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DTD Applied Research and Innovation Branch

Where Ideas Become Reality

INVESTIGATION OF BEST OPTIONS FOR USING SCRAP TIRES IN HIGHWAY NOISE BARRIERS

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16. Abstract

In Colorado, approximately 60 million scrap tires have been stockpiled and approximately 4.5 million scrap tires are generated annually. While CDOT does not generate these scrap tires, CDOT does have goals and policies to promote sustainability/recycling and receives requests for more traffic noise barriers than can be funded. CDOT identified an opportunity to combine these two topics by investigating new ways to incorporate scrap tires into highway noise barriers.

This research project reviewed potential noise barrier materials made from scrap tires, selected a material for field testing, designed and built a test barrier at the designated site using the material, and monitored barrier performance for one year. The material selected was a railroad tie replacement made from scrap tire treads.

Although not originally developed as a noise barrier material, the railroad ties were found to be effective. The ties provided a substantial noise reduction, consumed a number of scrap tires, had substantial internal strength that is a plus as a building material, and were easily assembled in a post-and-panel barrier design. The barrier performed well over its first year. The material and the wall design are recommended for consideration by CDOT on other projects.

Some challenges were identified through the project: the ties were not a low-cost alternative for reasons stated in the body of the report; the finish stain method may need adjusting for a better long-term appearance; rust will appear on the steel components; and a few minor construction/finish improvements were identified.

Implementation

CDOT's Research Branch will continue monitoring noise wall performance and attempt to conduct a life-cycle cost analysis for the tire ties material/design and other similar types of noise barriers in the future.

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INVESTIGATION OF BEST OPTIONS FOR USING SCRAP TIRES IN HIGHWAY NOISE BARRIERS

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EXECUTIVE SUMMARY

Approximately 570,000 scrap tires were added to existing tire stockpiles in Colorado in 2009, bringing the estimated in-state stockpiled total to more than 60 million tires. Approximately 4.5 million scrap tires are generated in Colorado annually and a high percentage of these (more than 90 percent) are being recycled, with most being burned as fuel. The Colorado Department of Transportation (CDOT) is not the direct source of these tires, but the State of Colorado, with the Department of Public Health and Environment and CDOT as lead agencies, is developing goals and policies to encourage and enhance sustainable practices, including reducing tire stockpiles. CDOT has a strong proactive environmental ethics statement for the development and operation of transportation systems. On a separate track, CDOT has experienced a persistent growing demand from local governments and residents neighboring highways for more traffic noise barriers than what CDOT can typically fund. A strategic area of CDOT research focuses on sustainability and protection of the environment, so by connecting these two seemingly unrelated topics, CDOT's Research Branch recognized an opportunity for developing more uses for scrap tires in CDOT projects through incorporation of tires in highway noise barriers. To that end, the Research Branch sponsored a research project to evaluate new options for using scrap tires in traffic noise barriers.

The research project consisted of four main tasks:

- Task 1: Investigate potential tire/barrier materials and select a test material(s);
- Task 2: Design a barrier incorporating the selected test material(s);
- Task 3: Construct a barrier at the designated test site following that design; and
- Task 4: Monitor barrier performance for one year.

For Task 1, a number of recycled tire materials were evaluated by the CDOT Selection Committee, and a synthetic railroad tie product made from laminated scrap tire treads (Tire-Tie™) was selected for the project.

For Task 2, a noise barrier wall was designed using the ties for a designated project test site in CDOT Region 6 along West 6th Avenue in Lakewood, Colorado. There were several unique physical characteristics to the site that had to be accommodated. The final barrier design was based on the common post-and-panel configuration.

For Task 3, CDOT awarded the construction contract to a local contractor through a competitive bidding process. The contractor was tasked with building the project noise wall in conformance with the design drawings, including: preparing the site for construction, drilling and pouring caissons, pouring a Type 7 crash barrier base, installing steel I-beam vertical supports, installing Tire-Ties™ between the vertical supports and applying a finish stain to the wall. The finished wall was approximately 275 feet long and 7.5 feet tall.

For Task 4, the noise reduction provided by the barrier was measured and the barrier material performance was monitored for one year.

Overall, the test wall performed well. The material was an effective traffic noise blocker and the wall provided a substantial noise reduction (approximately 7.8 decibels) to the homes behind it. The ties have excellent structural characteristics, having been developed for railroad loading. The ties were easily incorporated into a standard wall design and were relatively easy to handle onsite. Approximately 4,900 scrap tire treads went into the ties used in the wall. The tire treads were made of a material (rubber) that is more absorptive of sound than typical noise wall material (e.g., concrete). No physical deterioration or structural failures of the wall were observed. No delaminations or separations within the tire tread stacks were observed. The wall held up well structurally.

Some limitations were noted from the project. The ties for this project were relatively expensive, primarily because they were not a fully developed widely-available product. Also, the ties were not produced locally, so there were shipping costs. Therefore, the ties were not found to be a low cost alternative to the standard wall materials. (This may or may not change in the future.) The cost to construct approximately 2,062 square feet of wall was approximately $215,000. The joints between stacked ties should be sealed (e.g., caulked). While the finish stain appeared to adhere well to the rubber, a single application of the stain did not cover the tires as desired—multiple coatings of stain are recommended. The steel used in the ties and the vertical supports was found to have the potential to rust—while fairly minor after one year, it is an aspect to bear in mind. Specific treatments for reducing the rusting of the steel were not investigated. From a distance, wall details are not very visible, but on close examination the ties may be considered to be less aesthetically appealing than other wall materials.

In summary, the test barrier was successful and the design can be recommended for consideration on CDOT projects requiring noise abatement. The project wall material and design should be considered for inclusion on the CDOT Approved Product List. This will depend on the tie manufacturer completing the CDOT approval process, which was not included in this project. If approved, the design and material would be available for use on construction projects at the discretion of the contractor and concurrence of the CDOT project engineer/manager. If the tire ties become more cost-effective in the future, this type of noise wall would provide CDOT with an alternative where use of recycled materials or high overall environmental sustainability is an important goal of a construction project.

Implementation Plan

CDOT's Research Branch will continue monitoring the overall noise wall performance and will attempt to conduct a life-cycle cost analysis for the tire ties material/design. They will informally monitor the cost and availability of Tire-Ties™ and similar types of potential noise barrier materials. A separate process for inclusion in CDOT's Approved Product List, maintained and managed by the Staff Materials and Geotechnical Branch, may be pursued by the manufacturer at their discretion.

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1. INTRODUCTION

Approximately 300 million scrap tires are generated annually in the United States (1), creating an enormous waste stream and long-term disposal challenge for the nation. Past inconsistent disposal practices lead to enormous stockpiles of scrap tires across the nation, which represented public health and environmental safety concerns. Through concerted efforts over a number of years, the previously huge national stockpile of scrap tires has been reduced to a relatively small-by-comparison total of approximately 100 million tires. However, Colorado is one of a handful of states with large scrap tire stockpiles remaining and it is in the public interest to reduce these.

Approximately 4.5 million scrap tires were generated in Colorado in 2009 (2). While approximately 92 percent of these were recycled (most burned for fuel), approximately 570,000 scrap tires were landfilled or added to existing tire stockpiles, bringing the estimated in-state stockpiled total to more than 60 million tires (2). The tires not recycled have environmental consequences, so reducing both the number of scrap tires being added each year and the existing tire stockpiles would have environmental benefits and would be more sustainable.

A growing awareness and commitment to environmental sustainability has strengthened public resolve to address ongoing solid waste issues, such as the seemingly endless supply of scrap tires. Tires and automobiles are inextricably linked and neither is likely to disappear anytime soon, so developing functional uses for tires after their intended life will be crucial in successfully managing the scrap tire waste stream.

The State of Colorado, with the Colorado Department of Public Health and Environment (CDPHE) and the Colorado Department of Transportation (CDOT) as leading agencies, is developing goals and policies to encourage and enhance sustainable practices. CDOT has adopted a strong proactive environmental ethics statement for the development and operation of transportation systems: "*CDOT will support and enhance efforts to protect the environment and quality of life for all Colorado's Citizens in the pursuit of providing the best transportation systems and services possible*" (3). CDOT has made the commitment to go beyond simple environmental compliance and strive for environmental excellence. CDOT designs, constructs, maintains, and operates the statewide transportation system in a manner which helps preserve and sustain Colorado's historic and scenic heritage and fits harmoniously into communities and the natural environment (3).

One of the strategic areas of CDOT's research program includes sustainability and protection of the environment. Research in this area is intended to identify cost-effective ways to minimize the impact of the transportation system on the natural and human environments and effectively identify opportunities for low-cost environmental enhancement through early identification and cooperative review of issues with resource agencies.

Recycling is an important piece of sustainability as a way to reduce solid waste volumes and to reduce the use of natural resources. For some time, CDOT has been exploring opportunities for recycled materials in its projects. This has been driven in part by three important mandates:

- Former Governor Ritter's Greening of State Government Executive Orders D0011 07, D0012 07, and D 2010-006, which in part charge State agencies to develop recycling programs;

- US Environmental Protection Agency's (EPA's) goal to increase nationwide recycling to 35 percent of solid waste; and
- CDOT's desire to find methods of building more cost-effective road-side traffic noise barriers to meet a growing demand.

Furthermore, EPA has set five national goals which are of special interest to CDOT:

- The reduction and recycling of industrial waste products including coal combustion byproducts, slag materials and foundry sand—some of which could be incorporated into roadway materials used on CDOT highway projects;
- Minimizing and reusing construction and demolition materials—such as those generated from highway projects;
- Reducing priority chemical amounts found in waste streams;
- Reducing waste electrical and electronic equipment sent to landfills—a waste stream which is not a high volume material in highway projects; and
- Using recycled tires through various end-use products—on highway and other projects.

Two of these points are of particular interest in this study: recycling scrap tires and finding more cost-effective noise barriers.

The road building and maintenance performed by CDOT is not the direct source of Colorado's scrap tires, but the tires come from automobiles that use these roads so there is a clear link between them. CDOT has experienced a persistent growing demand from local governments and residents neighboring highways for more traffic noise barriers than what CDOT has been able to provide under typical project funding constraints. By connecting these two seemingly unrelated topics, CDOT's Division of Transportation Development (DTD) Research Branch has recognized an opportunity for developing more beneficial re-uses of scrap tires in CDOT projects that could reduce disposal of tires. And if the costs of noise barriers could be lowered through the use of scrap tires, construction of more barriers may be feasible by allowing CDOT to stretch its limited funds further. To that end, DTD Research Branch embarked upon the research project described below to evaluate options for using scrap tires in traffic noise barriers.

1.1 Project Overview

The overarching goal of this research project was to evaluate new and innovative ways to incorporate scrap tires into traffic noise barriers. Ideally, promising technologies would be identified and developed for use in future CDOT construction projects. This project was initiated by researching the state-of-the-art in tire reuse methods, identifying some recycled material(s) of interest for evaluation, and field testing and monitoring the selected material(s). The final objective was to determine if a durable and inexpensive recycled tire material was available that could be an effective noise barrier.

To accomplish this, CDOT applied for and received an Advanced Technology Grant from CDPHE to assist with funding the research project. In 2006, Colorado House Bill HB 06-1257 was passed, which directed that money collected into the waste tire fund should be made available and used for public projects which use waste tires. This bill created a process and state program whereby public projects utilizing recycled materials can be prioritized, funded and built. Part of this bill requires that the program include building of noise mitigation walls "along state highways as prioritized by the Department of Transportation." The bill also allows for this money to be used for "environmental, research, development, and technology transfer programs in the state for materials and products of any kind."

The research project consisted of four main tasks:

- Task 1: Investigate potential tire/barrier materials and select test materials;
- Task 2: Design a barrier(s) incorporating the selected test materials;
- Task 3: Construct a barrier(s) at the designated test site; and
- Task 4: Monitor barrier performance for one year.

Descriptions of the methodologies used in the project are relevant for Tasks 1, 2 and 4 of the project and are presented below. Note that Task 3 consisted of construction of the project noise barrier by an independent contractor using methods of their choosing, and this was not an aspect directly controlled by the DTD research project. The construction methods may or may not be relevant to other barriers or projects. However, CDOT staff made field observations of the construction methods for informational purposes that are presented in Section 6, along with other conclusions and recommendations from the project.

1.2 Background on Scrap Tires and Tire Recycling

Colorado has tire dumps and piles as well as permitted tire “monofills.” Some of these were created before there were effective laws to regulate them and some were created illegally. Colorado has a state program dedicated to the recycling of scrap tires administered by the Department of Local Affairs. The essential components of the program are that a fee is levied on consumers when old tires are replaced, and that the funds generated from the fees are then used to further tire recycling and reuse programs. The intended beneficiaries of the program are local governments and end users who convert or reuse the scrap tires. These programs have minimal state-level oversight, and the Department of Local Affairs performs an administrative function rather than a regulatory one.

One material of interest in scrap tires is the rubber. Recycled rubber can refer to a wide range of products, obtained from an equally wide range of rubber compounds beyond just tires. In practice, the rubber waste stream is dominated by scrap tires, but there are two other major scrap rubber sources:

- tire trim and off-spec tires from new tire production; and
- buffings from rubber product manufacturers.

Another material of recycling interest from tires is the steel present in many tire treads and beads. Steel is one of the most recycled man-made products, but the intermingled nature of the rubber and steel in tires makes the materials difficult to separate effectively and this inhibits tire recyclability.

2. TASK 1—SCRAP TIRE MATERIALS INVESTIGATION

Task 1 of the project involved gathering information on potential materials from recycled tires in noise barriers that could be used in this research project. Generally, Task 1 consisted of these major subtasks:

- Investigate and gather data on state-of-the-art design, construction characteristics and maintenance requirements of scrap tire materials amenable for noise barriers—both finished commercial products and rough building materials;
- Assemble and compare characteristics of the applicable recycled tire materials in a matrix for presentation to the project Selection Committee; and
- Selection Committee chooses one or more recycled tire material(s) to be used in the remaining tasks of the project.

Going into the project, it was known that some commercial noise barrier products that use scrap tires were already available and marketed (Section 6.1). Some of these products were known to have been installed in Colorado, so information on their performance may be available outside of this project. Some of the commercial products were not known to have been installed in Colorado so local performance data may not be available. But also of interest were other materials or concepts that did not depend on proprietary products from commercial vendors that may be available and creatively repurposed as noise barriers. This collection of products represented the potential pool of tire materials envisioned at the beginning of the project.

2.1 Scrap Tire Research

Task 1 began with an intensive library and Internet search for published international and domestic applications of recycled tire materials in noise barriers to review what had been done already and what new choices may be available. In addition, contacts were made with industry professionals and other state DOTs to build on their knowledge and experience with potential solutions. Both commercial systems and general building materials with potential as a noise barrier were examined in the research. This broad examination of potential scrap tire materials gave a good chance to discover an inexpensive material that could lower the relatively high cost of the noise barrier materials currently preferred on CDOT projects.

For example, a possible noise barrier could involve repurposing a product designed for another function or adapting a rough building product to use in noise barriers. Consideration was given to possible recycled tire materials that have been included in noise barriers already built outside Colorado and to promising materials featuring innovative designs that have not yet been built anywhere. Innovative use of an unexpected product was a conscious consideration in the initial broad material search.

From this research, a select group of products and materials were identified (Section 6.1) for further consideration in the project (Section 2.2). Characteristics of each product were gathered to the extent possible from manufactures' literature or published data for use in the selection process.

2.2 *Project Selection Committee*

The Selection Committee consisted of a group of CDOT staff and outside individuals (Appendix A) that were tasked with evaluating the materials identified from the earlier research to select the material(s) of greatest interest to carry through Tasks 2 through 4. For the project to be successful several hurdles had to be overcome in designing and building the barrier wall that were also important considerations in the material selection. Most notably, the important physical constraints at the site had to be compatible with the structural requirements of the barrier material. Because testing new materials was an important aspect of the research, it was recognized that CDOT was unlikely to have any prior experience with the product selected. Therefore, the Selection Committee developed several criteria to evaluate the candidate barrier materials.

The candidate material review and product selection was accomplished through two committee meetings. The first meeting reviewed the physical constraints of the field test site, provided direction to the consultant on the aim of the project and established the 10 evaluation criteria (listed below) and their relative order of importance. The second meeting consisted of a larger group of people that discussed the accumulated research findings, their impressions of the products relative to the project goals, and their opinions on best next steps.

The 10 evaluation criteria identified by the Selection Committee for the product comparison matrix were:

- Overall cost of the material/barrier, including design and ongoing maintenance;
- Constructability of the design/material;
- Previous experience of CDOT or others with the material;
- Aesthetics of the final barrier;
- Availability of construction materials and/or products;
- Maintainability of the finished barrier;
- Durability of the barrier material;
- Quantity of tires consumed in the barrier design;
- Noise abatement provided by the barrier material; and
- Vegetation preservation (this criterion was specific to the project test site).

Several sub-elements were developed for each criterion (Appendix B). The criteria were used to score each product/material for overall value and relevance to the research project as part of the process to select the final materials for Tasks 2 through 4.

Eight candidate materials (Section 6.1) were included in the evaluation matrix (Appendix B). Three concrete products often used on CDOT projects were also included for comparison, but were not candidates for this project. Each material was evaluated for each of the criteria sub-elements, either qualitatively or by numeric values (where appropriate and available). The various sub-elements for each criterion were then examined as a group and the eight materials were ranked for that criterion—by scoring 1 through 8 with 1 being best. In cases of ties, averaged rank scores were assigned to each material. The scores for each of the eight materials for each of the 10 criteria were summed to provide an initial overall score—a lower score is better. (Note: a separate weighted overall score was also calculated where the relative importance of each of the 10 criteria was also considered.) These scores were used to guide the final decision but were not the only consideration in the final decision (Section 6.1.10). Through this process, Tire-Tie™ was the product selected by the committee (Section 6.1.5).

3. TASK 2—BARRIER DESIGN

Once the barrier material was selected in Task 1, a noise barrier wall was designed for the designated project test site along the US 6 (W. 6th Avenue) Frontage Road near Arbutus Street and 7th Avenue in Lakewood, Colorado (Figure 1). The barrier design needed to accommodate both the structural characteristics of the selected barrier material as well as the unique physical characteristics of the site. The resulting design drawings were part of the bid-letting package used by CDOT to select a contractor to build the test barrier and to guide construction of the barrier (Task 3).

Figure 1. Overview of CDOT Barrier Test Location

The project test site was along the north side of the Frontage Road and approximately 300 feet in length (Figure 1). Although the main purpose of the barrier was as a platform to test new materials, the barrier was also intended to protect several homes in the Mountain View Estates neighborhood (approximately 13400 West 7th Avenue) from traffic noise from US 6.

Before project construction, the test site had a Type 3 guard rail in the approximate location of the test barrier (Figure 2). The test site also had a narrow platform of level ground for the test barrier due to the steep and deep ground slope into Lakewood Gulch immediately to the north—this was a limiting factor for both the material selection and barrier design.

Figure 2. CDOT Test Site before Construction (Looking East)

On either end of the test site, traffic noise barriers were constructed on private property in the neighborhood (Figure 1). These barriers were part of a private project also funded by CDPHE's Advanced Technology Grant Program but unrelated to CDOT's project.

During Task 2, CDOT decided to close the gaps between the CDOT test barrier and the neighborhood barriers to maximize traffic noise reduction benefits to the Mountain View Estates neighborhood. In conjunction, the size of barrier needed to provide the noise abatement benefits required by CDOT's guidelines (4) was assessed through the Federal Highway Administration (FHWA) Traffic Noise Model software. It was found that the barrier needed to be at least 6 feet tall. Through several consultations, a final decision was made for the barrier to be approximately 7.5 feet tall, which provided additional noise reduction.

Standard geotechnical testing for the site was performed prior to barrier design. Standard structural engineering design techniques were followed to arrive at a barrier design that recognized the physical constraints of the test site as well as the structural aspects of the selected barrier material and the limited project construction budget. The CDOT Field Inspection Review/Final Office Review process was followed; however, the process was compressed into a shorter schedule and a single project meeting. A complete set of reviewed and approved design drawings for the test barrier was provided to CDOT for this task (Appendix D).

4. TASK 3—BARRIER CONSTRUCTION

The design drawings prepared under Task 2 were used by CDOT to select a construction contractor (Jalisco International, Inc.) through a competitive bidding process. The contractor was tasked with building the project noise wall in conformance with the design drawings by methods of their choosing. CDOT Region 6 staff provided construction oversight.

Construction of the barrier wall design from Task 2 was completed by the contractor in conformance with the project specifications. The barrier design was based on the common post-and-panel configuration. The contractor prepared the site for construction, drilled and poured caissons, poured a Type 7 crash barrier base, installed steel I-beam vertical supports, installed Tire-Ties™ between the vertical supports and applied a finish stain to the wall (Figure 3). The Type 7 crash barrier was constructed in August 2009. The majority of the wall was assembled in January 2010. The final stain finish was completed in April 2010 to accommodate the minimum weather requirements for the stain. (Note: the stain was applied so that CDOT's wall would have a color similar to the surrounding neighborhood walls rather than the black of the tire rubber.)

Figure 3. Construction of CDOT Barrier Wall

5. TASK 4—BARRIER PERFORMANCE MONITORING

Once the project barrier was constructed, assessment of barrier performance began. This included measuring the noise reduction (insertion loss) provided by the barrier as well as monitoring barrier material performance for one year.

The measurement of barrier insertion loss was a one-time event shortly after completion of the barrier. The noise-reducing performance of the selected material (Tire-Tie™) was reviewed through concurrent sound-level measurements both in front of and behind the project barrier. The first location (in front of the barrier) faced US 6 with no mitigation of traffic noise (Figure 4). The second location was immediately (less than two feet) behind the project barrier approximately five feet above ground and was protected from US 6 traffic noise by the project barrier.

Figure 4. Measurement of Barrier Noise Reduction (Looking East)

The ongoing monitoring consisted of quarterly site visits for one year (May 2010 to May 2011) with documentation of barrier condition. While the entire test barrier was examined each quarter, two of the 32 barrier panels were selected for closer scrutiny (Panels 2 and 17) during each monitoring period to represent performance of the barrier in general. Panel 2 was an end panel (east end) that represented the panels with no external support and relied on their own internal strength to maintain the barrier structure (Figure 4). Panel 17 was near the center of the barrier and represented the panels consisting of six ties stacked on the Type 7 concrete barrier base (Figure 3) that made up the majority of the barrier.

Several barrier characteristics were tracked in qualitative terms during the monitoring period, including:

- Overall structural integrity (visual);
- Apparent physical performance and durability;
- Performance of applied finish;
- Aesthetic observations; and
- Documentation of any incidents (e.g., crashes).

6. CONCLUSIONS AND RECOMMENDATIONS

The findings from Tasks 1 through 4 are described below, followed by the overall project recommendations.

6.1 Task 1— Scrap Tire Materials Research

A robust investigation into potential recycled tire materials for noise barriers identified eight candidate materials or technologies that were reviewed by the CDOT Selection Committee. In addition, three types of concrete barriers (that do not use recycled tires) often used by CDOT were included for comparison. The assembled data for each material were gathered into a matrix (Appendix B) for evaluation by the Selection Committee. Each material was evaluated for 10 criteria (Section 2.2) with several sub-elements considered under each criterion. The Selection Committee used these data in selecting a tire material for field testing at the project test site.

The eight candidate materials are described below. This information was taken directly from the individual developer/manufacturer promotional data with their permission. For this project, no attempt was made to verify independently the statements or technical specifications. The data provided were assumed to be accurate and representative of the products.

6.1.1 Carsonite AcoustaShield™

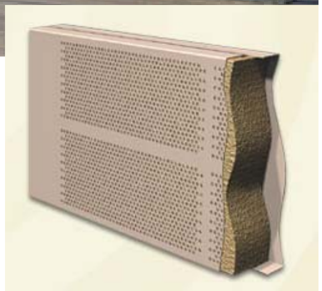
In a new process, scrap tire waste can be used in combination with a structural element to create an aesthetic, functional, and long-lasting barrier wall. The recycled scrap tire core consists of a mixture of several crumb rubber sizes and a phenolic binder. A ten-foot-high, one-mile-long wall would consume approximately 250,000 pounds of scrap tires.

The structural element, shaped into a tongue-and-groove building plank, is a fiberglass-reinforced plastic composite that has consistent and predictable mechanical properties with an expected life cycle of 50 years. The glass-reinforced plastic contains flame retardant, is self-extinguishing, and is protected by ultraviolet inhibitors to prevent solar degradation. The tongue-and-groove structural element is manufactured by a continuous process that ensures high quality and structural soundness to meet the load-bearing requirements of the sound wall.

