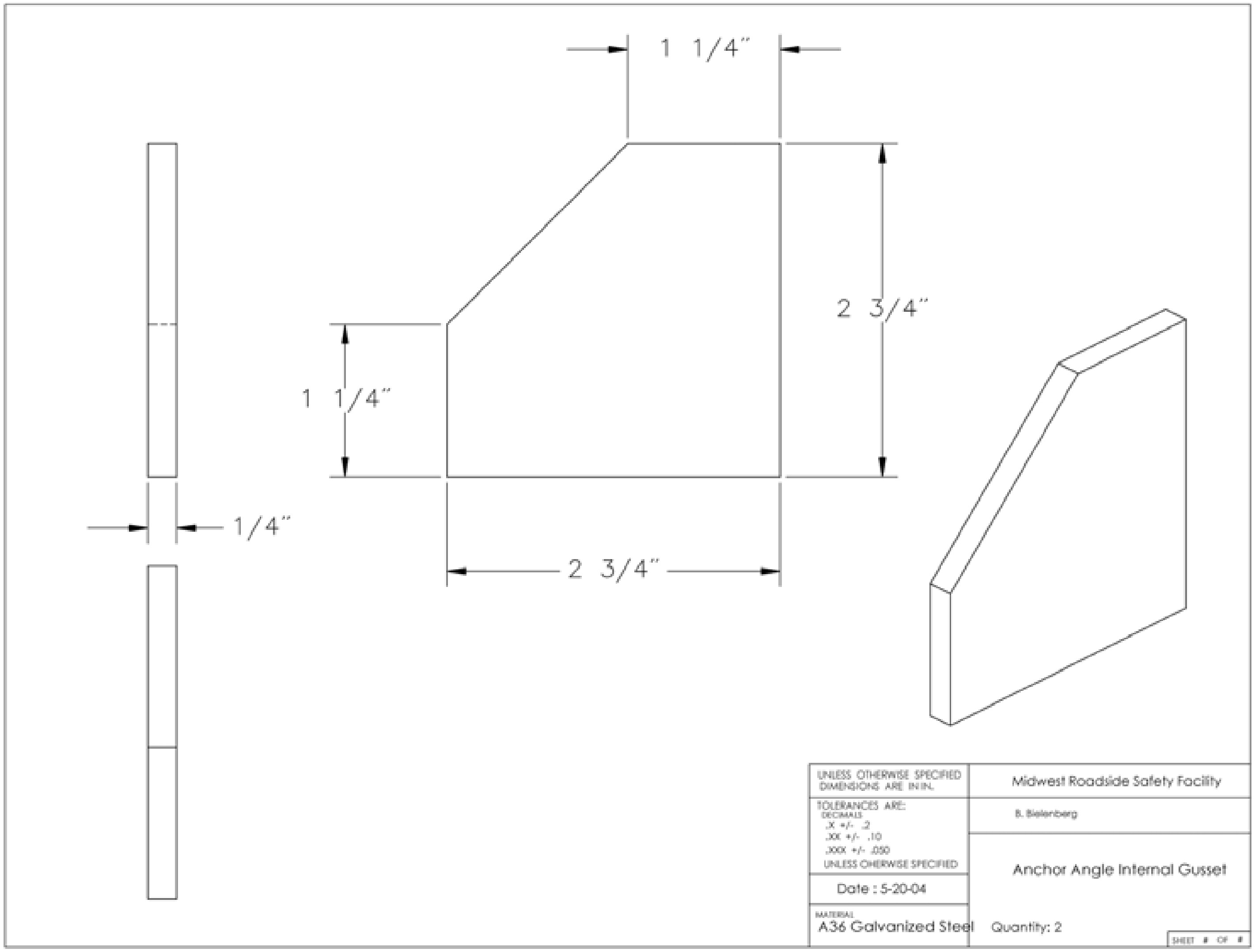


Figure 13. Modified NY Cable Anchorage Details