The wall is lightweight and modular and can be erected with light-duty equipment. Similarly, the wall can be removed, repaired, or moved to a new location without large construction equipment. The wall can be manufactured in virtually any color or with variable shading.

Note: Carsonite products have been used at multiple locations in Colorado, including along 6th Avenue near Perry Street. These standing Carsonite products may not include all of the latest product developments but are believed to be representative of the product overall.

6.1.2 Acoustax Noise Barriers



Acoustax is designed to absorb highway noise, not reflect it, and withstand the harsh environment alongside the nation's roads. With a base metal of aluminum powder-coated with paint specially designed to give years of service in the harsh environment along highways. Acoustax barriers can be painted. The opposite side of the panels can be painted different colors. Ease of installation is a major advantage of Acoustax noise walls. Once the support beams are in place the Acoustax panels are slid into the beam pockets in the common post-and-panel configuration.

The conventional design of an Acoustax panel includes a sound-absorbing filler material that is not made from recycled tires. However, the design could be modified to use pressed scrap tire mats as the filler material.

6.1.3 Compressed Tire Bales

Tire bales are a rough building material made by compressing whole tires into a block shape with a large hydraulic press and banding them with five or more restraining wires. The bales are typically 5 feet wide by 5 feet long by 2.5 feet high, although sizes can vary depending on the particular press and tires that are used. Smaller half bales are also available. One bale uses approximately 100 passenger car tires. Each full bale weighs approximately one ton and is relatively strong.

It is important to recognize that tires are flammable, can emit toxic smoke and fumes when burning, and can be difficult to extinguish if loosely stacked. Therefore, one tire bale supplier recommends arranging bales in running bond, as if they were very large bricks stacked one on another in an alternating pattern (see photo at right). The bales could then be finished with a cement-based grout and plaster/stucco to form a strong, stable wall. This method of construction would reduce flammability concerns. Coating the tire bales with a layer of noncombustible cement-based or earthen plaster or stucco eliminates the exposure to normal ignition sources and insulates the tires from the heat of a nearby fire. This measure reduces the possibility of a tire bale wall fire and the associated hazards.

Tire bales are relatively inexpensive but are large and wide, requiring more space for the final wall. The aesthetic value of the raw tire bales is not high, but imaginative thinking may identify durable inexpensive coatings that improve this.

6.1.4 Ecoflex Wall System

Ecoflex was a product specifically suggested by CDOT staff. Ecoflex is made from used car and truck tires and used rubber conveyor belting mainly for the Australian market and some exports.

Ecoflex is based on creating a structural "container" from used tires which are unsuitable for retreading. When the container is filled with crushed rock, gravel, sand or recycled concrete, it forms a structural building module which can be combined to form an interconnected cellular structure to perform basic engineering in accordance with engineering standards and specifications.

An Ecoflex wall offers a number of advantages:

- the wall has high strength;
- a range of facing materials is available;
- it adapts to the contours of the surrounding land; and
- it provides flexibility in design and appearance.

The wall is cost effective plus the system can be re-used, providing long-term savings. It is easy to construct which reduces construction time and cost. It also is lightweight and requires no special tools or fittings. Life durability research published on related topics indicates that the half-life of a tire in the environment (such as in an Ecoflex unit) would be greater than 100 years.

As with the tire bales, Ecoflex materials are relatively inexpensive but more space is needed for a finished unit.

6.1.5 Tire-Tie™

The Tire-Tie™ (NPG Innovations) is a product designed for the railroad industry as a replacement for wooden cross ties. During this project, the product was still in development and not mass produced. The ties are not a "polished" product in appearance in contrast to some of the other materials.

A Tire-Tie™ is made from scrap tire treads glued together in laminated strips attached to a central steel core for strength. The ties are strong and must be able to withstand the weight and force of freight trains. The reported strength data for a Tire-Tie™ indicate they are more than adequate to serve as structural members of a noise barrier.

Although not originally developed as a noise barrier product, the Tire-Tie™ is easily adapted into a post-and-panel wall design typical of other noise wall products. The nominal size of a Tire-Tie™ is 7 inches by 9 inches by 8.5 feet, although there can be flexibility with the final dimensions, particularly with length. The Tire-Tie™ design uses approximately 23 tires per tie.

6.1.6 SmartWall Systems®

SmartWall is a concrete wall panel system that is similar to typical precast concrete wall systems, but has an added element of shredded scrap tires as aggregate in the concrete mix. The SmartWall design consists of concrete panels nominally 4-inches thick, but also includes protruding angled surface elements intended to reduce horizontal sound reflections and thereby provide better noise reduction overall.

SmartWall is available in a wide variety of colors by tinting the concrete. SmartWall has been installed in the Mountain View Estates neighborhood and abuts both ends of the CDOT test site.

6.1.7 Tire Stack

The tire stack concept is a rough building material that is formed into a wall system. It consists of whole tires stacked on top of each other with a center vertical support column for structural stability. The tire stacks are usually filled with earth or rubble for strength. The stack height is easily modified, but the bottom tires are easily compressed by excess weight, which presents structural hurdles. The tire stack face can be finished with shot-crete or other material to fill voids, add strength and prevent noise transmission through gaps between tires.

This concept shares some similarities with other products using whole tires, but there are differences as well. A tire stack wall has been built in the Mountain View Estates neighborhood near the test site, adjacent to a SmartWall, at approximately 600 Braun Street.

6.1.8 Whisper-Wall

Whisper-Wall is a post-and-panel wall system. A typical precast noise wall panel is 8-inches thick and consists of four inches of a sound absorptive mixture on four inches of structural concrete. The panels are designed to be stacked using a top-down construction method. This method varies the height of the bottom panel and allows full height panels to be stacked up to the sound attenuation elevation. Cast into the top and bottom of each panel is a tongue and groove keyway that aligns and interlocks each panel along the horizontal joint. Panels can span up to 24 feet and be stacked as high as 54 feet.

Environmentally engineered, Whisper-Wall absorbs sound using a highway generated waste product, rubber vehicle tires. Rubber tires are recycled and processed into small chips. The rubber chips are then blended with natural sound absorbing aggregate and cement to produce a sound absorbing mixture. The final product is durable in all types of climates.

6.1.9 Standard Concrete Walls

Standard concrete materials do not use scrap tires but have often been used by CDOT. About half of the noise walls constructed in North America to date are made of concrete. Concrete is one of the most durable building materials currently available for many highway products, including noise barriers. It is rugged and able to withstand severe temperatures, intense sunlight, moisture, ice and salt. It is a versatile material capable of being shaped, molded, and textured to take on the appearance of many things such as weathered wooden boards, rock faces, stone blocks and sculpted mural topics. Its mass, even at a thickness of only a half inch, is well within Sound Transmission Class requirements for an effective noise barrier. Concrete products can be colored by either incorporating pigments into the concrete mix before pouring or by applying a stain onto the surface of the cured products.

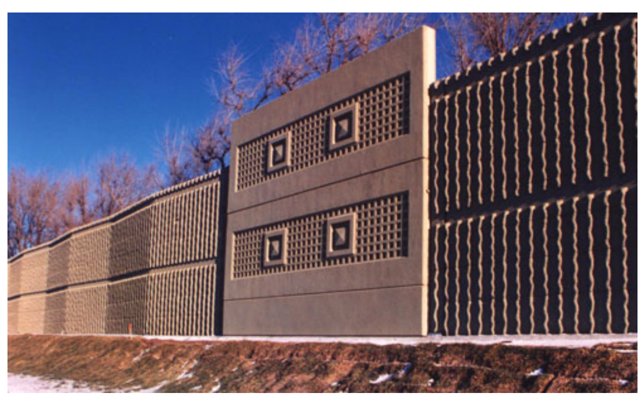
The versatility of concrete provides flexibility in the shape, size and finish of barriers that can be produced. Concrete allows for a broad range of installation techniques including post-and-panel, post integral with the panel, free standing, direct buried and on top of spread footings, continuous footings, traffic barriers or retaining walls.

Three types of concrete walls were included in the materials matrix for the Selection Committee: cast-in-place, precast panels and concrete block. These concrete materials do not include any recycled rubber products, but were provided for comparison and to provide a frame of reference for the unfamiliar scrap tire products.

Cast-in-Place Walls

Cast-in-place concrete walls have typically been used on bridges and retaining walls because of their flexibility of design, high structural strength and resistance to vehicle impact damage. These types of barriers are constructed at the project site. The thickness of the finished wall is variable. The construction process includes excavating for the footing, erecting form work, setting reinforcement steel, pouring concrete, surface finishing, and curing.

Precast Panels



Precast panels typically are poured off-site and transported to the final location, which minimizes site construction conflicts. The panels can be erected relatively quickly using cranes. Panels are often 4-inches thick. Landscape damage can be avoided by the use of properly sized cranes that can span over the landscaping when setting the panels. Precast concrete walls have the potential to be re-locatable and have been used for temporary as well as permanent walls. Several of the candidate materials described above are precast concrete panels.

Concrete Block Walls

Versatility, flexibility, performance and pleasing aesthetics are designed elements of concrete block walls. This helps to make construction easier for the installation contractors. In addition, design engineers can take advantage of this flexibility to produce a more efficient, economical and aesthetic engineered wall design.

Concrete block walls are constructed in a wide selection of shapes that have been crafted for efficiency in the design of segmental walls for structural performance, durability, flexibility, and aesthetics in the finished wall. Block walls are typically 8-inches thick. These walls can be painted or stained in a broad range of colors to fit into a chosen color scheme for a roadway project.

6.1.10 Selection Committee Barrier Material Decision

The Selection Committee reviewed the candidate scrap tire products/materials for the project (Section 2.2). The various strengths and weaknesses of the materials were reviewed by the Selection Committee. Specific items that were important for the material selection included:

- Wall had to fit in the narrow space available;
- Walls that minimized the need for site tree removal were favored;
- Walls that used more tires were favored;
- Wall had to maintain adequate site drainage;
- Walls that could fit a variety of building sites were favored;
- Walls that were easy to construct and maintain were favored;
- Wall finish that could blend with neighboring walls was favored; and
- New wall materials were favored over familiar products to increase future options.

The comprehensive scoring process using the 10 criteria permitted comparison and ranking of the various materials. The Selection Committee scores for each material are presented in Appendix B, but the overall scores in the matrix were only part of the final material selection. The final rankings from the scoring matrix were important considerations, but the professional judgment and consensus of the committee were also important in the final selection of the test material. The matrix was used to facilitate and guide the committee discussion on which material they believed would best serve the goals of the project.

Through consensus, the final order of preference for the top three candidate materials, as voted by the Selection Committee, was:

- Tire-Tie™ (1st);
- Carsonite AcoustaShield™ (2nd); and
- SmartWall (3rd)

The Selection Committee chose one preferred material—Tire-Tie™—to be used in Tasks 2 through 4 of the project. This was a proprietary product manufactured at a single location in New York. The committee recognized that it was not a fully developed widely-available product, nor was it primarily intended for noise walls. Therefore, Carsonite AcoustaShield™ and SmartWall were identified as backup materials should problems develop with Tire-Tie™ or opportunities arise to test multiple materials at the site. (Note: these conditions did not arise so only Tire-Ties™ were used for this project.)

The Selection Committee discounted SmartWall (and also the stacked tires) material somewhat because it was used in the private noise walls adjacent to CDOT's test site, so little added value from a research standpoint was seen in duplicating those efforts.

6.2 Task 2—Barrier Design

NPG Innovations was contacted to determine the details of its Tire-Tie™ product (Appendix C), including the approximate dimensional range for the fabricated ties, the anticipated production schedule, the expected cost of the ties, and other relevant information. Based on the information provided, a noise wall concept was developed utilizing an unmodified version of the standard Tire-Tie™.

A post-and-panel noise barrier system was developed, in which the Tire-Ties™ were stacked between appropriately spaced wide-flange steel posts (Appendix D). The depths of the posts were approximately the same depth as the ties, which allowed for the ties to be simply stacked between the posts to the heights required to meet the noise abatement goal.

To provide the most economical design, the wall needed to be as close to the 6th Avenue Frontage Road as possible. The grade alongside the roadway was level for a short distance before transitioning to steep slopes towards the Lakewood Gulch drainage to the north. By setting the wall close to the roadway, expensive grading along the steep roadside slopes was avoided. The wall location also minimized the impacts to a stand of mature trees along the roadside. This helped to reduce the tree mitigation needs, and assured the steep roadside embankment would remain stable from the established tree root system.

The proximity of the wall to the 6th Avenue Frontage Road required it to be designed to meet CDOT's full roadside safety requirements for structures within the clear zone of a roadway. The post-and-panel assembly directly adjacent to the roadway was mounted on a standard CDOT Type 7 Concrete Barrier capable of resisting the traffic impact loads for the design speed and vehicle types on the roadway. An efficient drilled concrete shaft foundation was used to support the barrier, which accommodated the traffic impact loads and minimized construction impacts to the existing grades. The east end of this wall segment is protected with a standard Type 3 barrier transition to protect oncoming traffic from the blunt end of the concrete barrier.

The wall segments closing the gaps between the new barrier and the adjacent neighborhood noise barrier were constructed full height using only the stacked ties—a concrete base was not needed. The structural characteristics of the Tire-Ties™ allowed for this without modification to the ties. Wide-flange steel posts were again used to support the stacked tie panels, which were founded on drilled concrete shafts.

The aesthetic treatment to the noise barrier system was limited to a painted finish matching the color of the existing noise barriers in the area. The concrete barrier and steel posts received painted finishes per the CDOT Standard Specifications. A water-based acrylic stain finish was the recommended finish for the Tire-Ties™, which was field applied after the ties were stacked in place.

6.3 Task 3—Barrier Construction

The barrier was built successfully, with the final construction activities (staining) in April 2010. Insertion of the Tire-Ties™ (Figure 5) into the wall panels was completed in two days. The ties proved to be relatively easy to handle during construction.

Figure 5. Tire-Ties™ Staged for Construction

A few challenges caused the overall construction period to last longer than anticipated. Among those, delivery of the building materials required a few months lead time and caused wall assembly to lag into January 2010. Application of the finish stain then was delayed until the weather was warm enough in April 2010. No significant construction problems were observed by CDOT staff. After construction, the CDOT field staff and the manufacturer were interviewed to capture "lessons learned" that may be of use in the future (Appendix E).

The finished wall was approximately 275 feet long by 7.5 feet tall and consisted of 32 panels made of Tire-Ties™. Twenty-seven of the panels consisted of six ties stacked on top of the Type 7 barrier (Figure 3). Five end panels (Figure 4) that wrap the CDOT wall back to the adjoining neighborhood walls (SmartWalls) consisted of 10 ties stacked on top of each other (7.5 feet tall). Steel plates were attached to the CDOT wall to cover the remaining gaps between the walls, but the walls were not connected physically. A total of 212 Tire-Ties™ were used in CDOT's wall, containing approximately 4,900 tire treads. In total, there was approximately 2,062 square feet of surface area per wall side. The construction contract for the wall totaled $215,000.

Each Tire-Tie™ (Figure 5) ultimately cost the project $250, which was more than originally anticipated. Several factors contributed to this. The supplier was still a start-up company and did not have personnel, supplies or production facilities to mass produce the Tire-Ties™ at the time. CDOT's order was reported to be the largest in their history to that point. The manufacturer has reported a desired price point of approximately $100 to $125 per Tire-Tie™, to be cost-competitive with the wooden railroad ties they are intended to replace. If this pricing goal is reached by the manufacturer, the finished product cost would be reduced dramatically, which would improve the cost-competitiveness relative to other wall materials.

6.4 Task 4—Barrier Performance Monitoring

This task consisted of two primary subtasks: evaluate the noise-blocking performance of the chosen barrier material in the finished barrier wall (Figures 6 and 7) and assess generally the physical performance of the barrier material for one year. These were achieved through a combination of quantitative sound level measurements and qualitative observations.

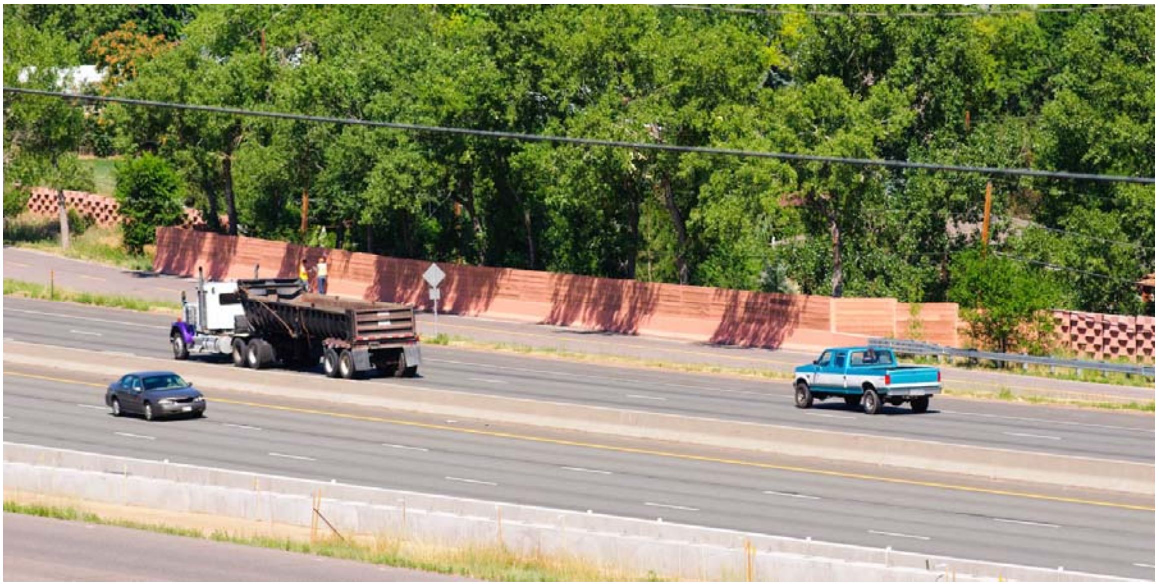


Figure 6. Completed CDOT Barrier Wall from US 6 Side

6.4.1 Noise Reduction

The barrier wall was designed in a way that the wall is approximately 7-inches thick (i.e., the short side of each tie). Each Tire-Tie™ was reported by the manufacturer to weigh in excess of 400 pounds, or more than 60 pounds per exposed square foot of Tire-Tie™. Therefore, Tire-Ties™ are more than sufficient in weight to be an effective sound-blocking material.

Subtracting the measured noise levels (Section 5) resulted in the project barrier providing approximately 7.8 dBA of insertion loss immediately behind the barrier. This noise reduction is well within the CDOT goal of noise reduction of 5-10 dBA and is noticeable behind the wall (4). This result was affected by several site conditions, including:

- Approximately 2.5 feet of barrier "free board" was present above the sound meter during the measurement and was affected by the amount of noise refraction over the top of the barrier.
- The Tire-Ties™ were intentionally stacked loosely on top of each other within the vertical I-beam supports for this project. Though the faces of the stacked Tire-Ties™ did fit together well, not all of the joints mated perfectly, so occasional small gaps between Tire-Ties™ were present. This was a minor effect, but sound can pass through these gaps. Such gaps could be closed, such as with caulking between ties.

Figure 7. Completed CDOT Barrier Wall from Neighborhood Side

6.4.2 Material Performance

Several qualitative aspects of the barrier material (Section 5) were monitored during the first year after construction. Two wall panels (Panel 2 and 17) were selected as proxies for the rest of the barrier for closer monitoring (Figure 8). The intention was to observe and document real-world performance of the wall design, materials and finishes.

Overall, the test wall performed well. No physical deterioration or structural failures of the wall were observed. No delaminations or separations within the tire tread stacks were observed. The fit (i.e., gaps) of the wall material did not change noticeably during the monitoring. For the most part, the finish stain adhered to the wall material and maintained its color reasonably well. The wall continued to provide a substantial noise reduction to the homes behind (to the north; Figure 1) of the wall. Structurally, the wall held up well.

Some things that could be improved were observed. As was noted previously, the ties did not always fit together perfectly, so there were occasional gaps between ties where noise may bleed through. These gaps were small and estimated to be much less than one percent of the wall surface and quite minor in noise terms, but it is recommended that any future installations of the wall design should seal these gaps to provide the greatest noise reduction.

The wall was stained with an FHWA-approved color that most closely matched the surrounding neighborhood walls to improve the aesthetics of CDOT's wall. The stain and paint has generally performed well in adhering to the wall material, particularly the Type 7 concrete base and the steel I-beams. However, the project used a single application of the stain on the ties and the color has diminished (apparently absorbed into the tire rubber) more than desired—the black tire substrate color became visible to varying degrees (photo at right). Some tires lost the stain color more than others, giving the wall a somewhat mottled appearance. The color loss was particularly visible on one tie (Figure 6). Note that from the manufacturing process, the tires exposed on the surface of the Tire-Ties™ are random, may come from different sources, may have different rubber characteristics and may have been trimmed differently. Another possible cause of the loss of stain color could have been foreign material such as oil on the tires.

The Tire-Ties™ were manufactured with steel and rust appeared on some of the exposed steel (Figure 8). This will be primarily an aesthetic issue. The rust was similar in color to the finish stain, but it is visible. It is unknown how this will progress over the life of the wall.

The Tire-Ties™ were not designed to be a visually refined product to fulfill their primary purpose with the railroads. Consequently, the manufacturing tolerances allowed for imperfections that were visible when the ties are used in a noise wall. For instance, some of the surficial tire treads contained "bubbles" (photo at right) and other visual breaks. This was an aesthetic consideration that did not affect the integrity of the wall and did not change noticeably during monitoring.

Wall Panel 2

May 2010

May 2011

Wall Panel 17

May 2010

May 2011

Figure 8. Photographs of Wall Panels Selected for Close Monitoring

No incidents (e.g., car crashes) are known to have occurred to the wall, but the wall was designed to CDOT standards and is expected to perform well in such an event.

6.5 Summary

The main goal of this research project was to evaluate new and innovative ways to incorporate scrap tires into traffic noise barriers, ideally with a promising technology(s) being developed for use in future CDOT projects. Several potential wall materials were reviewed and one recycled tire product (Tire-Tie™) was selected for field testing. A 275-feet-long noise wall was built at a designated test site in a familiar post-and-panel configuration. The wall was relatively easy to construct, even with the physical constraints of the test site. The panels rested on a Type 7 concrete crash barrier for most of the length. The wall was stained with a selected finish color and the general performance of the wall was monitored for one year.

The test wall was found to have performed well for the monitoring period. Tire-Ties™ were found to be an effective noise-reducing material for noise barriers. The Tire-Ties™ have an exposed face of tire rubber, which is a more sound-absorptive material that may reduce noise reflections from a noise wall relative to sound-reflective material such as standard concrete. The Tire-Ties™ held up well to exposure to weather. After one year, the performance of the wall appeared to be as good as when it was new.

A few concerns were noted. The Tire-Ties™ were more expensive that initially expected and would not be a low cost alternative material at that price. The finish stain appeared to have been absorbed into the tire rubber more than expected, causing a faded look to many of the rubber parts of the wall—more than one coat of stain is advised to minimize this. Rust became visible in spots, from the steel in the Tire-Ties™ and the vertical support columns—this likely will continue over time. Small gaps are present between some of the stacked Tire-Ties™. While this is a minor overall noise consideration, noise wall performance would be improved with these gaps sealed.

6.6 Recommendations

The test barrier made from Tire-Ties™ has performed well thus far and can be recommended for consideration on other CDOT projects requiring noise abatement. There are several positive aspects to Tire-Ties™ as a noise barrier material:

- The material is more than substantial enough to block traffic noise effectively;
- Tire-Ties™ have considerable internal strength and could be structural elements in a wall, if needed;
- Tire-Ties™ use a considerable number of scrap tires—approximately 23 tire treads per 8.5-foot tie;
- The wall face would be a sound-absorptive material (rubber);
- Walls of varying heights would be relatively simple to achieve—7-inch or 9-inch increments would be possible;
- Walls would be relatively simple and quick to construct;
- Wall height could be changed relatively easily and quickly even after initial installation;
- Wall could be dismantled and recycled at another location relatively easily; and

- Tie lengths up to 25 feet were reported by the manufacturer, allowing some flexibility in panel spans.

Note that Tire-Ties™ were not developed by the manufacturer with noise barriers in mind. Subsequent informal discussions with the manufacturer indicated that a variation of the product that has been purpose-built for noise barriers may be feasible and available in the future, which may be of interest to CDOT in the future.

Nevertheless, there are some aspects of a Tire-Tie™ wall that at present would require attention:

- The material is relatively heavy and likely unsuitable when total weight is a concern;
- Sealing the joints between stacked ties should be required;
- Public reaction to the overall visual aesthetics is unpredictable and may not be preferred;
- Consideration should be given to the final wall finish/stain specifications;
- There is only one supplier of Tire-Ties™;
- Tire-Ties™ were relatively expensive on this project and not a low-cost alternative; prices would have to drop for it to have a cost advantage over other materials; and
- Tire-Ties™ are made with rubber so consideration should be given to potential fire issues.

Therefore, it is the finding of this research project that Tire-Ties™ and the accompanying project wall design should be considered for pre-approval by CDOT for use on projects (note: it will be up to the manufacturer to pursue this). This would provide CDOT with an alternative when use of recycled materials or overall sustainability is an important goal of a construction project.

6.7 Implementation Plan

Several steps are suggested to implement the recommendations for this project. Research Branch staff should continue monitoring the performance of the noise wall and attempt to conduct a life-cycle cost analysis for the tire ties material/design and other similar types of noise barriers in the future. Application for inclusion in CDOT's Approved Product List will be up to the product manufacturer. The cost and availability of Tire-Ties™ should occasionally be revisited by Research Branch staff. As indicated in Section 6.6, new materials based on scrap tires are being developed, and Research Branch staff should be attentive to innovations in potential barrier materials.

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APPENDIX A
Project Selection Committee

The following individuals participated in or supported the efforts of the Selection Committee for this research project:

Name	**Affiliation**
Roy Smith	CDOT
Dan Groeneman	CDOT Bridge
Brad Beckham	CDOT Environmental Programs Branch
Zac Graves	CDOT Environmental Programs Branch
Hsing-Cheng Liu	CDOT Geotechnical
Melissa Nelson	CDOT Government Relations & Policy
Scott Leiker	CDOT Hydraulics
Bob Mero	CDOT Region 6
Irv Mallo	CDOT Region 6
Jordan Rudel	CDOT Region 6
Katie Dawson	CDOT Region 6
Sarah Czajka	CDOT Region 6
Jake Kononov	CDOT Research Branch
Pat Martinek	CDOT Research Branch
Roberto De Dios	CDOT Research Branch
John Padon	City of Lakewood
Bill Marcato	Felsburg Holt & Ullevig
Cody Huff	Felsburg Holt & Ullevig
Dale Tischmak	Felsburg Holt & Ullevig
Steve Dole	Felsburg Holt & Ullevig

APPENDIX B
Product Selection Matrix

Waste Tire Noise Barrier
Cost Factor Assessment

Cost
Diverse factors affect the cost of manufacturing, transporting, and erecting noise barriers and their components.
These measurement factors present elements that should be considered:

Approx Cost per linear foot	Cost break down (top of caisson, 10ft on center)
Tire cost	Overall cost/energy consumption of processing the tires into a wall application.
Superstructure cost	Is the cost of the superstructure elaborate and expensive?
Site preparation cost	Any elaborate needs when prepping the site?
Engineering cost	Any special engineering needs?
Labor intensity	What is the level of labor needed to erect the wall system?
Energy input	Energy use for the manufacturing, delivering, and installation of the wall system.
Reusable system	Is the wall system reusable?
Foundation Cost	Approx cost of the foundation system needed for the wall application?

	Measurement Factors	**Carsonite (tire crumb in wall)**	**Acoustax (pressed tire mat in wall)**	**Tire Bales (compressed tires)**	**Ecoflex (stacked tires with gravel)**	**Tire-Tie (compressed R.R. ties of tire)**	**Smart Wall (crumb tire in concrete mix)**	**Tire Stack (stacked tires)**	**Whisper-Wall (crumb tire in concrete mix)**	**Cast in Place Wall**	**Pre-Cast Wall**	**Concrete Block Wall**
1	Approx cost per linear foot (panel only)	$144 /LF	$225 /LF	$28 /LF	UNKNOWN	$130 /LF	$314 /LF	$34/LF	UNKNOWN	$185 /LF	$200/LF	$160/LF
2	Tire cost	HIGH	HIGH	LOW	LOW	LOW	HIGH	LOW	HIGH	N/A	N/A	N/A
3	Superstructure cost	HIGH	HIGH	LOW	LOW	HIGH	HIGH	MEDIUM	HIGH	HIGH	HIGH	HIGH
4	Site preparation costs	LOW	LOW	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	HIGH	HIGH	HIGH
5	Engineering costs	LOW	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	LOW	LOW	LOW
6	Labor intensity	HIGH	HIGH	LOW	HIGH	MEDIUM	MEDIUM	LOW	HIGH	HIGH	HIGH	HIGH
7	Energy input	HIGH	HIGH	LOW	LOW	MEDIUM	HIGH	LOW	HIGH	N/A	N/A	N/A
8	Reusable system	YES	YES	YES	NO	YES	YES	NO	YES	NO	YES	NO
9	Foundation cost	$140 /LF	$140 /LF	NONE	NONE	$140 /LF	$140 /LF	NONE	$140 /LF	$140 /LF	$140 /LF	$140 /LF
10												
	Ranking (1 thru 8)	4	5	1	7.5	3	6	2	7.5	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Constructability Assessment

Constructability
Constructability is the ease of construction, life cycle and maintenance cost, and potential environmental benefits/impacts.
These measurement factors present elements that should be considered:

Width of wall system	How does the wall system width affect the constructability at a particular site?
Construction schedule	How does erecting the noise barrier impact the construction schedule?
Special equipment	Required special equipment for installation?
Special material	Required special material?
Standard procedures	Application of standard procedures
Safety issues	Are safety issues present when installing this wall system?
Offsite construction	Will the wall system be constructed at an offsite location?
Crash protection	Can the wall system be installed on top of a concrete barrier or is barrier needed in front of the wall system?

	Measurement Factors	**Carsonite (tire crumb in wall)**	**Acoustax (pressed tire mat in wall)**	**Tire Bales (compressed tires)**	**Ecoflex (stacked tires with gravel)**	**Tire-Tie (compressed R.R. ties of tire)**	**SmartWall (crumb tire in concrete mix)**	**Tire Stack (stacked tires)**	**Whisper-Wall (crumb tire in concrete mix)**	**Cast in Place Wall**	**Pre-Cast Wall**	**Concrete Block Wall**
1	Width of wall system	1 FT	1 FT	5FT	3 ft	1 FT	1 FT	2 FT	1 FT	1 FT	1FT	2 FT
2	Construction schedule	**Schedule unaffected by material or equipment availability**								N/A	N/A	N/A
3	Special equipment	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	CRANE	CRANE	NONE
4	Special material	YES	YES	NO	NO	YES	YES	NO	YES	NO	NO	NO
5	Standard procedures	YES	YES	YES	YES	UNKNOWN	YES	YES	YES	YES	YES	YES
6	Safety issues	YES	YES	YES	NO	YES	YES	No	YES	YES	YES	YES
7	Offsite construction	YES	YES	YES	NO	NO	NO	NO	YES	NO	YES	NO
8	Can the wall system be installed on top of barrier or behind it	BOTH	BOTH	BEHIND	BEHIND	BEHIND	BOTH	BEHIND	BOTH	BOTH	BOTH	BEHIND
9												
10												
	Ranking (1 thru 8)	3	2	5.5	5.5	1	7.5	7.5	4	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Experience Assessment

Experience
The wall systems will be evaluated on all levels of experience both in the state of Colorado and in all other states.
These measurement factors present elements that should be considered:

CDOT experience	Does CDOT have prior experience with this wall system?
Local construction experience	Is this a wall system that has been used in the state of Colorado?
National experience	Is this wall system being used in other states?
Prototype construction	Is this wall system a prototype or an established system?

	Measurement Factors	Carsonite (tire crumb in wall)	Acoustax (pressed tire mat in wall)	Tire Bales (compressed tires)	Ecoflex (stacked tires with gravel)	Tire-Tie (compressed R.R. ties of tire)	Smart Wall (crumb tire in concrete mix)	Tire Stack (stacked tires)	Whisper-Wall (crumb tire in concrete mix)	Cast in Place Wall	Pre-Cast Wall	Concrete Block Wall
1	CDOT experience	YES	NO	NO	NO	NO	PENDING	PENDING	NO	YES	YES	YES
2	Local construction experience	YES	NO	NO	NO	NO	PENDING	PENDING	YES	YES	YES	YES
3	National experience	YES	YES	NO	NO	NO	PENDING	PENDING	YES	YES	YES	YES
4	Prototype construction	NO	NO	YES	NO	YES	YES	YES	NO	NO	NO	NO
5												
6												
7												
8												
9												
10												
	Ranking (1 thru 8)	1	3	7.5	7.5	5	4	6	2	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Aesthetics Assessment

Aesthetics
Aesthetics is an issue of concern in the ultimate selection and design of a noise barrier. It is subjective, but often considered as important as the noise reduction provided by the barrier.
These measurement factors present elements that should be considered:

General aesthetics	Aesthetic perception of barriers to road users and people living there affect visual impact and to a certain degree determine the character of the community. The design the barriers should have appropriate scale and character compatible with the local environment.
Intrusive appearance	Is the wall considered intrusive or and "eye sore"?
Color	Is the base color of the wall system appealing?
Paintable to any color	Ease of different color application.

	Measurement Factors	**Carsonite (tire crumb in wall)**	**Acoustax (pressed tire mat in wall)**	**Tire Bales (compressed tires)**	**Ecoflex (stacked tires with gravel)**	**Tire-Tie (compressed R.R. ties of tire)**	**Smart Wall (crumb tire in concrete mix)**	**Tire Stack (stacked tires)**	**Whisper-Wall (crumb tire in concrete mix)**	**Cast in Place Wall**	**Pre-Cast Wall**	**Concrete Block Wall**
1	General aesthetics	HIGH	HIGH	LOW	LOW	LOW	HIGH	LOW	HIGH	MEDIUM	MEDIUM	HIGH
2	Intrusive appearance	NO	NO	YES	YES	YES	NO	YES	NO	YES	YES	NO
3	Base color	YES	YES	NO	NO	NO	YES	NO	YES	NO	NO	YES
4	Paintable to any color	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	NO
5												
6												
7												
8												
9												
10												
	Ranking (1 thru 8)	2	3	7.5	5	6	4	7.5	1	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Availability Assessment

Availability
Availability of materials is an important consideration. If materials must be specially ordered, or if long manufacturing lead time is required, construction schedules can be affected, adding costs to the barrier construction.
These measurement factors present elements that affect availability and energy consumption:

All local materials Are all materials local or from out-of-state?

Some out-of-state material Are some materials local or from out-of-state?

All imported materials Are all materials from out-of-state?

Transportation costs What is the cost level for the transportation of the wall system?

Mobilization costs Are mobilization costs needed for the wall system?

	Measurement Factors	Carsonite (tire crumb in wall)	Acoustax (pressed tire mat in wall)	Tire Bales (compressed tires)	Ecoflex (stacked tires with gravel)	Tire-Tie (compressed R.R. ties of tire)	Smart Wall (crumb tire in concrete mix)	Tire Stack (stacked tires)	Whisper-Wall (crumb tire in concrete mix)	Cast in Place Wall	Pre-Cast Wall	Concrete Block Wall
1	All local materials	NO	NO	YES	NO	NO	YES	YES	YES	YES	YES	YES
2	Some out-of-state imports	YES	YES	NO	YES	YES	NO	NO	NO	NO	NO	NO
3	All imported materials	NO	YES	NO	NO	YES	NO	NO	NO	NO	NO	NO
4	Transportation costs	HIGH	HIGH	MEDIUM	MEDIUM	HIGH	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
5	Mobilization costs	YES	YES	YES	N/A	YES	NO	YES	YES	YES	YES	YES
6												
7												
8												
9												
10												
	Ranking (1 thru 8)	6	7	3	5	8	1	4	2	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Maintainability Assessment

Maintainability

Noise barriers will become damaged at some point in their life, either from handling mishaps during construction, installation defects that appear well after the barrier has been installed, vehicles or debris hitting the wall, or simply from old age and exposure to the elements over time.

These measurement factors present elements that should be considered:

Ease of reconstruction or repair — Replacement of barrier elements may be required throughout the life of the noise barrier, the availability of replacement parts becomes a critical issue. The issue of future availability becomes even more critical when the components have to be custom fitted with either very few or none of the pieces the same. In this situation, stock piling may not be an option. This consequence should be seriously considered during the design stage and should be avoided if at all possible.

Paint longevity — How long does paint last on the surface of the wall?

Vandalism protection — Rougher surfaced and darker colored barriers may provide more resistance to being "hit" by graffiti artists as compared to light colored, and/or smooth-surfaced barrier surfaces. Some materials are particularly susceptible to vandalism from paint, knives, and lighters.

Use of standard materials — Are materials standard for wall construction?

	Measurement Factors	**Carsonite (tire crumb in wall)**	**Acoustax (pressed tire mat in wall)**	**Tire Bales (compressed tires)**	**Ecoflex (stacked tires with gravel)**	**Tire-Tie (compressed R.R. ties of tire)**	**Smart Wall (crumb tire in concrete mix)**	**Tire Stack (stacked tires)**	**Whisper-Wall (crumb tire in concrete mix)**	**Cast in Place Wall**	**Pre-Cast Wall**	**Concrete Block Wall**
1	Ease of reconstruction or repair	EASY	EASY	HARD	HARD	EASY	MEDIUM	EASY	MEDIUM	MEDIUM	MEDIUM	MEDIUM
2	Paint longevity	HIGH	HIGH	LOW	LOW	LOW	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	LOW
3	Vandalism protection	NO	NO	YES	YES	YES	NO	YES	NO	NO	NO	NO
4	Use of standard materials	NO	NO	NO	NO	NO	YES	NO	YES	YES	YES	YES
5												
6												
7												
8												
9												
10												
	Ranking (1 thru 8)	3.5	3.5	7.5	7.5	1.5	5.5	1.5	5.5	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Durability/Design Life Assessment

Durability/Design Life

Durability/design life includes product longevity, uv protection, and weathering. Rubber material, on its own, does not have sufficient rigidity to be considered as a structural component of a noise barrier panel. Therefore, bonding agents must provide adequate stiffness to enable the panels to be considered strong enough to withstand wind loading, or the rubber material must be firmly attached to a suitable stiffener, such as channel backings, cores, or casings

These measurement factors present elements that should be considered:

Service life	Though there is no specific requirement of service life, noise barrier material manufacturer is, however, required to guarantee for at least 10 years on properties such as color resistance, stone impact resistance, aging and corrosion resistance, light transmission, fire retardant properties etc.
Surface durability	Some coatings suitable for rubber have a questionable life expectancy. They have a tendency to oxidize prematurely, particularly when used in conjunction with certain pigments.
UV protection	Ultraviolet light can cause rapid deterioration of pigments, surface appearance, and material strength.
Weathering penetration	Able to withstand severe temperatures, intense sunlight, moisture, ice, and salt.

	Measurement Factors	**Carsonite (tire crumb in wall)**	**Acoustax (pressed tire mat in wall)**	**Tire Bales (compressed tires)**	**Ecoflex (stacked tires with gravel)**	**Tire-Tie (compressed R.R. ties of tire)**	**Smart Wall (crumb tire in concrete mix)**	**Tire Stack (stacked tires)**	**Whisper-Wall (crumb tire in concrete mix)**	**Cast in Place Wall**	**Pre-Cast Wall**	**Concrete Block Wall**
1	Service life	HIGH	HIGH	LOW	LOW	HIGH	MEDIUM	LOW	HIGH	HIGH	HIGH	HIGH
2	Surface durability	HIGH	HIGH	LOW	LOW	HIGH	MEDIUM	LOW	HIGH	HIGH	HIGH	HIGH
3	UV protection	YES	YES	NO	NO	UNKNOWN	NO	NO	UNKNOWN	HIGH	HIGH	HIGH
4	Weathering penetration	GOOD	GOOD	POOR	POOR	GOOD	UNKNOWN	POOR	GOOD	GOOD	GOOD	GOOD
5												
6												
7												
8												
9												
10												
	Ranking (1 thru 8)	1	2	7	8	3	5	6	4	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Tire Use Assessment

Use of Tires
Scrap tire waste can be used in combination with a structural element to create an aesthetic, functional, and long-lasting barrier wall.
These measurement factors present elements that should be considered:

Type of tire material	Energy consumption is affected by the type of tire usage in the wall system.
Weight of tires per foot	Same.
Special handling needs	Any special needs when using this wall application and tire usage?

	Measurement Factors	Carsonite (tire crumb in wall)	Acoustax (pressed tire mat in wall)	Tire Bales (compressed tires)	Ecoflex (stacked tires with gravel)	Tire-Tie (compressed R.R. ties of tire)	Smart Wall (crumb tire in concrete mix)	Tire Stack (stacked tires)	Whisper-Wall (crumb tire in concrete mix)	Cast in Place Wall	Pre-Cast Wall	Concrete Block Wall
1	Type of tire material	CRUMB TIRE	PRESSED TIRE MAT	COMPRESSED WHOLE TIRES	STACKED WHOLE TIRES	COMPRESSED TIRE TREADS	CRUMB TIRE	STACKED WHOLE TIRES	CRUMB TIRE	CONCRETE	CONCRETE	CONCRETE
2	Weight of tires per sqft	4.0 lbs /SQFT	4.2 lbs /SQFT	160 lbs /SQFT	30 lbs /SQFT	77.8 lbs /SQFT	2.5 lbs /SQFT	21 lbs /SQFT	2.5 lbs /SQFT	N/A	N/A	N/A
3	Special handling needs	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	N/A	N/A	N/A
4												
5												
6												
7												
8												
9												
10												
	Ranking (1 thru 8)	6	5	1	3	2	7	4	8	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Noise Reduction Assessment

Noise Reduction
Excessive traffic noise is one of the most common complaints among residents. Noise from automobile traffic is primarily from the tires on the pavement. Noise from large trucks is typically engine and exhausts noise and is approximately 8 feet above ground. Noise walls are limited in their ability to reduce noise by their height and density. In order to be effective, a barrier wall must at least block the line of sight from the noise source to the receiver.
These measurement factors present elements that should be considered:

Density of material In the case of a solid surface, the denser and the more uniform the material is, the better the sound is transmitted. Porous material absorbs the noise knocking its surface.

Potential for holes to form Does material have the potential to allow for holes to form on the front face or top of wall?

Reported noise abatement potential The approx level of noise abatement potential for the wall system.

Ability to increase height The ability to add or subtract to the height of the wall system.

	Measurement Factors	Carsonite (tire crumb in wall)	Acoustax (pressed tire mat in wall)	Tire Bales (compressed tires)	Ecoflex (stacked tires with gravel)	Tire-Tie (compressed R.R. ties of tire)	Smart Wall (crumb tire in concrete mix)	Tire Stack (stacked tires)	Whisper-Wall (crumb tire in concrete mix)	Cast in Place Wall	Pre-Cast Wall	Concrete Block Wall
1	Density of material	SUFFICENT FOR NOISE REDUCTION PURPOSES										
2	Potential for holes to form	LOW	LOW	HIGH	HIGH	LOW	LOW	MEDIUM	LOW	N/A	N/A	N/A
3	Reported noise abatement potential	HIGH	HIGH	UNKNOWN	UNKNOWN	UNKNOWN	UNKNOWN	UNKNOWN	HIGH	N/A	N/A	N/A
4	Ability to increase height	EASY	EASY	HARD	HARD	EASY	EASY	MEDIUM	EASY	MEDIUM	MEDIUM	EASY
5												
6												
7												
8												
9												
10												
	Ranking (1 thru 8)	3	3	7.5	7.5	3	3	6	3	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Vegetation Preservation Assessment

Vegetation Preservation
Vegetation preservation is a growing concern that greenery, and trees in particular, are an indispensable part of the urban environment. It is an amenity and aesthetic that contributes to the well being of its residents and visitors. In addition, a well managed "urban forest:" contributes significant infrastructure cost savings in areas such as stormwater, air quality control, and evasive weedy species reduction. These measurement factors present elements that should be considered:

Potential vegetation loss Preferences should be given to vegetation that provides food, cover, and nesting sites for birds and game such as in the Migratory Bird Act (preserve nesting habitats) Also review of the State Governor's Order (less disturbance reduces invasive weedy species).

Ease of maintenance to access back of wall 4-foot clearance of the back of wall for maintenance.

Height of wall affects vegetation Trimming of trees and shadow of the barrier

	Measurement Factors	Carsonite (tire crumb in wall)	Acoustax (pressed tire mat in wall)	Tire Bales (compressed tires)	Ecoflex (stacked tires with gravel)	Tire-Tie (compressed R.R. ties of tire)	Smart Wall (crumb tire in concrete mix)	Tire Stack (stacked tires)	Whisper-Wall (crumb tire in concrete mix)	Cast in Place Wall	Pre-Cast Wall	Concrete Block Wall
1	Potential vegetation lost at 6th Ave site	LOW	LOW	HIGH	HIGH	LOW	LOW	MEDIUM	LOW	LOW	LOW	MEDIUM
2	Ease of maintenance to access back of wall	HIGH	HIGH	LOW	LOW	HIGH	HIGH	MEDIUM	HIGH	HIGH	HIGH	MEDIUM
3	Height of wall affects vegetation	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM
4	Environmental Impact	LIMITED	LIMITED	ELEVATED	ELEVATED	LIMITED	LIMITED	ELEVATED	LIMITED	LIMITED	LIMITED	LIMITED
5												
6												
7												
8												
9												
10												
	Ranking (1 thru 8)	3	3	8	7	3	3	6	3	N/A	N/A	N/A

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Raw Ranking

	Measurement Factors	Carsonite (tire crumb in wall)	Acoustax (pressed tire mat in wall)	Tire Bales (compressed tires)	Ecoflex (stacked tires with gravel)	Tire-Tie (compressed R.R. ties of tire)	Smart Wall (crumb tire in concrete mix)	Tire Stack (stacked tires)	Whisper-Wall (crumb tire in concrete mix)
1	Cost	4	5	1	7.5	3	6	2	7.5
2	Constructability	3	2	5.5	5.5	1	7.5	7.5	4
3	Experience	1	3	7.5	7.5	5	4	6	2
4	Aesthetics	2	3	7.5	5	6	4	7.5	1
5	Availability	6	7	3	5	8	1	4	2
6	Maintainability	3.5	3.5	7.5	7.5	1.5	5.5	1.5	5.5
7	Durability	1	2	7	8	3	5	6	4
8	Tire Use	6	5	1	3	2	7	4	8
9	Noise Abatement	3	3	7.5	7.5	3	3	6	3
10	Vegetation Preservation	3	3	8	7	3	3	6	3
	Total Raw Score	32.5	36.5	55.5	63.5	35.5	46	50.5	40

Note: Ranking by panel consensus

Waste Tire Noise Barrier
Weighted Ranking **(Lower Score Is More Favorable)**

	Measurement Factors	Carsonite (tire crumb in wall)	Acoustax (pressed tire mat in wall)	Tire Bales (compressed tires)	Ecoflex (stacked tires with gravel)	Tire-Tie (compressed R.R. ties of tire)	Smart Wall (crumb tire in concrete mix)	Tire Stack (stacked tires)	Whisper-Wall (crumb tire in concrete mix)	Weighting* Factor
1	Cost	12	15	3	22.5	9	18	6	22.5	**3**
2	Constructability	3	2	5.5	5.5	1	7.5	7.5	4	**1**
3	Experience	7	21	52.5	52.5	35	28	42	14	**7**
4	Aesthetics	16	24	60	40	48	32	60	8	**8**
5	Availability	54	63	27	45	72	9	36	18	**9**
6	Maintainability	7	7	15	15	3	11	3	11	**2**
7	Durability	4	8	28	32	12	20	24	16	**4**
8	Tire Use	36	30	6	18	12	42	24	48	**6**
9	Noise Abatement	15	15	37.5	37.5	15	15	30	15	**5**
10	Vegetation Preservation	30	30	80	70	30	30	60	30	**10**
	Total Weighted Score	184	215	314.5	338	237	212.5	292.5	186.5	
	Weighted Rank	**1**	**4**	**7**	**8**	**5**	**3**	**6**	**2**	
	Meeting Voting	**2**				**1**	**3**			

*Note: Weighting Factor derived by panel consensus

Waste Tire Noise Barrier
State DOTs Contacted

STATE	Recycled Tire Wall Usage	TYPE	Comments
California	NO		
Indiana	N/A		unavailable
Maine	NO		
Minnesota	NO		
New Jersey	NO		
Nevada	**YES**	1500 LF of Carsonite	Due to a potential flammable aspect, NDOT decided not to pursue this wall application after a crash and fire occurred.
North Carolina	NO		
Oregon	NO		
Pennsylvania	NO		
South Carolina	NO		
Texas	NO		
Vermont	NO		
Virginia	N/A		unavailable
Washington	NO		
Wisconsin	NO		

APPENDIX C
NP&G Innovations, Summary Report, NP&G TireTie™

(USED WITH PERMISSION)

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ROCHESTER INSTITUTE OF TECHNOLOGY

Center for Integrated Manufacturing Studies
Rochester Institute of Technology

NP&G Innovations

Summary Report
NP&G TireTie™
October 21, 2008

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1. Background

NP&G Innovations, Inc. (NP&G) has developed an alternative rail cross tie trade named TireTie™. This unique cross tie concept uses the reclaimed treads from discarded car and truck tires as a key embodiment of the product. This avoids the need for ancillary protective treatments like creosote used with traditional wood cross ties. Creosote has been designated as a restricted use material by the EPA. This new cross tie also provides a second use for the over 250 million tires discarded annually in the US.

NP&G has designed and fabricated a test machine that can perform lateral testing on rail cross ties to evaluate the system used to attach the rail to the rail tie. Currently in the United States, the rails are attached to wood cross ties using spikes. However, for these tests the rails are attached to the TireTie™ by screws (see bolt heads in circled area), a method commonly used in Europe.

This fixture with simple modifications also can apply a load to the center of the cross tie in a 3-pt bend configuration.

Figure 1: NP&G TireTie™ Lateral and 3-Point Bend Fixture

2. Results

Using the NP&G Test Fixture and other equipment at RIT, the following tests were performed for NP&G on the following cross tie configurations:

- Three point bend testing:
    - Wood railroad cross tie (oak)
    - Plastic railroad cross tie
    - 11 Gage NP&G TireTie™ (with compression doubler plates)
    - 12 Gage NP&G TireTie™ (with compression doubler plates)
    - 14 Gage NP&G TireTie™ (with bending doubler plates)
- Fatigue testing:
    - Plastic railroad cross tie
    - 11 Gage NP&G TireTie™ (with compression doubler plates)
    - 14 Gage NP&G TireTie™ (with bending doubler plates)
- Compression Testing:
    - 11 Gage NP&G TireTie™ (without compression doubler plates)
    - 11 Gage NP&G TireTie™ (with compression doubler plates)
    - 12 Gage NP&G TireTie™ (with compression doubler plates)
    - 14 Gage NP&G TireTie™ (without compression doubler plates)
    - 14 Gage NP&G TireTie™ (with compression doubler plates)
- Modulus of Rupture Testing (MOR):
    - 14 Gage NP&G TireTie™ (with bending doublers but without compression doubler plates)
    - 12 Gage NP&G TireTie™ (with compression doubler plates)

Additionally, the Sustainable Systems Research Center (SSRC) at RIT performed and Environmental Health and Safety assessment of adhesives used in the manufacture of NP&G's composite cross ties. The SSRC also proposed alternative adhesives and suggested methods for reducing environmental impact.

The objective of this report is to summarize the results of all testing performed by RIT from October 2007 to the present.

A variety of railroad cross ties were tested. Below are the specifications for each:

Wooden Crosstie:

Material:	Oak
Dimensions:	7" x 9" x 102" (height x base x length)

Plastic Cross Tie:

Material:	Extruded Plastic
Dimensions:	7" x 9" x 101" (height x base x length)

NP&G Cross Tie Specifications:

Material:	Composite (Steel webbing w/ automotive tire laminates)
Dimensions:	7" x 9" x 102" (height x base x length)

Note, there were multiple NP&G composite crosstie configurations. All NP&G crossties were steel and tire tread laminate composites, see figure 3 below for crossection details.

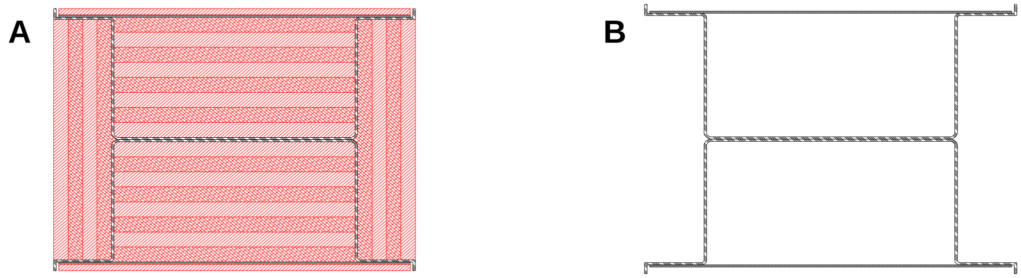


Figure 2: NP&G Tire tie crossection with tire tread laminates (red) (A) and with tread laminates removed showing only the steel webbing. (B)

Further, the NP&G composite cross ties were also tested with and without "doubler plates". The doubler plates are 15" x 5-7/8" 12 gage plates welded to specific regions of the crosstie's steel webbing prior to installation of tread laminates. Figure 4 below depicts the doubler plate locations.

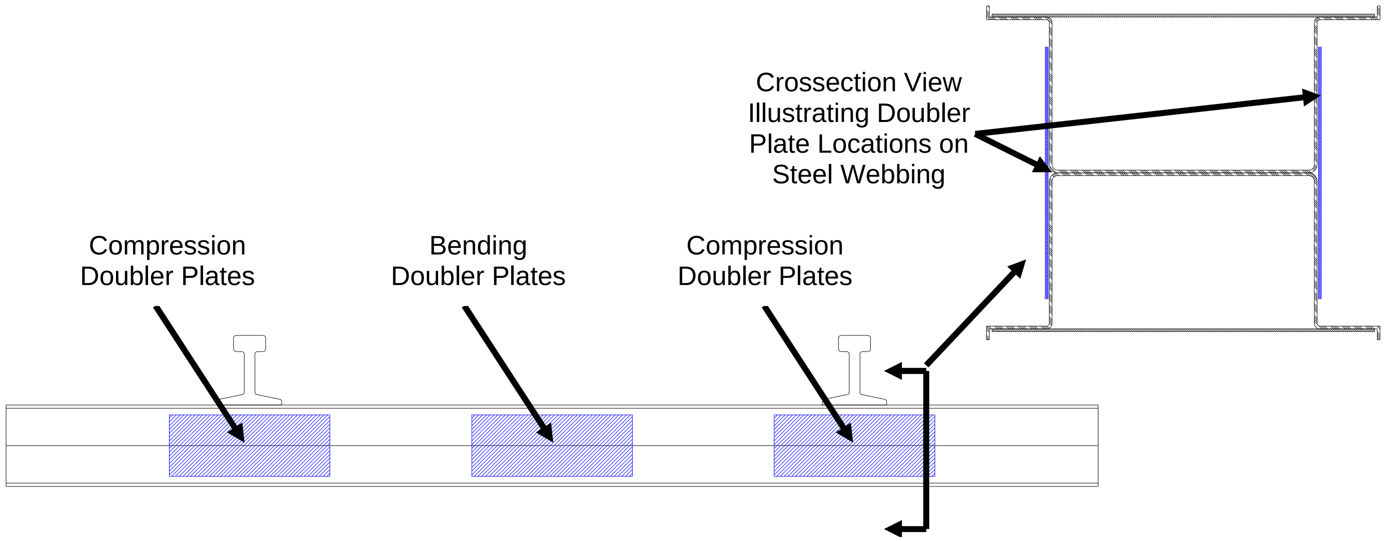


Figure 3: Illustrations of NP& G Tire Tie doubler plate locations.

NP&G provided (6) configurations of its composite cross tie;

1. 11 gage steel webbing with and without compression doubler plates
2. 12 gage steel webbing with and without compression doubler plates
3. 14 gage steel webbing with and without bending doubler plates.

It should be noted also that no cross tie provided had both compression and bending doubler plates installed.

A. 3-Point Bend Testing:

The 3 point bend test was performed on the NP&G cross tie test fixture depicted in figure 1. The crosstie under test was supported by two plastic blocks 60 inches apart with a vertical load applied centered between the two blocks. Figure 4 below shows the support and loading configuration.

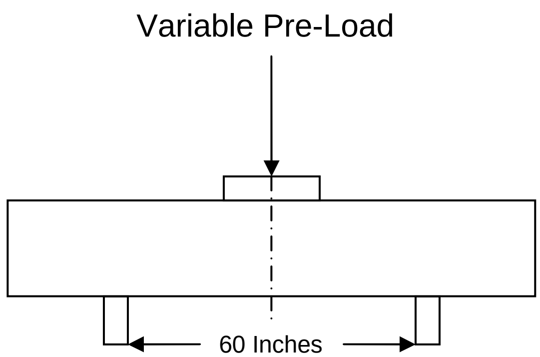


Figure 4: Three Point Bend Test Configuration

NP&G Crosstie configurations for the 3 point bend test included:
1. 11 gage steel webbing with compression doubler plates installed
2. 12 gage steel webbing with compression doubler plates installed
3. 14 gage steel webbing with bending doubler plates installed.

Table 1 contains the results of the 3-point bend tests performed at RIT

Table 1: Three Point Bend Results all deflections in inches.

Preload (Pounds)	Wood Tie Deflection	Plastic Tie Deflection	NP&G 11 Gage Deflection	NP&G 12 Gage Deflection	NP&G 14 Gage Deflection
1000	0.015	0.118	0.071	0.042	0.080
3000	0.080	0.458	0.089	0.072	0.106
5000	0.120	0.560	0.114	0.087	0.141
7000	No data	0.781	0.138	0.111	0.170
8000	0.195	No data	0.152	0.118	0.185
10,000	0.235	No data	0.173	0.152	0.195
12,000	0.280	No data	0.194	0.181	0.222
14,000	0.320	No data	0.216	0.225	No Data

These results were then compared to the 3-point bend results of a wood rail tie and the NP&G TireTie™ measured and reported by Vossloh Switch System in Test Report IX ES 0118 Rev 0, Tyre tie prototype Pull out, bending and Fatigue tests, 15 June 2007. Figure 5 contains these results.

Figure 5 also shows that the CIMS 3-point bend test results for the wood rail road tie were very similar to the Vossloh wood tie 3-pont bend results (plots overlap). It should be noted that the wooden crosstie used in the Vossloh evaluation had a cross section of 5.90" x 13.77", as opposed to the wood crosstie tested at RIT which had a cross section of 7" x 9".

Figure 5 also shows that the NP&G cross ties had the least deflection per given load and the plastic tie had the most deflection. The 3-point bend test performed on the plastic tie was stopped after deflecting 0.78" at a loading of 7000lbs.

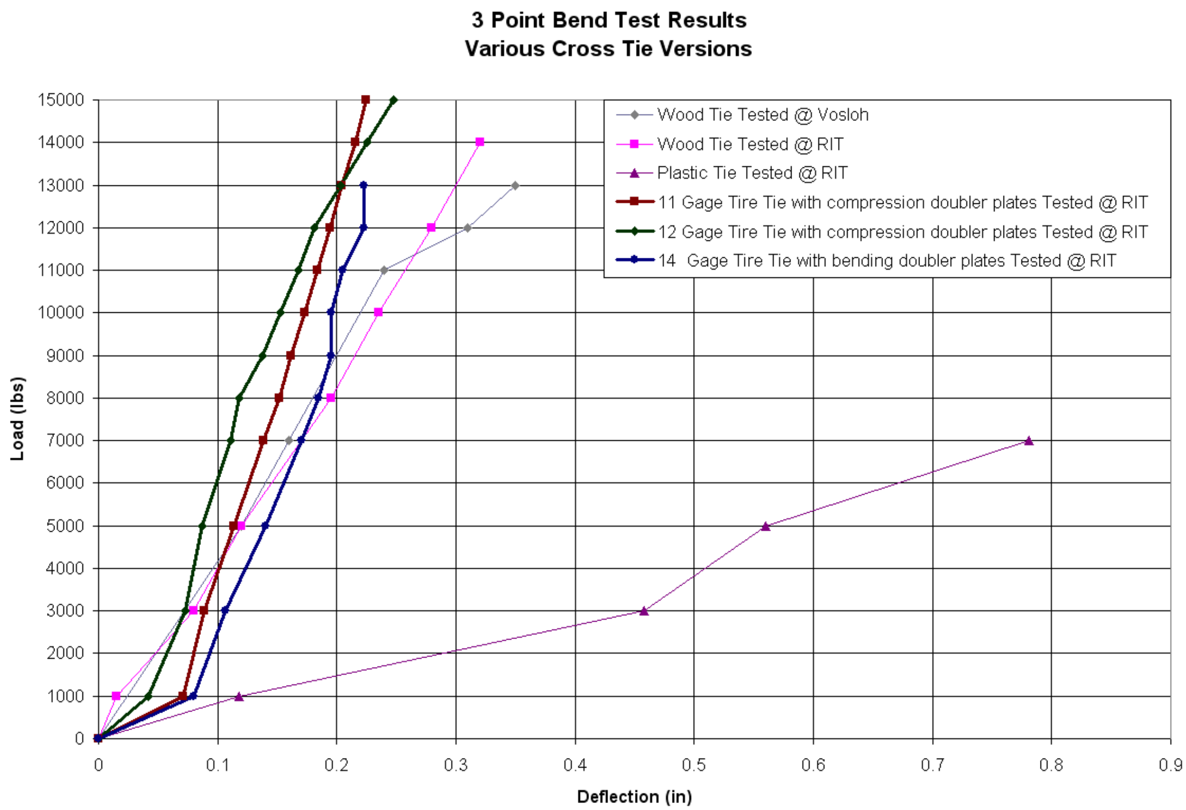


Figure 5: Three Point Bend Results all deflections in inches.

B. Fatigue Testing:

Fatigue testing was also performed on the NP&G cross tie test fixture depicted in figure 1.

The test conditions were:

- 20,000 pound load was applied normal to the rail, and
- Cyclic load of 8,000 pounds extend and 4,000 pounds retract.

The lateral movement of the top of the rail, top of the rail plate, and top of TireTie™ were measured using a laser gauge after ~150,000, 500,000, ~1.5 million and ~2.0 million cycles.

Three cross ties were fatigue tested at RIT:

1. Plastic Cross tie
2. NP&G composite cross tie with 11 gage steel webbing and compression doubler plates
3. NP&G composite cross tie with 14 gage steel webbing and bending doubler plates

Figures 6, 7 and 8 show the position of the laser gauge for the three measurements.

Figure 6: Laser Orientation for Interrogating the "Top of Rail" displacement.

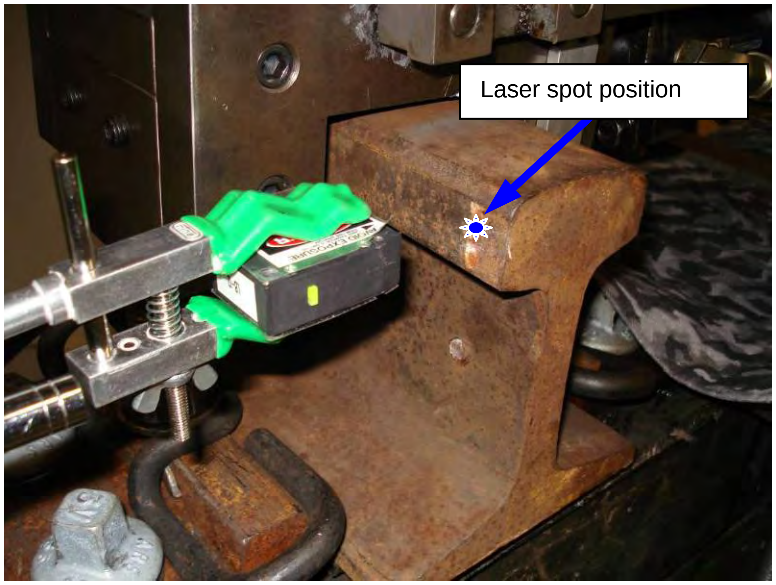


Figure 7: Laser Orientation for Interrogating the "Rail Plate" Displacement.

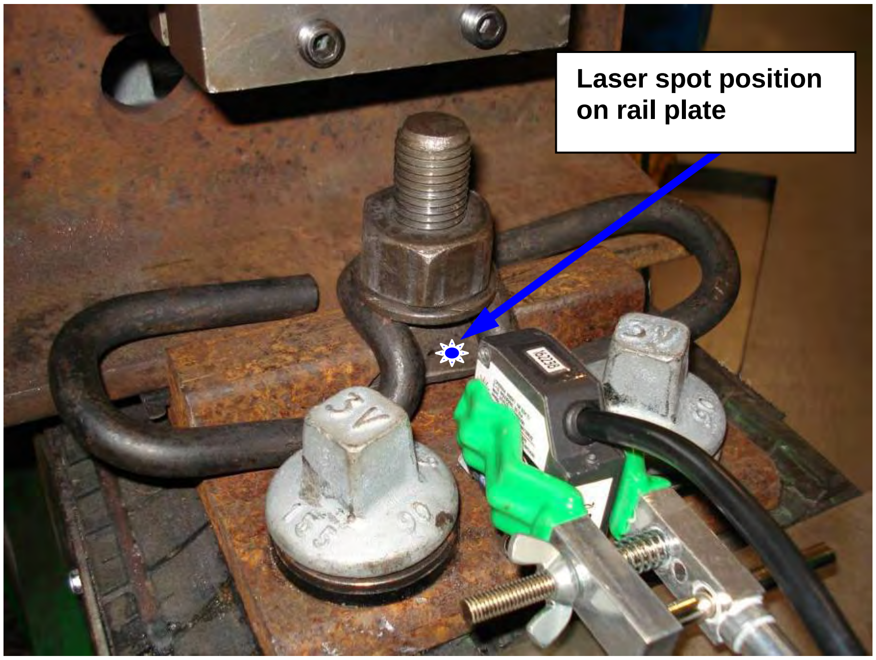
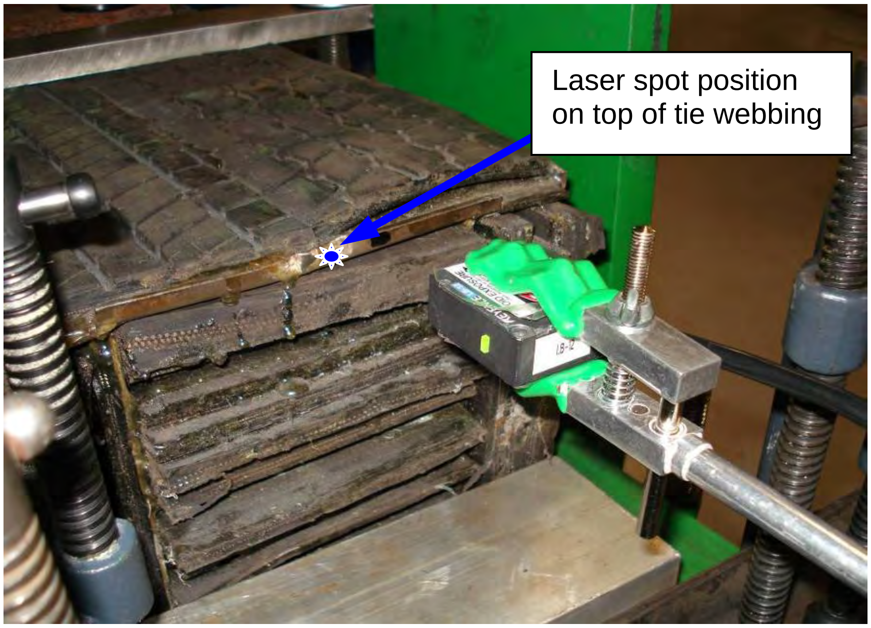


Figure 8: Laser Orientation for Interrogating the "Top of Tie" Displacement.



The results for the laser displacement measurements are illustrated in Figures 9, and 11 as well as tables 2 and 3.

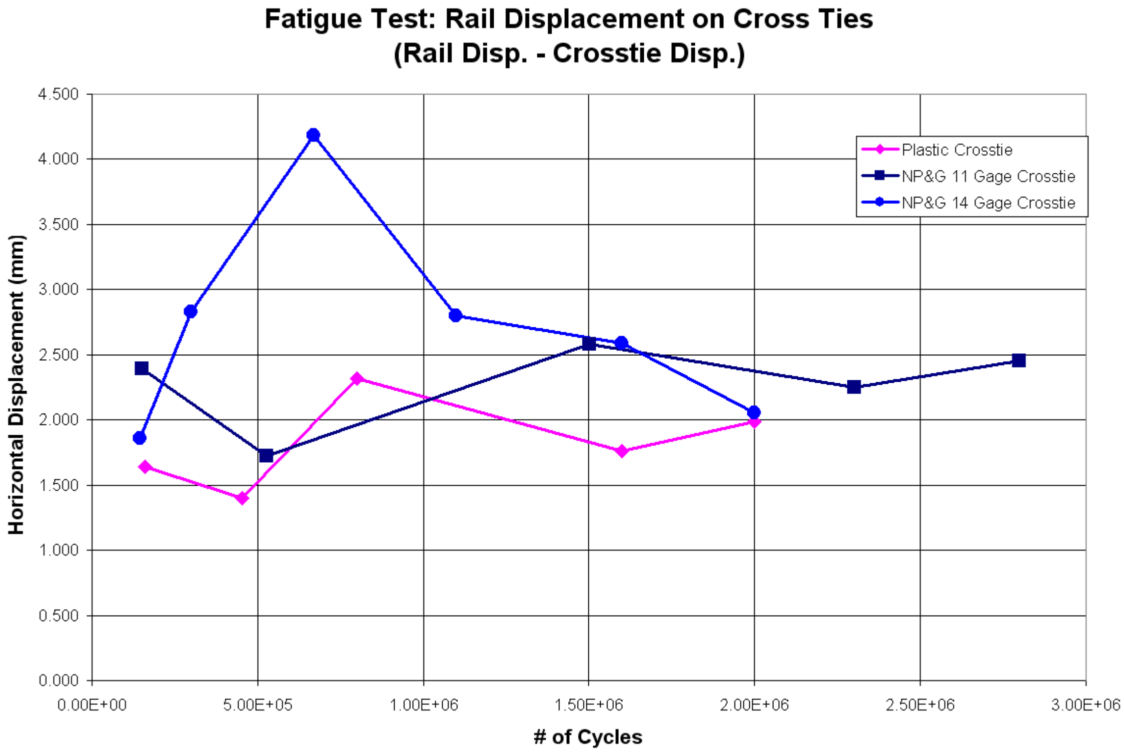


Figure 9: Fatigue test results (deflection of top of rail – deflection fo the cross tie top surface) for the two configurations of the NP&G composite cross tie and the plastic cross tie.

Figures 9 and 11 show that the NP&G TireTie™ was not adversely affected by 2 million+ cycles of fatigue testing. More specifically, none of the attachment screws failed and there was no significant change in the top rail lateral deflection (Table 2 column 5).

Figure 8 depicts the shear loading that is induced on a crosstie due to lateral loading of the rail during test. Figure 9 shows the amount of displacement or shear from the top of the rail to the bottom (assuming no slip at the bottom of the crosstie).

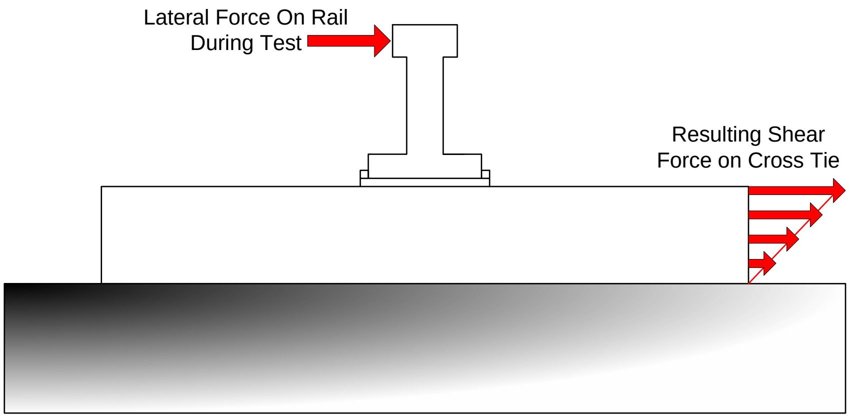


Figure 10: Depiction of shear loading on cross tie as a result of lateral loading of the rail.

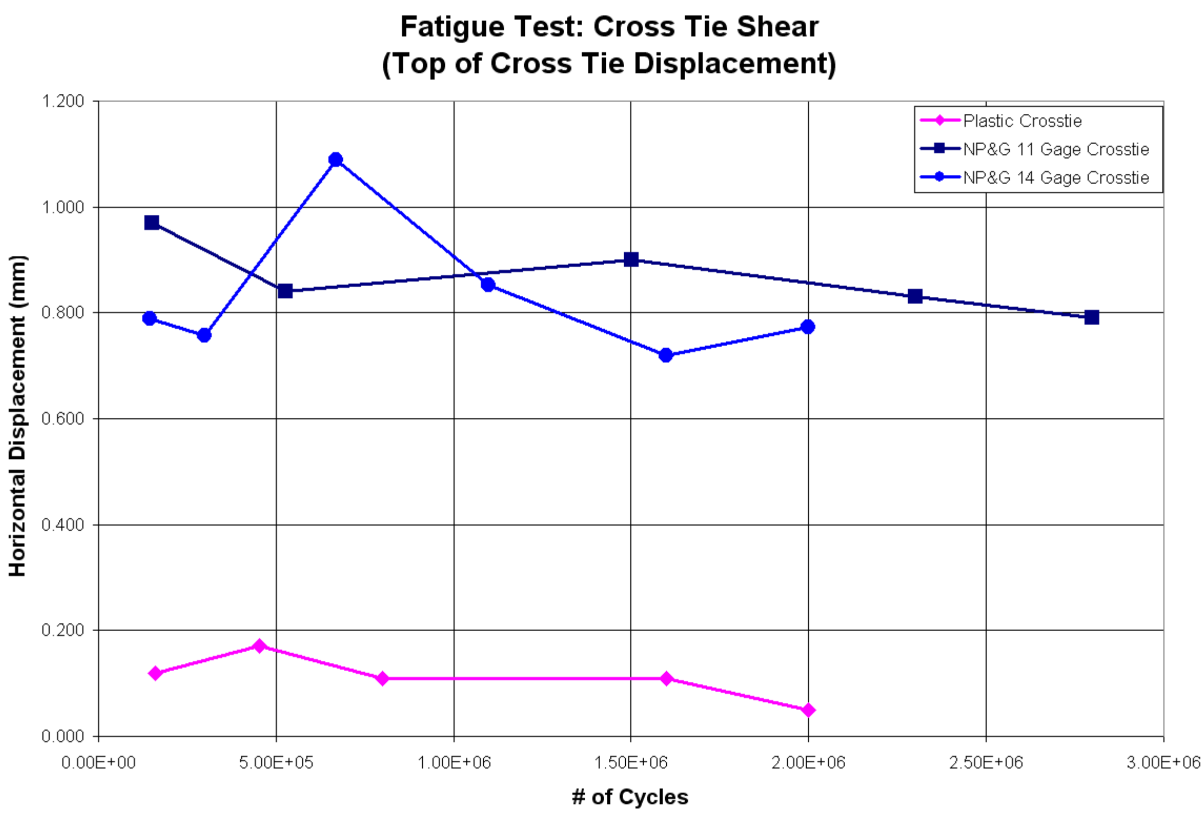


Figure 11: Fatigue test results (cross tie surface deflection) for the two configurations of the NP&G composite cross tie and the plastic cross tie.

Table 2: NP&G 11 gage composite cross tie; Top of Rail, Rail Plate, and Top of crosstie Deflection

Number of Cycles	Top of Rail Displacement (mm)	Rail Plate Displacement (mm)	Top of Cross Tie Displacement (mm)	(Top of Rail)– (Top of Tie) Displacement (mm)
150K	3.360	2.210	0.970	2.390
528K	2.560	1.390	0.840	1.720
1.5M	3.480	1.830	0.900	2.580
2.3M	3.080	1.810	0.830	2.250
2.8M	3.240	1.880	0.790	2.450

Table 3: NP&G 14 gage composite cross tie; Top of Rail, Rail Plate, and Top of crosstie Deflection

Number of Cycles	Top of Rail Displacement (mm)	Rail Plate Displacement (mm)	Top of Cross Tie Displacement (mm)	(Top of Rail)– (Top of Tie) Displacement (mm)
145K	2.645	1.635	0.789	1.856
300K	3.587	1.645	0.756	2.830
670K	5.271	2.640	1.089	4.182
1.1M	3.650	1.570	0.853	2.797
1.6M	3.310	1.361	0.720	2.590
2.0M	2.826	1.255	0.773	2.054

Table 4: Plastic cross tie; Top of Rail, Rail Plate, and Top of crosstie Deflection

Number of Cycles	Top of Rail Displacement (mm)	Rail Plate Displacement (mm)	Top of Cross Tie Displacement (mm)	(Top of Rail)– (Top of Tie) Displacement (mm)
1.6K	1.760	0.420	0.120	1.640
454K	1.570	0.540	0.170	1.400
800K	2.430	0.670	0.110	2.320
1.6M	1.870	0.480	0.110	1.760
2.0M	2.040	0.460	0.050	1.990

Table 2 shows that after 2.8 million cycles the actual rail displacement (Column 5) was approximately equal to the actual rail deflection after 150,000 cycles. Thus, cycling the rail in the NP&G TireTie™ for 2.8 million cycles did not cause any significant increase in the top of the rail lateral displacement.

Similarly Table 3 shows that the 14 gage NP&G cross tie performed within acceptable parameters.

Both the "Tire Tie" and plastic crosstie did not show a large increase in the amount of lateral displacement from the start to the conclusion of the fatigue tests. The amount of displacement of both ties were well below the maximum allowable movement (0.25" = 6.35mm).

It should be noted that the decrease in top of the rail lateral displacement after 528,000 test cycles probably occurred because after the 150,000 cycle test two of the bolts were torqued to 350 ft-lbs. Also, at the end of the 528,000 cycle run the rail was removed and replaced to enable fixture maintenance.

C. Compression testing Testing:

Compression testing consisted of vertically loading a cross tie while it was rigidly supported on its bottom surface from a preload force of 200 to 1000lbs to a maximum load of 100,000 lbs (100Kips). Failure of the specimen is demonstrated by the point in the load vs. deflection graph were a knee is apparent. Further, physical buckling of the specimen is often visually apparent.

Figure 12 below depicts the test apparatus setup. In this evaluation, a Tinius Olsen Compression Test Apparatus was used to apply the required test loads.

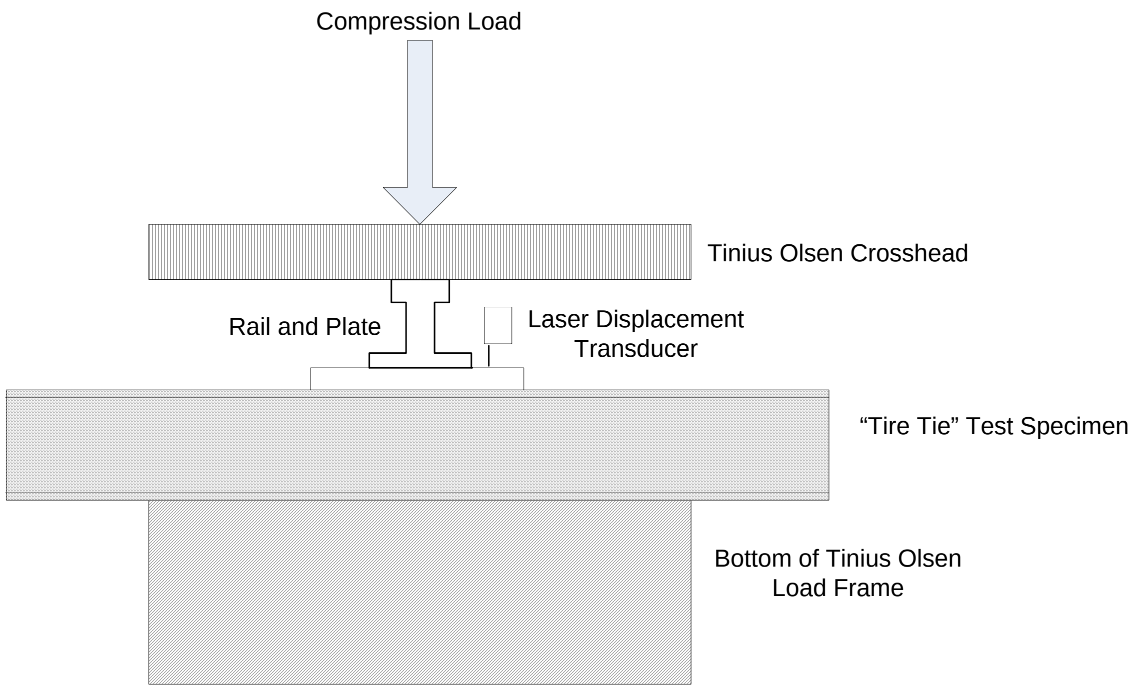


Figure 12: Compression test setup

Testing constituted the following load settings:
1) 200lb preload
2) 20 KIP load
3) 40 KIP load
4) 60 KIP load
5) 80 KIP load
6) 100 KIP load
7) Return to 0 load

Compression testing was performed on (5) versions of the NP&G composite cross tie:

1. 11 gage steel webbing with out compression doubler plates installed
2. 11 gage steel webbing with compression doubler plates installed
3. 12 gage steel webbing with compression doubler plates installed
4. 14 gage steel webbing with out compression doubler plates installed
5. 14 gage steel webbing with compression doubler plates installed

Figure 13 below illustrates the results of the compression tests on the aforementioned cross ties. Tables 5, shows the results of the compression test

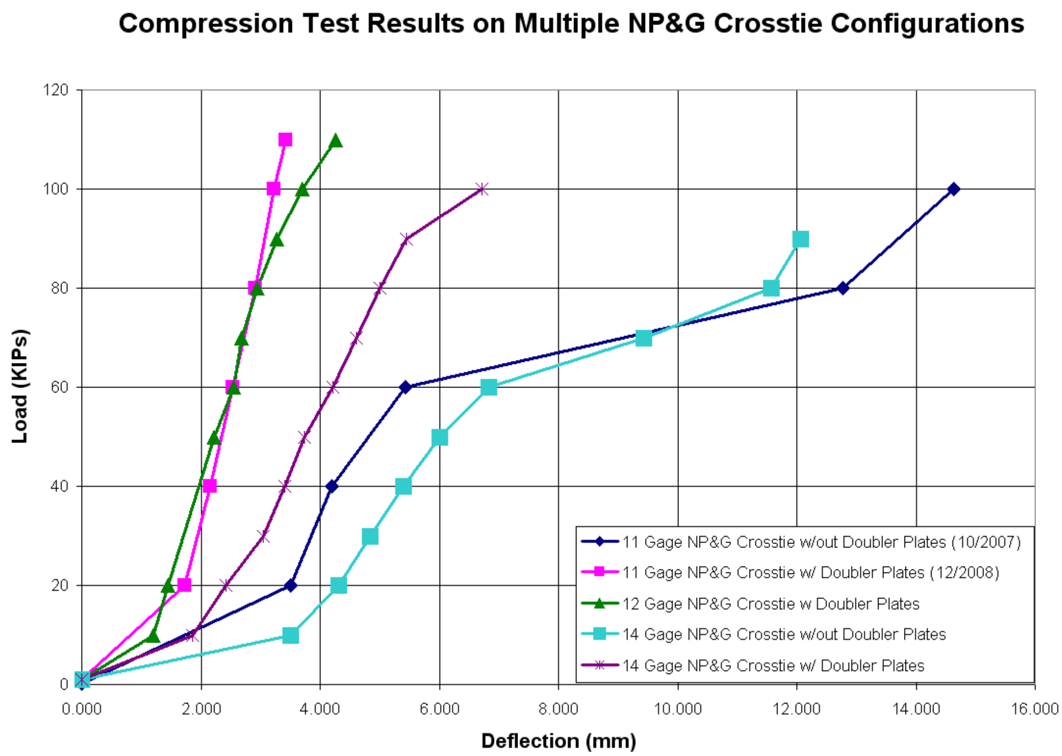


Figure 13: Compression test results Load (kips) vs deflection in (mm)

Table 5: Compression test results Load (kips) vs deflection in (mm) Note that at the end of each data set is a recovery value which indicates the final deflection when the majority of the load is released.

Configuration	Compression Load (KIPS)	Displacement (mm)
11 Gage NP&G Cross Tie w/ out Doubler 10/2007	0.2	0.000
	20	3.505
	40	4.191
	60	5.436
	80	12.776
	100	14.630
	0	6.629
11 Gage NP&G Cross Tie w/ Doubler 12/2008	1	0.000
	20	1.727
	40	2.159
	60	2.540
	80	2.921
	100	3.226
	110	3.429
	0	0.508
12 Gage NP&G Cross Tie w/ Doubler Plates 5/2008	1	0.000
	10	1.200
	20	1.450
	50	2.230
	60	2.550
	70	2.680
	80	2.950
	90	3.270
	100	3.700
	110	4.270
	1	1.490
14 Gage NP&G Cross Tie w/out Doupler Plates 5/2008	1	0.000
	10	3.500
	20	4.310
	30	4.840
	40	5.400
	50	6.000
	60	6.830
	70	9.440
	80	11.570
	90	12.070
	1	5.270
14 Gage NP&G Cross Tie w/ Doubler Plates 5/2008	1	0.000
	10	1.860
	20	2.420
	30	3.040
	40	3.400
	50	3.730
	60	4.220
	70	4.610
	80	5.010
	90	5.450
	100	6.710
	1	2.060

D. Modulus of Rupture Testing (MOR):

Modulus of rupture also known as flexural strength, bending strength or fracture strength is typically measured in terms of stress. The value is the highest stress experienced within the material at it moment of rupture. A common method of performing a MOR test is to continue a 3 point bend test until the specimen fails. For this evaluation MOR testing consisted of vertically loading a cross tie while it was simply supported on its bottom surface.

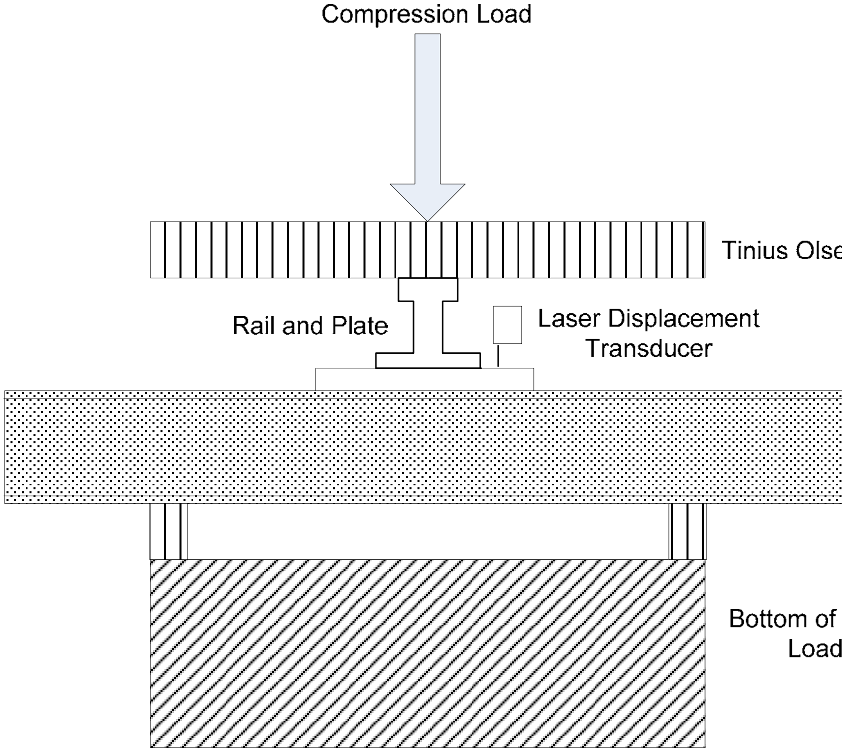


Figure 14: Test setup for MOR evaluation using the Tinius Olsen compression tester.

It should be noted that while the three point bend test lower supports were 60 inches apart, the supports on this evaluation were much closer (approximately 48") due to the size limitation of the load frame of the Tinius Olsen compression tester.

For this evaluation only two configurations of the NP&G composite cross tie were evaluated:

1. 12 gage steel webbing with out doubler plates.
2. 14 gage steel webbing with bending doubler plates

Figure 15 below illustrates the results of the two MOR tests.

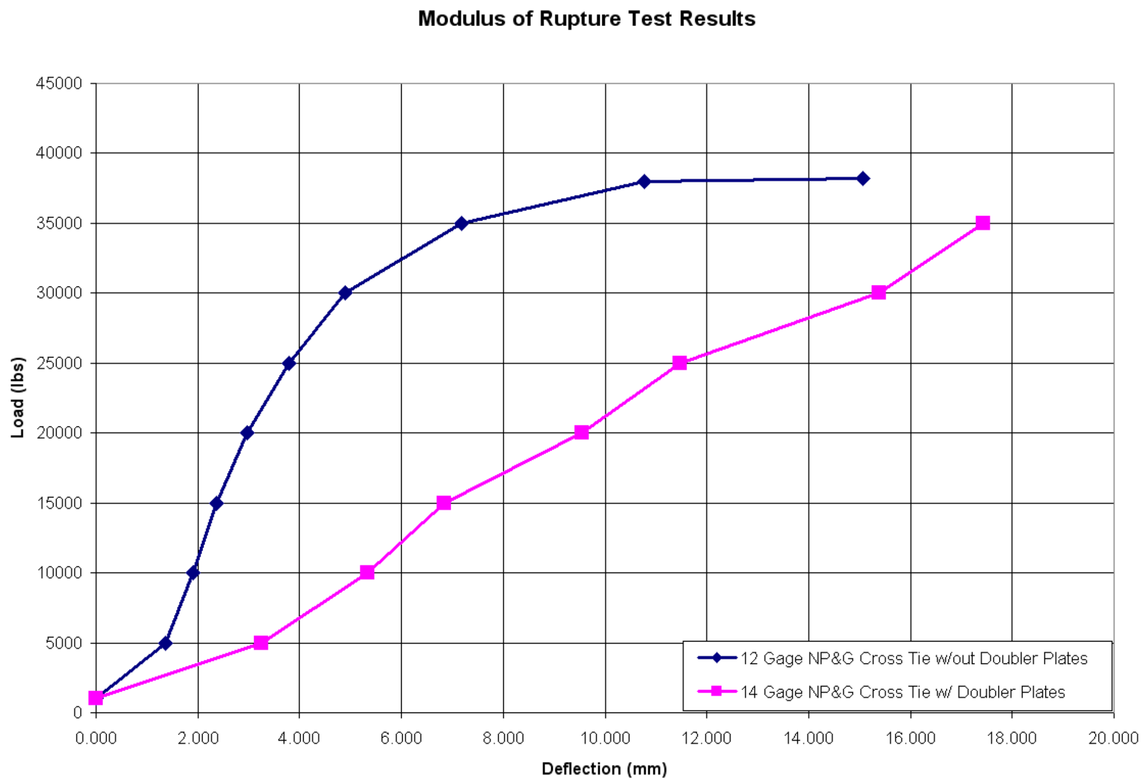


Figure 15: MOR test results for the NP&G 12 and 14 gage composite cross ties.

It should be pointed out that while the data from the 12 gage cross tie is consistent with expected results, the data from the 14 gage cross tie is not. Severe compression of the lower cross tie supports, coupled with substantial cross tie deflection prevented realization of the cross tie rupture. Essentially the 14 gage cross tie deflected until the center point made contact with the load frame platform, thus ending the test prematurely.

E. Environmental Health and Safety Performance Results:

SSRC engaged in two principal activities during the course of this project.

1. Provided technical assistance in the evaluation of the environmental, health and safety aspects of the two adhesives

Adhesive	Manufacturer	Bond Type
EP 1215 Clear, Two Part Epoxy Adhesive	Resinlab L.L.C	Tire rubber to steel core
3M Scotch-Weld Neoprene High Performance Contact Adhesive 1357	3M, Industrial Adhesives and Tapes Division	Tire rubber to tire rubber

(referred to as "1215" and "1357").

2. Assisted NP&G in identifying alternative adhesives with low environmental health & safety impact.
3.

The methods used to conduct these activities are described below.

1. Evaluation of the 1215 and 1357 adhesives

a. <u>1215</u>

The 1215 adhesive is a two part epoxy designed for bonding applications requiring high strength and good impact resistance. It is designed to chemically cure at room temperature but its curing time can be accelerated by the application of heat.

The MSDSs identify three hazardous[1] ingredients for the 1215, as indicated in the table below (the full MSDSs are presented in Appendix A). The MSDSs do not indicate the percent composition of each hazardous ingredient in the product.

1215 Adhesive Component	Ingredient Name	CAS Number	% by Wt
EP 1215 Part A	Bisphenol-A Type Epoxy Resin	25068-38-6	Not provided
EP 1215 Part B	Polyamide Resin	NA	Not provided
	Hydrogenated Terphenyls	61788-32-7	Not provided

[1] According to U.S. Occupational Safety and Health Administration (OSHA), Hazard Communication Standard (*Title 29, Code of Federal Regulations,Part 1910.1200),* a chemical manufacturer must provide a Material Safety Data Sheet (MSDS) for each product manufactured listing any hazardous ingredient. See http://www.osha.gov/dsg/hazcom/ghd053107.html for a description of OSHA's guildelines for determining whether a chemical is hazardous.

SSRC engaged Paradigm Environmental Services, Inc. in Rochester New York[2] to perform environmental chemical analysis of the 1215 adhesive. The focus of the testing was on the Bisphenol-A (BPA) component of the adhesive since this chemical is an endocrine disruptor[3] and recent studies have found that BPA exposure during fetal development has carcinogenic effects and produces precursors of breast cancer.[4]

The objective of the test was to determine if the BPA would leach out of the cured adhesive into water. The testing of the 1215 involved several steps. First a thin sample of cured adhesive was prepared according to the manufacturer's instructions. Second, the sample was subjected to a set of simulated outdoor conditions: Water immersion, low pH, salinity and elevated temperature. The leachate was then analyzed for the presence of BPA. There was no detectable BPA in the sample extract. The full laboratory report is attached in Appendix B.

While the laboratory tests indicate that no detectable amount of BPA leached from the adhesive, there is still potential for exposure at the point of manufacture, handling and use of the BPA-based adhesive to fabricate the ties.

[2] Paradigm Environmental Services, Inc. is certified by the New York State Department of Health to perform environmental analysis of air, water and waste.
[3] See for example, the National Institute for Environmental Health Sciences http://www.niehs.nih.gov/health/topics/agents/endocrine/docs/endocrine.pdf, accessed on October 18, 2007.
[4] See for example, Tessa J. Murray, Maricsel V. Maffini, Angelo A. Ucci, Carlos Sonnenschein, and Ana M. Soto, "Induction of mammary gland ductal hyperplasias and carcinoma in situ following fetal bisphenol A exposure, Reprod Toxicol. 2007; 23(3): 383–390.

a. 1357

The 1357 adhesive is a one-part neoprene-based[5] contact adhesive with high initial bond strength and heat resistance. This adhesive can dry at room temperature or can be force dried with heat, which will accelerate the removal of the solvent fraction.

The table below identifies the following ingredients for the 1357 as indicated in the MSDSs (the full MSDSs are presented in Appendix C).

1357 Ingredient Name	CAS Number	% by Wt
Petroleum Distillates	64742-89-8	10 - 30
Petroleum Distillates	64741-84-0	10 - 30
Acetone	67-64-1	10 – 30
Methyl Ethyl Ketone	78-93-3	7 - 13
Magnesium Resinate	68611-24-5	7 - 13
Polychloroprene	9010-98-4 7	7 - 13
n-Hexane	110-54-3	5 - 10
Toluene	108-88-3	3 – 7
Zinc Oxide	1314-13-2	0.1 - 1

SSRC engaged Paradigm Environmental Services, Inc. in Rochester New York[6] to perform environmental chemical analysis of the 1357 adhesive. In this case, the focus of the testing was on the volatile solvents present in the wet adhesive. Four tests were conducted. In all cases, a thin layer of adhesive was made and dried. The sample was then submerged in a liquid which was subsequently analyzed for the presence of volatile compounds using EPA Test Method 8260B.

[5] Neoprene is a synthetic rubber based on polychloroprene.

[6] Paradigm Environmental Services, Inc. is certified by the New York State Department of Health to perform environmental analysis of air, water and waste.

The four tests differed as follows:

Test 1: The sample was air dried for 24 hours
Test 2: The sample created for Test 1 was held in ambient conditions for 30 days and then retested.
Test 3: The sample created for Test 1 was placed in an oven for 1 hour at 103 degrees centigrade
Test 4: A new sample was created and placed in an over for 65 hours at 103 degrees centrigrade

In Tests 1 through 3, levels of volatile compounds were detected in the range of 0.6 ppm to almost 2,000 ppm, with Test 3 showing the lowest levels. Volatiles analyzed in Test 4 were non-detect (i.e., not detectable) with the exception of Toluene which was detected at a level of 13 parts per billion (ppb). The full laboratory report is attached in Appendix D.

2. Identifying alternative adhesives with low environmental health & safety impact
SSRC initiated an investigation into alternative adhesives with Franklin International – a large adhesive manufacturing company with an established "green" adhesive product line. The company identified a possible alternative – Titebond WeatherMaster™ Sealant – that was performance tested both by Franklin and NP&G. The product is a polymeric adhesive. The MSDS, prepared by Franklin International, reports no solvents, isocyanates or other chemicals considered hazardous by OSHAs (see MSDS in attachment E).

NP&G's testing was deemed unsuccessful. The layers of tire tread were easily separated by hand after air drying.

Franklin's initial testing yielded results that Franklin deemed positive. A six by 2 inch sample of steel and tread was glued under moderate pressure to enhance contact between the tread and the steel. After air drying, the bond between the two components was found to be "adequate." In this first phase test, Franklin did not conduct quantitative testing of bond strength, though they subjectively estimated the bond strength to be in the range of 30 to 40 pounds per linear inch or PLI. According to Lu Gilbert at NP&G, tests conducted by the suppliers of the 1215 and 1357 adhesives reported test results from a pull-type test in the range of 125 PLI. A minimum PLI requirement for the product has not been determined by NP&G.

3. Conclusions

The CIMS three point bend test results for the wood rail road tie were very similar to the results obtained from Vossloh Switch Systems as reported in their test report IX ES 0118 rev 0, dated June 15, 2007. All configurations of the NP&G composite cross ties showed less deflection at loads above 4000 lbs that the wood or the plastic cross ties. The plastic cross tie testing was stopped at 7000lbs due to the amount of deflection realized.

The NP&G TireTie™ successfully passed a 2.8 million cycle fatigue test with the 11 gage composite cross tie and a 2.0 million cycle fatigue test with the 14 gage cross tie. . During the tests, no damage occurred to the NP&G cross ties and the amount of top rail lateral displacement did not increase significantly.
Both the NP&G Tire Tie and the plastic crosstie had maximum lateral displacement values well below the maximum allowable limit of 0.25" (6.36mm).

The results of the compression testing on various configurations of the NP&G composite cross tie illustrated the positive effect of the utilization of doubler plate to increase overall stiffness of the cross ties. As expected, the cross ties manufactured of the larges gage steel webbing and doubler plates performed better that lighter steel webbing with and without the doublers. The limited testing indicates that a compromise between webbing gage can be made with the utilization of the doubler plates.

The completed MOR testing had limited results. The 12 gage composite cross tie demonstrated a plastic deformation but the 14 gage composite cross tie did not. Due to the incomplete data set and the lack of data on other cross tie products (wood, plastic etc), limited conclusions can be made at this time.

The environmental research conducted found the following:
1. The Bisphenol-A component of the 1215 adhesive did not leach into water under in a laboratory test designed to simulate outdoor environmental conditions;
2. The volatile fraction of the 1357 adhesive can be effectively driven off, prior to the installation of the tire tie in the outdoor environment, by exposure to heat over a period of time. Testing during this project yielded good results with a 65 hour dwell time. The optimal dwell time was not determined.
3. The ability of the Franklin International WeatherMaster product to deliver an acceptable bond strength is uncertain at this time. Additional quantitative testing by Franklin is required to compare performance to the 1215 and 1357.

SSRC recommended the following:
1. NP&G continue to pursue alternative adhesives without hazardous ingredients.
2. If NP&G decides to use the 1215 and 1357 adhesives in full-scale product manufacturing, it should ensure that proper engineering procedures and controls are utilized to minimize both worker exposure to these adhesives and environmental emissions from the manufacturing facility.

APPENDIX D
Plan Set for Waste Tire Noise Wall Design

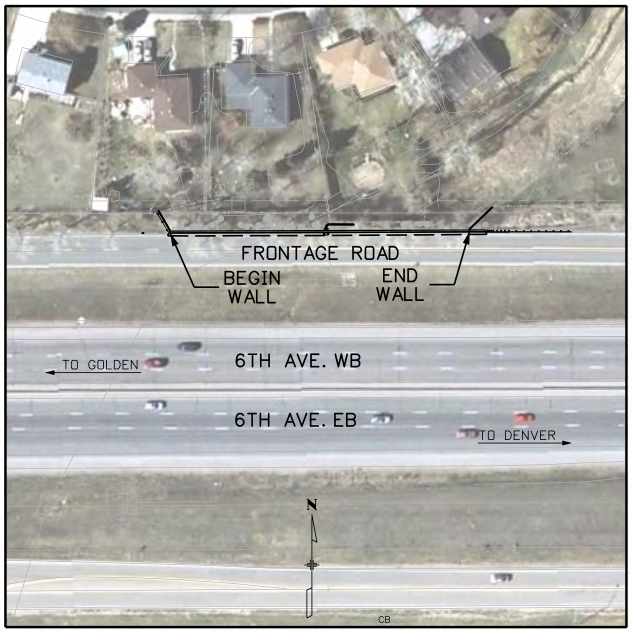
Oversight / NHS	
FHWA REGION VIII OVERSIGHT?	■ NO □ YES
NATIONAL HIGHWAY SYSTEM?	□ NO □ YES

DEPARTMENT OF TRANSPORTATION
STATE OF COLORADO

Related Projects:
P.E. UNDER PROJECT:
Project Number XXXXXXXXX
Project Code: XXXXX

R.O.W. Projects:
R.O.W. Project Description
XXXXXXXXXXXXXXX

HIGHWAY CONSTRUCTION BID PLANS OF PROPOSED
US 6 NOISE WALL AT NORTH FRONTAGE ROAD,
COORS STREET TO ALKIRE STREET
FEDERAL AID PROJECT NO. 0062-024
STATE HIGHWAY NO. 6
JEFFERSON COUNTY
CONSTRUCTION PROJECT CODE NO. 17198



PROJECT LOCATION MAP

0' 50' 100' 200'

FOR ADVERTISEMENT
March 27, 2009

Print Date: 3/27/2009
File Name: 01579DES_TitleSht.dgn
Horiz. Scale: 1:100 Vert. Scale: As Noted
Unit Information Unit Leader Initials

Sheet Revisions		
Date:	Comments	Init.

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Region 6 Central Engineering PDJ

As Constructed
No Revisions:
Revised:
Void:

WASTE TIRE NOISE WALL
TITLE
SHEET

Designer: J. Christopher
Detailer: R. Amack
Sheet Subset: Title
Structure Numbers
Subset Sheets: TL-1 of 1

Project No./Code
C 0062-024
SA 17198
Sheet Number 1

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□ M-203-2	□	DITCH TYPES	5
□ M-203-11	□	SUPERELEVATION CROWNED AND DIVIDED HIGHWAYS (3 SHEETS)	6-8
□ M-203-12	□	SUPERELEVATION STREETS (2 SHEETS)	9-10
□ M-206-1	□	EXCAVATION AND BACKFILL FOR STRUCTURES (2 SHEETS)	11-12
□ M-206-2	□	EXCAVATION AND BACKFILL FOR BRIDGES (2 SHEETS)	13-14
■ M-208-1	□	TEMPORARY EROSION CONTROL (7 SHEETS)	15-21
□ M-210-1	□	MAILBOX SUPPORTS (2 SHEETS)	22-23
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□ M-606-13	□	GUARDRAIL TYPE 7 F-SHAPE BARRIER (4 SHEETS)	77-80
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□ S-614-1	□	GROUND SIGN PLACEMENT (2 SHEETS)	136-137
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■ S-614-3	□	CLASS II SIGNS	139
□ S-614-4	□	CLASS III SIGNS (3 SHEETS)	140-142
□ S-614-5	□	BREAK-AWAY SIGN SUPPORT DETAILS FOR GROUND SIGNS (2 SHEETS)	143-144
□ S-614-6	□	CONCRETE FOOTINGS AND SIGN ISLANDS FOR CLASS III SIGNS (2 SHEETS)	145-146
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THE STANDARD PLAN SHEETS INDICATED HEREON BY A MARKED BOX ARE TO BE USED TO CONSTRUCT THIS PROJECT.

ALL OF THE M&S STANDARD PLANS, AS SUPPLEMENTED AND REVISED, APPLY TO THIS PROJECT WHEN USED BY DESIGNATED PAY ITEM OR SUBSIDIARY ITEM.

COLORADO
DEPARTMENT OF TRANSPORTATION

STANDARD PLANS LIST
M&S STANDARDS
July 04, 2006

Print Date: 3/27/2009	Sheet Revisions (Date: / Comments / Init.)	Colorado Department of Transportation	As Constructed
File Name: 01579DES_Standard_Plans_List.dgn		425 B Corporate Circle, Golden, CO 80401, Phone: 720-497-6961 FAX: 720-497-6951	No Revisions:
Horiz. Scale: 1:1 Vert. Scale: As Noted		Region 6 Central Engineering PDJ	Revised:
Unit Information Unit Leader Initials			Void:

WASTE TIRE NOISE WALL STANDARD PLANS LIST		Project No./Code
Designer: J. Christopher	Structure Numbers	C 0062-024
Detailer: R. Amack		SA 17198
Sheet Subset: Wall	Subset Sheets: SP-1 of 1	Sheet Number 2

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GENERAL NOTES

For plan quantiti ... ls, the following rates o
used:

Tack Coat Dil ... .@ 0.1 Ga
Hot Mix Aspha ... .@ 110 Lb
Aggregate Bas ... .@ 133 Lb

Water shall be us ... e where required. Locati
directed by the E

The following sha ... ach bituminous paver:
1. A ski typ ... eet in length.
2. Short ski
3. 257 Feet ... akes.

Any layer of hot ... have a succeeding layer
be completed full ... ng layer is placed.

Asphalt joints sh ... ulders lines on median li

service laterals ... rior to beginning excavati

Contractor shall ... potential conflicts with e
facilities with th ... as shown on the plans or
markings. If con ... posed construction plans
buried utility fac

It is estima ... thermoplastic pavement marking will be
required
on this proj
White.... ... feet

It is estima ... pprox. 10 tons) of hot mix asphalt (patching)
(asphalt) wi ... ect.

The existing ... ll be matched. If existing pavement section
includes agg ... e and depth of the aggregate base course
shall be mat ... ement section. The aggregate base course
will not be ... all be included in the cost of hot mix
asphalt (pat

Where new pa ... pavement, the existing pavement shall be
removed to a ... cutting saw or other method as approved by
the Engineer. ... not be paid for separately, but shall be
included in ... alt Mat.

All surveyin ... project will not be paid for separately, but

thickness of ... qual to or greater than the lift directly
above.

In the event ... eontological resources are discovered during
construction. ... a shall cease, and Steve Wallace, CDOT
paleontologi ... 3-757-9632. For archaeological resources call
Dan Jepson, ... t 303-757-9631.

Print Date: 3/25/2009			
File Name: 01579DES_General_Notes.dgn			
Horiz. Scale: 1:1	Vert. Scale: As Noted		
Unit Information	Unit Leader Initials		

Sheet Revisions

Date:	Comments	Init.

Colorado Department of Transportation

DOT DEPARTMENT OF TRANSPORTATION

425 B Corporate Circle
Golden, CO 80401
Phone: 720-497-6961 FAX: 720-497-6951

Region 6 Central Engineering PDJ

As Constructed
No Revisions:
Revised:
Void:

WASTE TIRE NOISE WALL
GENERAL NOTES

Designer: J. Christopher
Detailer: R. Amack
Structure Numbers
Sheet Subset: Wall
Subset Sheets: GN-1 of 1

Project No./Code
C 0062-024
SA 17198
Sheet Number 3

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CONTRACT ITEM N0.		UNITS	ROA[D] PLAN	PROJECT TOTALS
201-00000	Clearing an[d]	LS	1	1
202-00011	Tree Trimmi[ng]	EA		50
202-00220	Removal of	SY	29	29
202-01130	Removal of	LF	270	270
202-01300	Removal of	EA	2	2
203-01597	Potholing	HR	2	2
208-00002	Erosion Log	LF		290
210-00810	Reset Grou[nd]	EA	2	2
403-00721	Hot Mix As[phalt]	SY	58	58
503-00024	Drilled Cais[son]	LF		350
507-00000	Concrete Sl[ope]	CY		1.0
509-00000	Structural S[teel]	LB		2443
601-40300	Structural C	SY		229
601-40400	Structural C	SY		240
606-01370	Transition T	EA	1	1
606-02003	End Anchor	EA	1	1
606-10705	Bridge Rail	LF		255
607-15100	Fence (Sou	EA		160
627-00005	Epoxy Pave	GAL	6	6
630-80335	Barricade (T	EA	8	8
630-80341	Constructio[n]	EA	10	10
630-80342	Constructio[n]	EA	16	16
630-80344	Constructio[n]	SF	41	41
630-80360	Drum Chan[nelizing]	EA	100	100
630-80380	Traffic Cone	EA	50	50
700-70011	F/A Partner	F A	1	1
700-70022	F/A OJT Co	F A	1	1
700-70380	F/A Erosion	F A	1	1

Print Date: 3/25/2009
File Name: 01579DES_SAQ's.dgn
Horiz. Scale: 1:1 Vert. Scale: As Noted
Unit Information Unit Leader Initials

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation
425 B Corporate Circle
Golden, CO 80401
Phone: 720-497-6961 FAX: 720-497-6951
Region 6 Central Engineering PDJ

As Constructed
No Revisions:
Revised:
Void:

WASTE TIRE NOISE WALL
SUMMARY OF APPROX. QUANTITIES

Designer: J. Christopher
Detailer: R. Amack
Sheet Subset: SAQ
Structure Numbers
Subset Sheets: SAQ-1 of 1

Project No./Code
C 0062-024
SA 17198
Sheet Number 4

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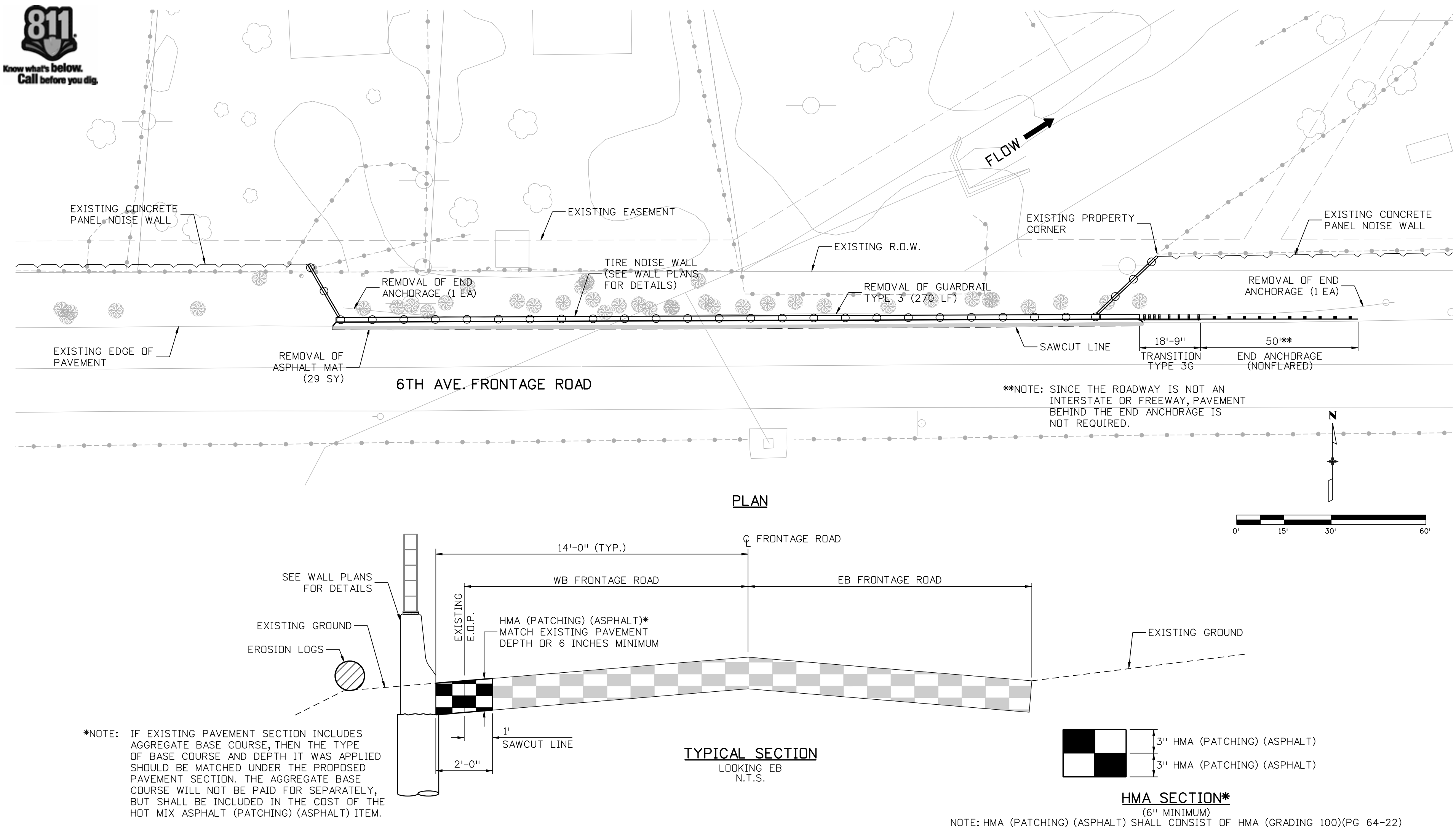

*NOTE: IF EXISTING PAVEMENT SECTION INCLUDES AGGREGATE BASE COURSE, THEN THE TYPE OF BASE COURSE AND DEPTH IT WAS APPLIED SHOULD BE MATCHED UNDER THE PROPOSED PAVEMENT SECTION. THE AGGREGATE BASE COURSE WILL NOT BE PAID FOR SEPARATELY, BUT SHALL BE INCLUDED IN THE COST OF THE HOT MIX ASPHALT (PATCHING) (ASPHALT) ITEM.

NOTE: HMA (PATCHING) (ASPHALT) SHALL CONSIST OF HMA (GRADING 100)(PG 64-22)

Print Date: 3/26/2009	Sheet Revisions	Colorado Department of Transportation	As Constructed	WASTE TIRE NOISE WALL NOISE WALL ROADSIDE PLAN
File Name: 01579DES_NoiseWall_Rem & Typ.dgn	Date: / Comments / Init.	425 B Corporate Circle Golden, CO 80401 Phone: 720-497-6961 FAX: 720-497-6951	No Revisions:	Designer: J. Christopher
Horiz. Scale: 1:30 / Vert. Scale: As Noted			Revised:	Detailer: R. Amack / Structure Numbers
Unit Information / Unit Leader Initials		Region 6 Central Engineering PDJ	Void:	Sheet Subset: Wall / Subset Sheets: R-1 of 1

Project No./Code
C 0062-024
SA 17198
Sheet Number 5

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GENERAL NOTES

ALL WORK SHALL BE DONE IN ACCORDANCE WITH THE COLORADO DEPARTMENT OF TRANSPORTATION (CDOT) 2005 STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION, APPLICABLE TO THE PROJECT.

EXPANSION JOINT MATERIAL SHALL MEET AASHTO SPECIFICATION M-213.

ALL CAST-IN-PLACE CONCRETE SHALL BE CLASS D. ALL CONCRETE IN CONTACT WITH GROUND SHALL MEET THE CRITERIA OF STANDARD SPECIAL PROVISION, REVISION OF SECTIONS 601 AND 701, STRUCTURAL CONCRETE, FOR EXPOSURE CLASS 2.

ALL EXPOSED CONCRETE EDGES SHALL HAVE A ¾" CHAMFER UNLESS DETAILED OR OTHERWISE NOTED.

STRUCTURAL CONCRETE COATING WILL BE REQUIRED ON EXPOSED SURFACES OF THE BRIDGE RAIL TYPE 7 TO 1'-0" BELOW FINISHED GRADE, AS SHOWN ON THE PLANS. THE COLOR SHALL BE EQUIVALENT TO FEDERAL STANDARD 595B, COLOR NO. 31433 (LYONS RED/PINK).

GRADE 60 REINFORCING STEEL IS REQUIRED.

ALL REINFORCING STEEL SHALL BE BLACK (NON-COATED) UNLESS OTHERWISE NOTED.

(E) DENOTES EPOXY-COATED REINFORCING STEEL.

THE FOLLOWING TABLE GIVES THE MINIMUM CLASS B LAP SPLICE LENGTH FOR EPOXY COATED REINFORCING BARS PLACED IN ACCORDANCE WITH SUBSECTION 602.06. THESE SPLICE LENGTHS SHALL BE INCREASED BY 25% FOR BARS SPACED AT LESS THAN 6" ON CENTER.

BAR SIZE	#4	#5	#6	#7	#8	#9	#10	#11
SPLICE LENGTH FOR CLASS D CONCRETE	1'-3"	1'-7"	2'-5"	2'-10"	3'-8"	4'-8"	5'-11"	7'-3"

WHEN THE CONTRACTOR ELECTS TO SUBSTITUTE EPOXY COATED REINFORCEMENT FOR BLACK REINFORCING BARS, THE MINIMUM LAP SPLICE SHALL BE AS DESCRIBED ABOVE.

THE FOLLOWING TABLE GIVES THE MINIMUM CLASS B LAP SPLICE LENGTH FOR BLACK REINFORCING BARS PLACED IN ACCORDANCE WITH SUBSECTION 602.06. THESE SPLICE LENGTHS SHALL BE INCREASED BY 25% FOR BARS SPACED AT LESS THAN 6" ON CENTER.

BAR SIZE	#4	#5	#6	#7	#8	#9	#10	#11
SPLICE LENGTH FOR CLASS D CONCRETE	1'-1"	1'-4"	1'-7"	1'-11"	2'-6"	3'-1"	3'-11"	4'-10"

THE INFORMATION SHOWN ON THESE PLANS CONCERNING THE TYPE AND LOCATION OF UNDERGROUND UTILITIES IS NOT GUARANTEED TO BE ACCURATE OR ALL INCLUSIVE. THE CONTRACTOR IS RESPONSIBLE FOR MAKING HIS OWN DETERMINATION AS TO THE TYPE AND LOCATION OF UNDERGROUND UTILITIES AS MAY BE NECESSARY TO AVOID DAMAGE THERETO. THE CONTRACTOR SHALL CONTACT THE UTILITY NOTIFICATION CENTER OF COLORADO AT 1-800-922-1987 AT LEAST 2 DAYS (NOT INCLUDING THE DAY OF NOTIFICATION) PRIOR TO ANY EXCAVATION OR OTHER EARTHWORK.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE STABILITY OF THE STRUCTURES DURING CONSTRUCTION.

SOIL BORING LOCATIONS ARE SHOWN ON THE GENERAL LAYOUT SHEET. ALSO SEE BORING LOG INFORMATION, SHT. W-12.

WXX / XX

CROSS REFERENCE DRAWING NUMBER (IF BLANK, REFERENCE IS TO SAME SHEET)

SECTION OR DETAIL IDENTIFICATION

UTILITY LINES AS SHOWN ON THE PLAN SHEETS AREPLOTTED FROM THE BEST AVAILABLE INFORMATION. THE CONTRACTORS ATTENTION IS DIRECTED TO SUBSECTION 105.10 OF THE STANDARD SPECIFICATIONS CONCERNING UTILITIES.

THE CONTRACTOR SHALL COMPLY WITH ARTICLE 1.5 OF TITLE 9, CRS ("EXCAVATION REQUIREMENTS") WHEN EXCAVATING OR GRADING IS PLANNED IN THE AREA OF UNDERGROUND UTILITY FACILITIES. THE CONTRACTOR SHALL NOTIFY ALL AFFECTED UTILITIES AT LEAST TWO (2) BUSINESS DAYS, NOT INCLUDING THE ACTUAL DAY OF NOTICE, PRIOR TO COMMENCING SUCH OPERATIONS. THE CONTRACTOR SHALL CONTACT THE UTILITY NOTIFICATION CENTER OF COLORADO (UNCC) AT 811 OR 1-800-922-1987, TO HAVE LOCATIONS OF UNCC REGISTERED LINES MARKED BY MEMBER COMPANIES. ALL OTHER UNDERGROUND FACILITIES SHALL BE LOCATED BY CONTACTING THE RESPECTIVE OWNER. UTILITY SERVICE LATERALS SHALL ALSO BE LOCATED PRIOR TO BEGINNING EXCAVATION OR GRADING.

CONTRACTOR SHALL LOCATE AND POTHOLEALL POTENTIAL CONFLICTS WITH EXISTING BURIED UTILITY FACILITIES WITH THE PROPOSED CONSTRUCTION AS SHOWN ON THE PLANS OR BY FIELD LOCATION MARKINGS. IF CONFLICT EXISTS, MODIFY PROPOSED CONSTRUCTION PLANS TO AVOID ALL EXISTING BURIED UTILITY FACILITIES.

DESIGN DATA

AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS, 4th EDITION (2007)

AASHTO GUIDE SPECIFICATIONS FOR STRUCTURAL DESIGN OF SOUND BARRIERS (1989 WITH 2002 INTERIM)

DESIGN METHOD:

LOAD & RESISTANCE FACTOR DESIGN

DESIGN LOADS (NOISE WALLS):

UNIT WEIGHT OF CONCRETE = 150 pcf
WIND LOAD = 34 psf (90 mph, Exposure C)
BARRIER IMPACT LOAD = TL-2 (TEST LEVEL 2)

REINFORCED CONCRETE:

CONCRETE CLASS D: f'c = 4500 psi
CONCRETE CLASS BZ (CAISSONS): f'c = 4000 psi
REINFORCING STEEL: Fy = 60,000 psi

STRUCTURAL STEEL:

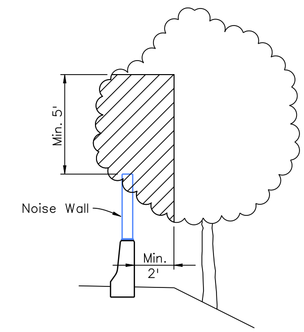
ASTM A572 (W,C & L SHAPES): Fy = 50,000 psi

ABBREVIATIONS

E.F. = EACH FACE
I.D. = INSIDE DIAMETER
I.F. = INSIDE FACE
B.F. = BACK FACE
O.F. = OUTSIDE FACE
F.G. = FINISHED GRADE
BOT. = BOTTOM
T.O. = TOP OF
EL. = ELEVATION
EQ. = EQUAL
SPA. = SPACING
U.N.O. = UNLESS NOTED OTHERWISE

FOR BURIED UTILITY INFORMATION
811.
THREE (3) BUSINESS DAYS BEFORE YOU DIG
CALL 811
(or 1-800-922-1987)
UTILITY NOTIFICATION CENTER OF COLORADO (UNCC)
www.uncc.org

INDEX OF DRAWINGS



Notes:

1. Tree trimming shall be conducted in coordination with CDOT and City of Lakewood forces.
2. A total of 50 trees have been estimated to require trimming. Trimming limits shall extend along full length of wall (approx. 268' long).
3. Payment for tree trimming will be only for limits shown.
4. Trimming shall conform to project special provision 202 Trimming Trees.

MINIMUM TREE TRIMMING LIMITS

Print Date: 3/26/2009		
File Name: 01579DES_General_Info.dgn		
Horiz. Scale: 1:1	Vert. Scale: As Noted	
Unit Information	Unit Leader Initials	

Sheet Revisions

Date:	Comments	Init.

Colorado Department of Transportation
425 B Corporate Circle
Golden, CO 80401
Phone: 720-497-6961 FAX: 720-497-6951
Region 6 Central Engineering PDJ

As Constructed
No Revisions:
Revised:
Void:

WASTE TIRE NOISE WALL
GENERAL INFORMATION

Designer:	B. Marcato	Structure Numbers	
Detailer:	R. Dillon		
Sheet Subset:	Wall	Subset Sheets:	W-1 of 9

Project No./Code
C 0062-024
SA 17198
Sheet Number

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[redacted]

① Includes 5 Additional Tire Tie Units than indicated in plans, per specifications.

Print Date: 3/26/2009			
File Name: 01579DES_NoiseWall_Quantities.dgn			
Horiz. Scale: 1:1	Vert. Scale: As Noted		
Unit Information	Unit Leader Initials		

Sheet Revisions

Date:	Comments	Init.

Colorado Department of Transportation
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Phone: 720-497-6961 FAX: 720-497-6951
Region 6 Central Engineering PDJ

As Constructed
No Revisions:
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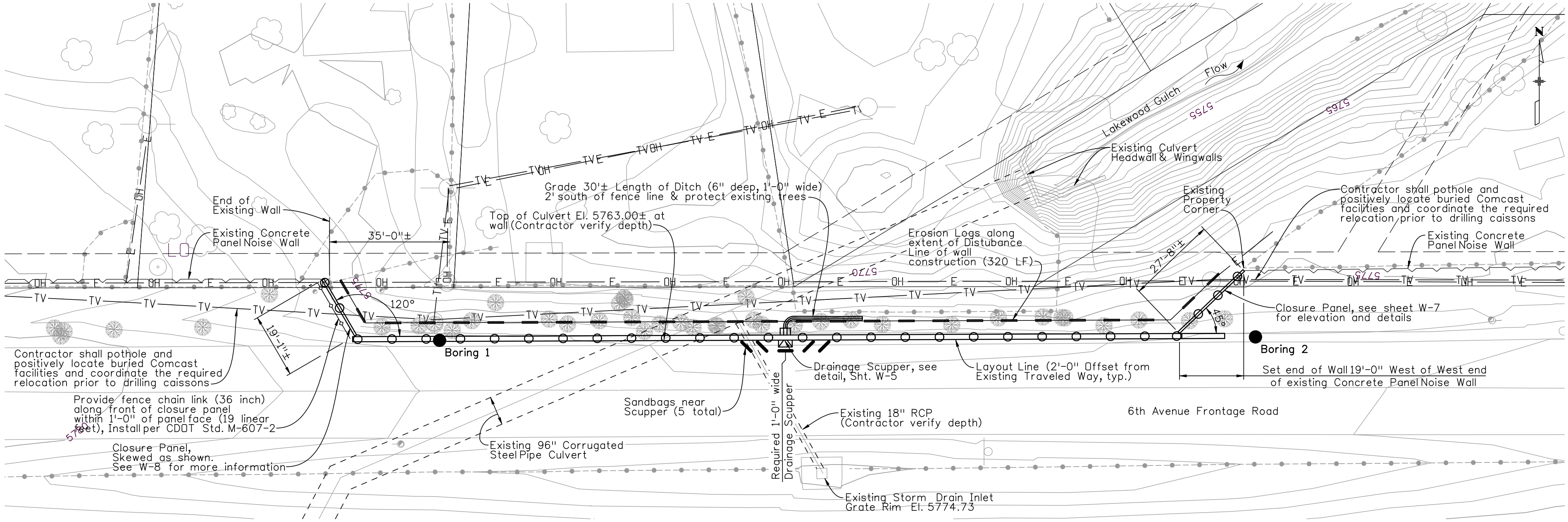
Void:

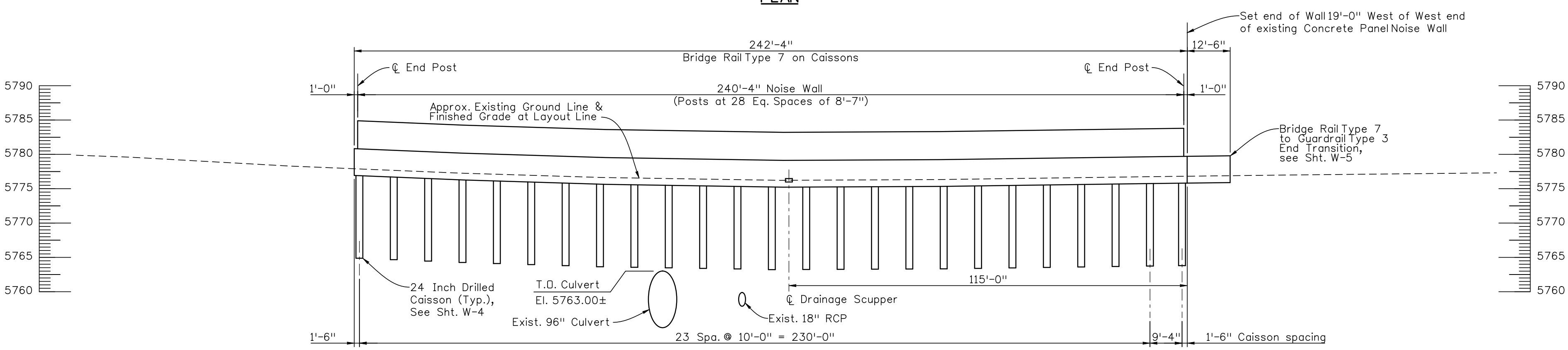
WASTE TIRE NOISE WALL
SUMMARY OF QUANTITIES

Designer: B. Marcato	Structure Numbers		
Detailer: R. Dillon			
Sheet Subset: Wall	Subset Sheets: W-2 of 9		

Project No./Code
C 0062-024
SA 17198
Sheet Number



PLAN



ELEVATION AT WALL LAYOUT LINE

Print Date: 3/25/2009	
File Name: 01579DES_NoiseWall_Plan & Elev.dgn	
Horiz. Scale: 1:30	Vert. Scale: As Noted
Unit Information	Unit Leader Initials

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation
425 B Corporate Circle
Golden, CO 80401
Phone: 720-497-6961 FAX: 720-497-6951
Region 6 Central Engineering PDJ

As Constructed
No Revisions:
Revised:
Void:

WASTE TIRE NOISE WALL
NOISE WALL PLAN
& ELEVATION

Designer:	B. Marcato	Structure Numbers	
Detailer:	R. Dillon		
Sheet Subset:	Wall	Subset Sheets:	W-3 of 9

Project No./Code
C 0062-024
SA 17198
Sheet Number 8

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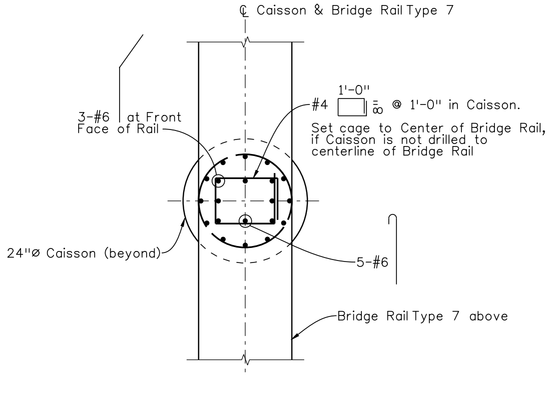
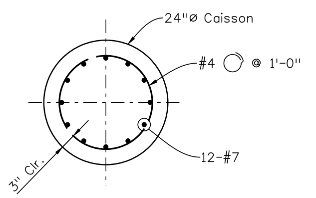
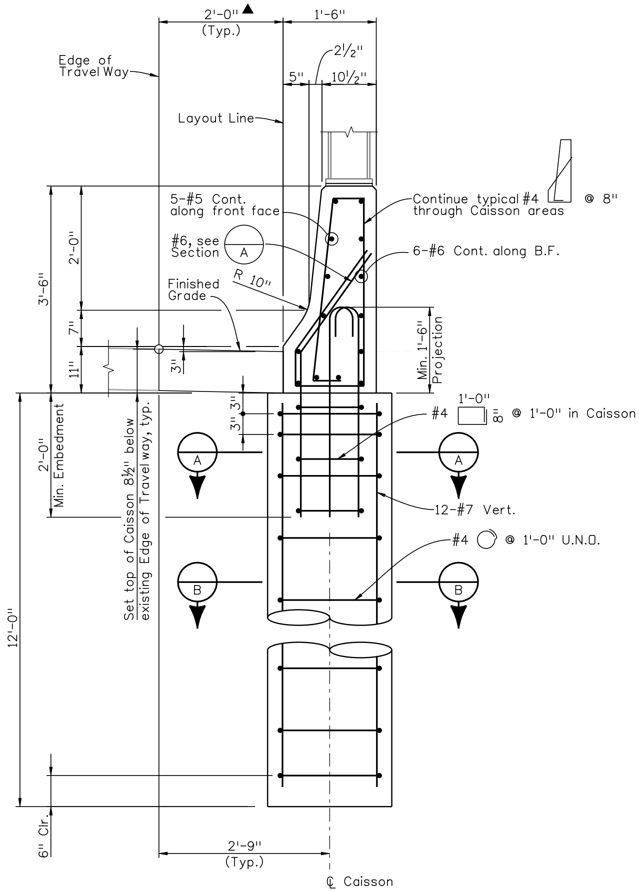


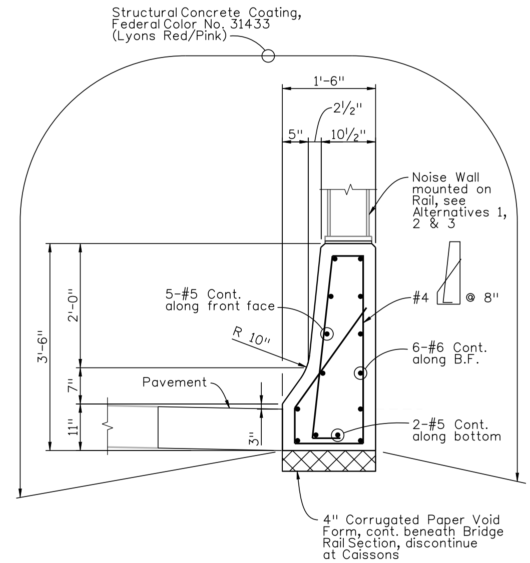
SECTION A



SECTION B



TYPICAL BRIDGE RAIL TYPE 7
& CAISSON SECTION



TYPICAL BRIDGE RAIL TYPE 7
SECTION BETWEEN CAISSONS

Notes:

1. All excavation and backfill associated with Caisson and Bridge Rail installation shall be included in the work.
2. Backfill on back side of Bridge rail (away form roadway) shall be on-site material, meeting requirements and re-compacted for requirements for Structure Backfill (Class 2), per the CDOT Standard Specifications.
3. All Reinforcing Steel required for Construction shall not be paid for seperately, but shall be included in Item 503 Drilled Caisson or Item 606 Bridge Rail Type 7 as applicable.

▲ Maintain Bridge Rail alignment relative to roadway, not to centerline of caissons (in the case that the Caissons are not aligned correctly). Per Revision of section 503, Drilled Caissons, tolerance for Caisson offset is 1" for a 24" Caisson. Thus, Bridge Rail may need to be centered up to 1" from constructed Caisson.

Print Date: 3/26/2009	
File Name: 01579DES_Caisson&Barrier_Details.dgn	
Horiz. Scale: 1:1	Vert. Scale: As Noted
Unit Information	Unit Leader Initials

Sheet Revisions

Date:	Comments	Init.

Colorado Department of Transportation
425 B Corporate Circle
Golden, CO 80401
Phone: 720-497-6961 FAX: 720-497-6951
Region 6 Central Engineering PDJ

As Constructed
No Revisions:
Revised:
Void:

WASTE TIRE NOISE WALL
BRIDGE RAIL TYPE 7
& CAISSON DETAILS

Designer: P. Stein	Structure Numbers	
Detailer: Dillon/Schneider		
Sheet Subset: Wall	Subset Sheets: W-4 of 9	

Project No./Code
C 0062-024
SA 17198
Sheet Number

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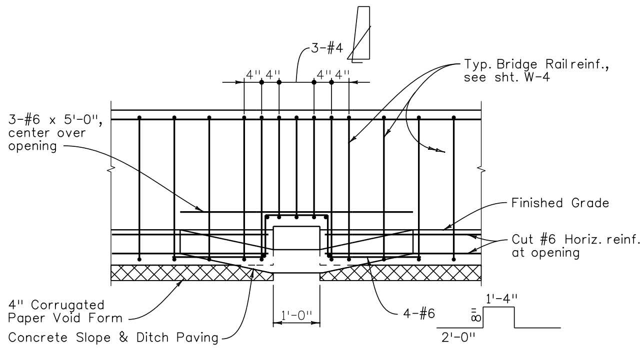
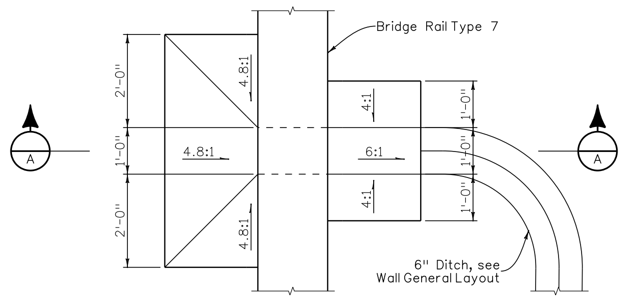
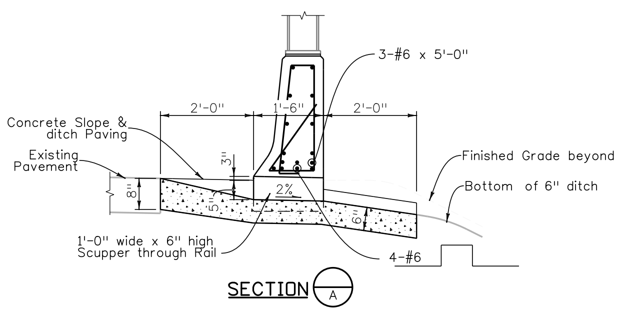


ELEVATION

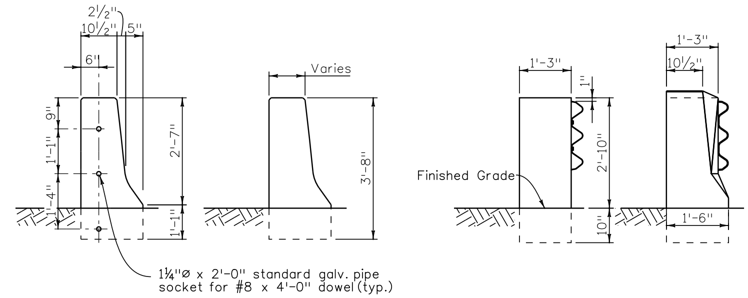


PLAN



SECTION A

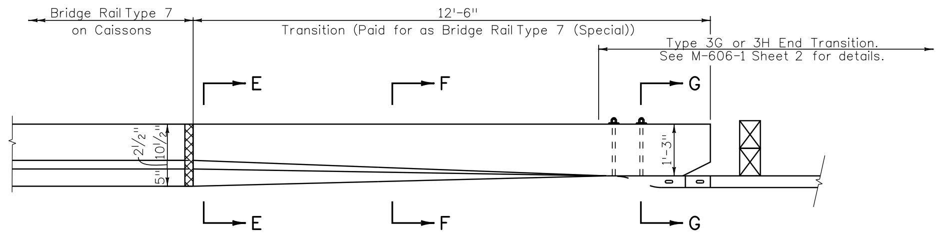
DRAINAGE SCUPPER



SECTION E-E

SECTION F-F

SECTION G-G



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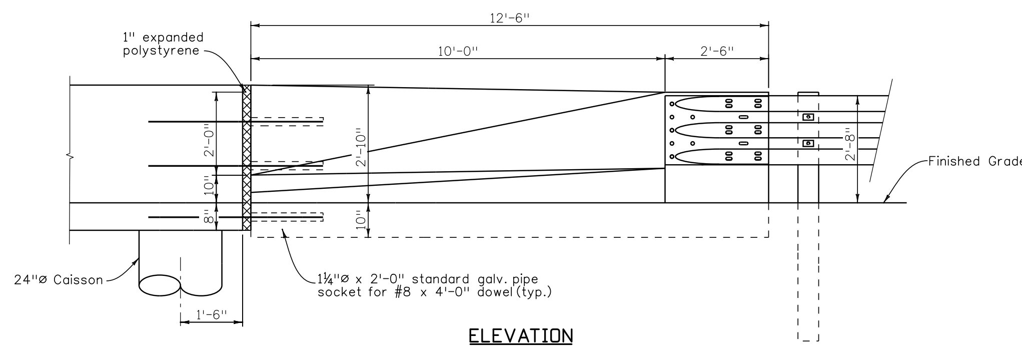

ELEVATION

BRIDGE RAIL TYPE 7 TO GUARDRAIL TYPE 3 END TRANSITION

Print Date: 3/26/2009 File Name: 01579DES_BridgeRail_Transition.dgn Horiz. Scale: 1:1 Vert. Scale: As Noted Unit Information Unit Leader Initials	Sheet Revisions Date: / Comments / Init.	Colorado Department of Transportation 425 B Corporate Circle Golden, CO 80401 Phone: 720-497-6961 FAX: 720-497-6951 Region 6 Central Engineering PDJ	As Constructed No Revisions: Revised: Void:	WASTE TIRE NOISE WALL DRAINAGE SCUPPER & TRANSITION TO GUARDRAIL TYPE 3 Designer: B. Marcato Detailer: R. Dillon Sheet Subset: Wall Structure Numbers Subset Sheets: W-5 of 9	Project No./Code C 0062-024 SA 17198 Sheet Number

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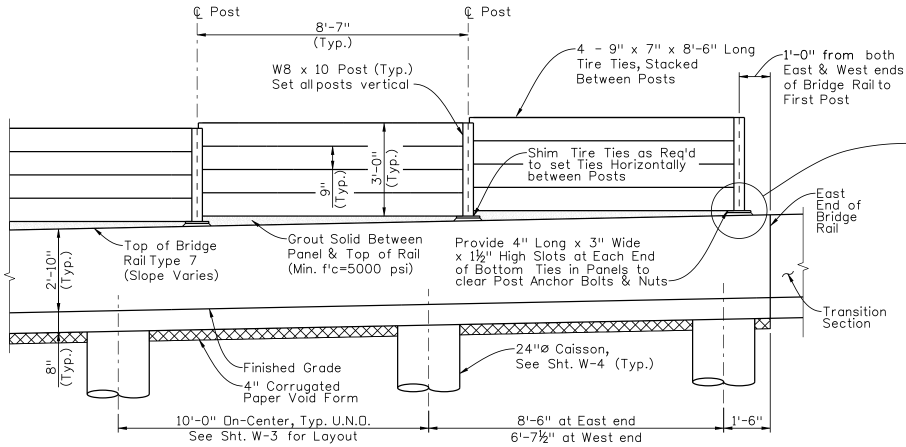
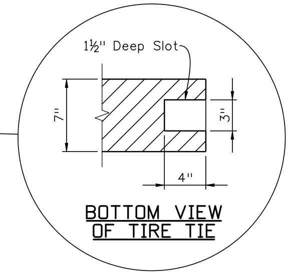
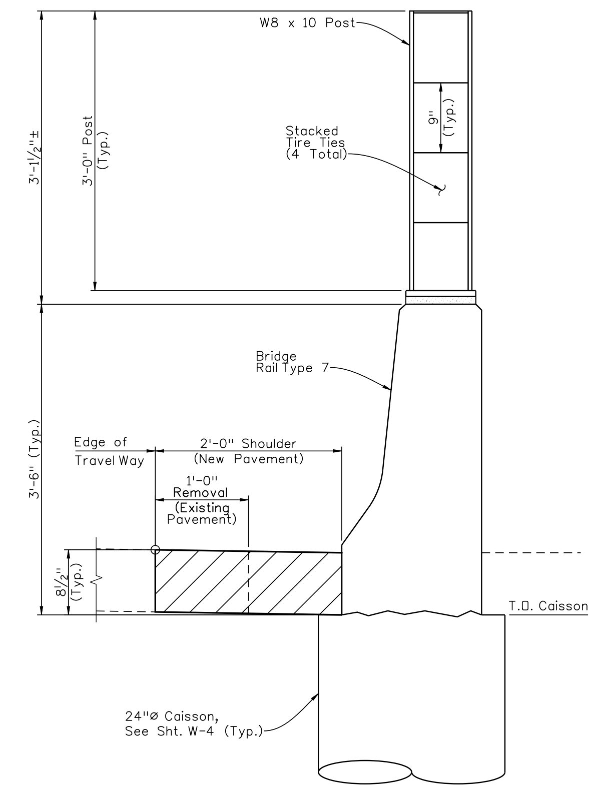


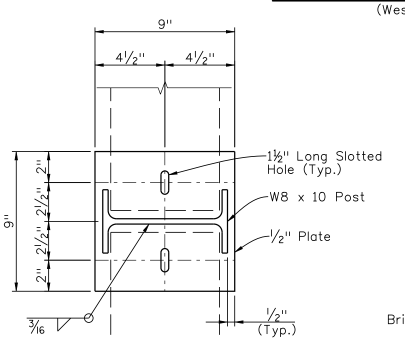
TIRE TIE NOISE WALL
PARTIAL ELEVATION AT EAST END OF RAIL
(West end similar, opposite hand)



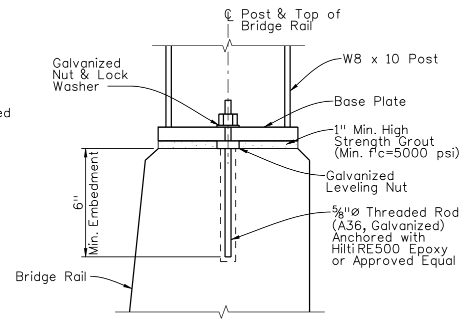
BOTTOM VIEW
OF TIRE TIE



TYPICAL SECTION



POST BASE PLATE PLAN



POST BASE PLATE ELEVATION

Noise Wall Notes:

1. Structural Steel W, C & L Shapes and Plates shall conform to ASTM A-572, fy=50ksi.
2. All Noise Wall Posts shall be plumb (vertical).
3. All Steel shall be painted in accordance with Section 509 of the CDOT Specifications. The Color shall be Red/Pink, matching Federal Color No. 31433, which resembles the color of the Existing Noise Wall in the Project Vacinity.
4. All Reinforcing Steel shall conform with ASTM A-615, Grade 60.
5. Tire Ties shall be coated with a 100% Waterbased Acrylic Emulsion Stain, similar to Sherwin-Williams B97-200 Series. The Contractor shall submit 6 copies of the proposed product information for approval prior to application. All exposed surfaces shall receive a single application by spray, brush or roller per the manufacturer's recommendations. Tire Ties shall be clear of dirt or grease prior to application. Color shall be red/pink, matching Federal Color No. 31433. Stain shall be paid for as Item 601, Structural Concrete Stain.

Print Date: 3/26/2009	Sheet Revisions (Date / Comments / Init.)	Colorado Department of Transportation	As Constructed	WASTE TIRE NOISE WALL NOISE WALL DETAILS (1 OF 3)
File Name: 01579DES_TireTieWall_Details01.dgn		425 B Corporate Circle Golden, CO 80401	No Revisions:	Designer: B. Marcato
Horiz. Scale: 1:1 Vert. Scale: As Noted		Phone: 720-497-6961 FAX: 720-497-6951	Revised:	Detailer: Dillon/Schneider
Unit Information Unit Leader Initials		Region 6 Central Engineering PDJ	Void:	Structure Numbers
				Sheet Subset: Wall Subset Sheets: W-6 of 9

Project No./Code
C 0062-024
SA 17198
Sheet Number

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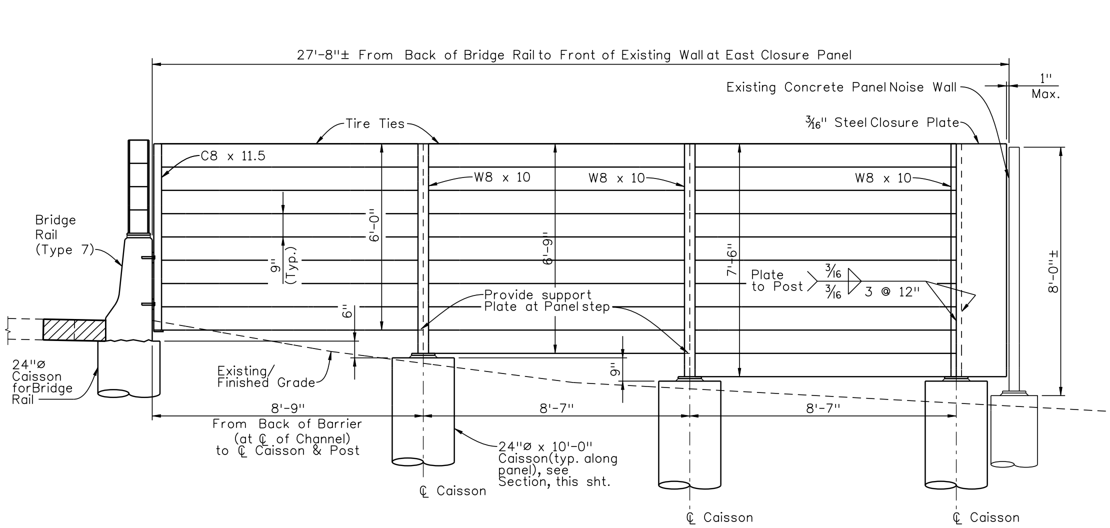
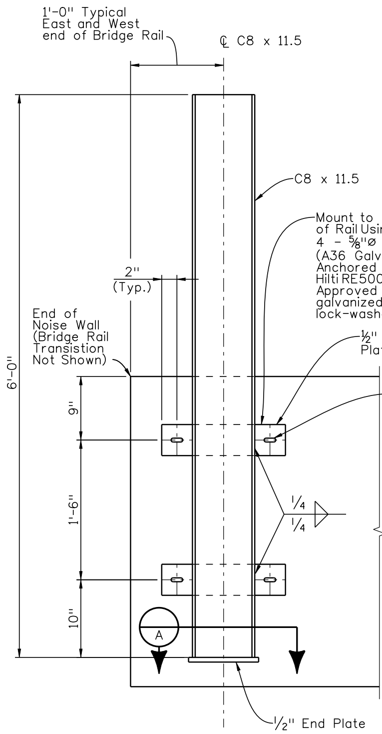
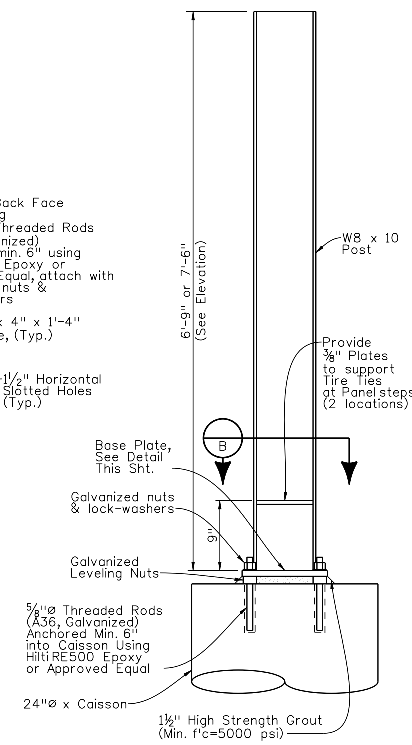


TIRE TIE EAST CLOSURE PANEL ELEVATION

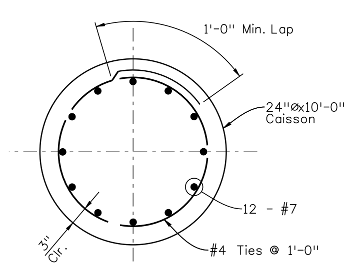


END CONNECTION DETAIL AT BRIDGE RAIL



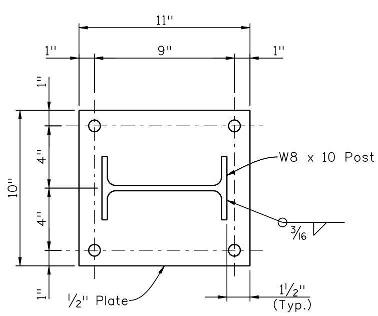
CLOSURE PANEL POST DETAIL

Note: Adjust Post locations on Caissons as required to fit Tire Tie panels. Posts may be centered up to 2" away from center of Caisson in any direction.

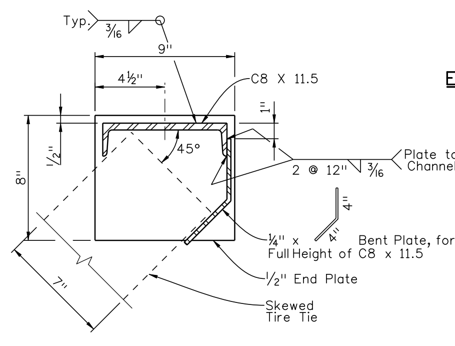


24 INCH CAISSON SECTION

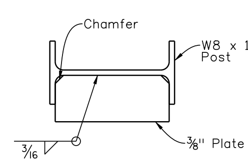
(See Detail on Sht. W4 for additional information)



CLOSURE PANEL POST BASE PLATE DETAIL



SECTION A



SECTION B

Print Date: 3/26/2009
File Name: 01579DES_TireTieWall_Details01.dgn
Horiz. Scale: 1:1 Vert. Scale: As Noted
Unit Information Unit Leader Initials

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation
425 B Corporate Circle
Golden, CO 80401
Phone: 720-497-6961 FAX: 720-497-6951
Region 6 Central Engineering PDJ

As Constructed
No Revisions:
Revised:
Void:

WASTE TIRE NOISE WALL
NOISE WALL DETAILS
(2 OF 3)

Designer: B. Marcato
Detailer: Dillon/Schneider
Structure Numbers
Sheet Subset: Wall
Subset Sheets: W-7 of 9

Project No./Code
C 0062-024
SA 17198
Sheet Number

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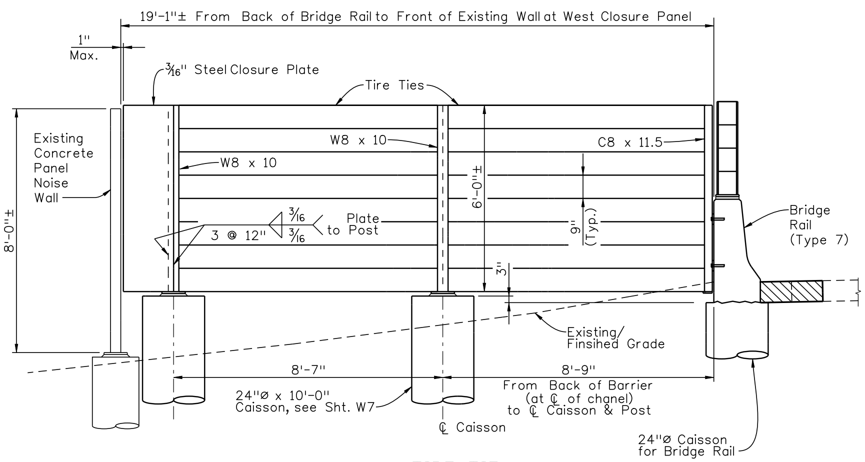
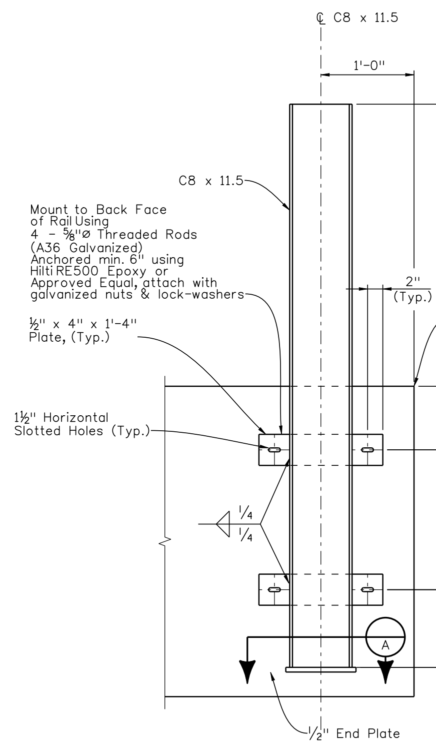
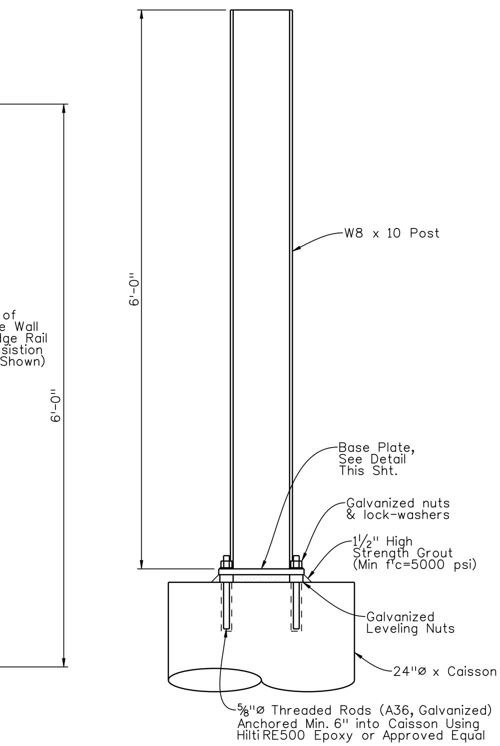


TIRE TIE
WEST CLOSURE PANEL ELEVATION

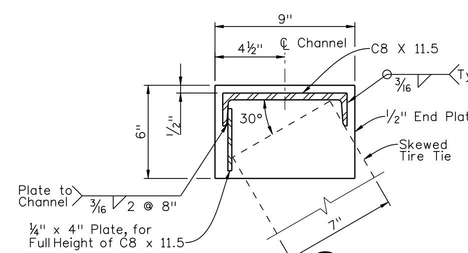


END CONNECTION DETAIL
AT BRIDGE RAIL



CLOSURE PANEL POST DETAIL

Note: Adjust Post locations on Caissons as required to fit Tire Tie panels. Posts may be centered up to 2" away from center of Caisson in any direction.



SECTION (A)

Print Date: 3/26/2009	
File Name: 01579DES_TireTieWall_Details02.dgn	
Horiz. Scale: 1:1	Vert. Scale: As Noted
Unit Information	Unit Leader Initials

Sheet Revisions

Date:	Comments	Init.

Colorado Department of Transportation
425 B Corporate Circle
Golden, CO 80401
Phone: 720-497-6961 FAX: 720-497-6951
Region 6 Central Engineering PDJ

As Constructed
No Revisions:
Revised:
Void:

WASTE TIRE NOISE WALL
NOISE WALL DETAILS
(3 OF 3)

Designer: B. Marcato
Detailer: Dillon/Schneider
Structure Numbers
Sheet Subset: Wall
Subset Sheets: W-8 of 9

Project No./Code
C 0062-024
SA 17198
Sheet Number

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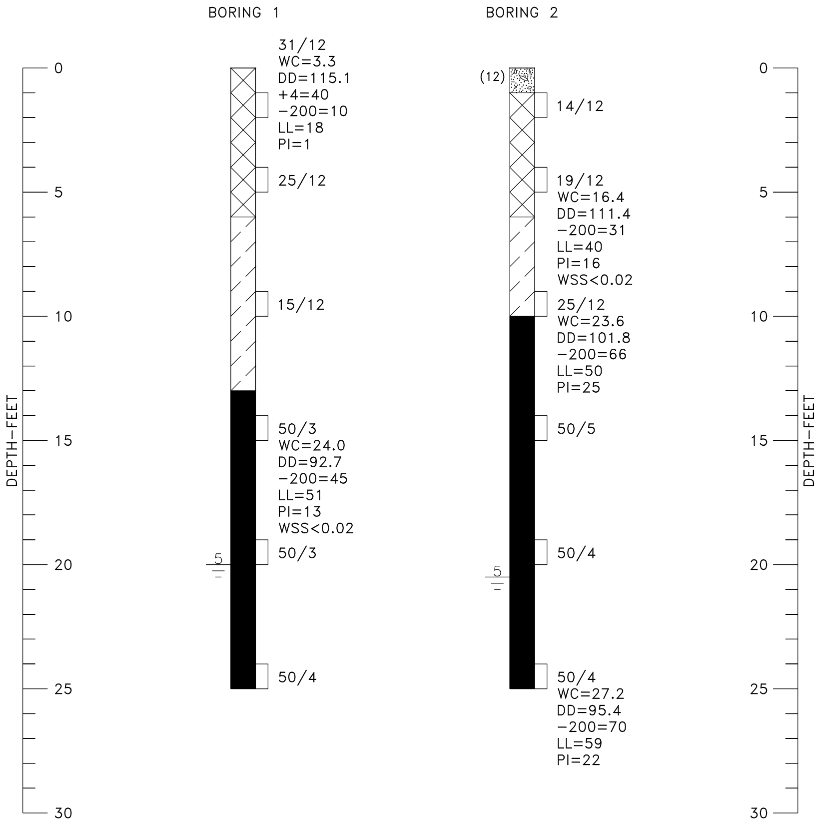

LEGEND

(12) AGGREGATE BASE COURSE, THICKNESS IN INCHES SHOWN IN PARENTHESES TO LEFT OF THE LOG.

FILL: POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM) TO CLAYEY SAND (SC) ZONES OF SANDY LEAN CLAY (CL), FINE TO COARSE GRAINED, NON-PLASTIC TO LOW PLASTICITY, SLIGHTLY MOIST TO VERY MOIST, BROWN.

SANDY LEAN CLAY (CL) TO SANDY FAT CLAY (CH), STIFF TO VERY STIFF, MOIST TO VERY MOIST, BROWN.

CLAYSTONE/SILTSTONE BEDROCK, OCCASIONAL SANDSTONE INTERBEDS, HARD TO VERY HARD, MOIST TO VERY MOIST, GRAY, OLIVE, IRON STAINING, BLOCKY.

DRIVE SAMPLE, 2-INCH I.D. CALIFORNIA LINER SAMPLE.

31/12 DRIVE SAMPLE BLOW COUNT. INDICATES THAT 31 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE THE SAMPLER 12 INCHES.

5 DEPTH TO WATER LEVEL AND NUMBER OF DAYS AFTER DRILLING MEASUREMENT WAS MADE.

NOTES

1. THE EXPLORATORY BORINGS WERE DRILLED ON OCTOBER 8, 2008 WITH A 4-INCH DIAMETER CONTINUOUS FLIGHT POWER AUGER.
2. THE LOCATIONS OF THE EXPLORATORY BORINGS WERE MEASURED APPROXIMATELY BY PACING FROM FEATURES SHOWN ON THE SITE PLAN PROVIDED.
3. THE ELEVATIONS OF THE EXPLORATORY BORINGS WERE NOT MEASURED AND THE LOGS OF THE EXPLORATORY BORINGS ARE PLOTTED TO DEPTH.
4. THE EXPLORATORY BORING LOCATIONS SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
5. THE LINES BETWEEN MATERIALS SHOWN ON THE EXPLORATORY BORING LOGS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES AND THE TRANSITIONS MAY BE GRADUAL.
6. GROUND WATER LEVELS SHOWN ON THE LOGS WERE MEASURED AT THE TIME AND UNDER CONDITIONS INDICATED. FLUCTUATIONS IN THE WATER LEVEL MAY OCCUR WITH TIME.
7. LABORATORY TEST RESULTS:
   WC = WATER CONTENT (%) (ASTM D 2216);
   DD = DRY DENSITY (pcf) (ASTM D 2216);
   +4 = PERCENTAGE RETAINED ON NO. 4 SIEVE (ASTM D 422);
   -200 = PERCENTAGE PASSING NO. 200 SIEVE (ASTM D 1140);
   LL = LIQUID LIMIT (ASTM D 4318);
   PI = PLASTICITY INDEX (ASTM D 4318);
   WSS = WATER SOLUBLE SULFATES (%) (AASHTO T 290).

K+A Kumar & Associates
2390 S. Lipan St.
Denver, Colorado, 80223
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FAX: 303-742-9666

Print Date: 3/26/2009	Sheet Revisions			Colorado Department of Transportation	As Constructed	WASTE TIRE NOISE WALL BORING LOG INFORMATION	Project No./Code
File Name: 01579Engineering_Geology.dgn	Date:	Comments	Init.	425 B Corporate Circle Golden, CO 80401 Phone: 720-497-6961 FAX: 720-497-6951	No Revisions:		C 0062-024
Horiz. Scale: 1:1 Vert. Scale: As Noted					Revised:	Designer: / Detailer: / Structure Numbers	SA 17198
Unit Information Unit Leader Initials				Region 6 Central Engineering PDJ	Void:	Sheet Subset: Wall / Subset Sheets: W-9 of 9	Sheet Number

1. SITE

A

of the following:
.ogs).

abilize construction entrance (if needed).
ir / replace as needed. Sweep paved surfaces as needed.
t at BMP's as needed (continual throughout construction).
ept sediment laden storm water or snow melt runoff.
ulch tacifier all disturbed surfaces that are not to be paved.
ntinual throughout construction).
IP's.

B

acre

r locations [redacted]

D

wn on the ct site.
ne ultimate outfalls into the South Platte River.
project: 15
ed TMDL:
ne

E

ne

2. PLAN

Pre-const

A sheets.
B R SURFAC
C L RESOU ets.

3. STO FIRST C

D SWMP. D ted boxes

S diment co

			INTERIM/FINAL STABILIZATION
20	o be used a mbankment	n	
20	o be used to hey shall be e capable o oncrete lade apable of be e concrete ardened co pecifications nytime conc	es. shall hall be Vater in ning stand d	

Print Date: 3/26/2009	
File Name: 01579DES_SWMP'S.dgn	
Horiz. Scale: 1:1	Vert. Scale: As Noted
Unit Information	Unit Leader Initials

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation
425 B Corporate Circle
Golden, CO 80401
Phone: 720-497-6961 FAX: 720-497-6951
Region 6 Central Engineering PDJ

As Constructed
No Revisions:
Revised:
Void:

WASTE TIRE NOISE WALL
STORMWATER MANAGEMENT PLAN

Designer: J. Christopher	Structure Numbers		
Detailer: R. Amack			
Sheet Subset: SWMP	Subset Sheets: SWMP-1 of 3		

Project No./Code
C 0062-024
SA 17198
Sheet Number 15

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208 Gravel Bags	sediment	T be used in the gutter flow lines to capture sediment laden water be re it e ters any storm drains. To be placed prior to any earth disturbing a tivities.		X	x	
Other:						

NON-STRUCTURAL BMP practices for erosion and se iment control: practices may include, but are not limited to:

BMP	TYPE OF CONTROL	MP as Designed	In use on site	FIRST CONSTRUCTION ACTIVITIES	DURING CONSTRUCTION	ITERIM/FINAL TABILIZATION
Seeding & Mulch/Mulch Tackifier	erosion	T be completed within 48 hours of final grading. To be placed directl after s eding has been completed.				
Vegetative Buffer Strips	erosion	T be used to provide vegetation between active construction and nor		x	x	
Sweeping (Pick-Up-Broom)	sediment	T be used to pick up sediment from the roadway so it does not wash nto lc al stormdrains, throughout construction. Sweeping shall be include in tl cost of the work, if necessary.			x	
Erosion Control Supervisor	erosion and sediment	S e ECS responsibilities in the 208 specification				
700 Erosion Control	Force Account	S e Force Account description				
Other:						

Erosion control devices are used to limit the amount of erosion on site.
Sediment control devices are designed to capture se diment on the project site.
Construction control are BMPs related to constructio access and staging.
BMP locations are indicated on the site map.

C. PERIMETER CONTROL

1. Perimeter control shall be established as e first item of construction to prevent the potential for polluta ts leaving the construction site boundaries, entering the storr water drainage

SWMP Administrator/Erosion Control Supervisor (ECS) in ac cordance with Section 208

A. MATERIALS HANDLING AND SPILL PREVENT ON: Contractor *to provide Spill Prevention Control & Counten easures plan.*
B. CONCRETE WASHOUT *Concrete wash out wat r or waste from field laboratories and wall construction shall e contained in accordance with subsection 208.05.*
C. SAW CUTTING *saw cutting shall be handled in a cordance with subsection 208.04 and 208.05.*
D. STREET CLEANING *shall be handled in accorda nce with subsection 208.04.*

5. INSPECTIONS

A. Inspections shall be in accordance with subsecti n 208.03 (c).

6. BMP MAINTENANCE

A. Maintenance shall be in accordance with subsec on 208.04 (e).

7. RECORD KEEPING

A. Records shall be kept in accordance with subsec on 208.03 (c).

8. INTERIM AND FINAL STABILIZATON

A. SEEDING PLAN
Soil conditioning, seeding (native), mulching (weed and mulch tackifier will be required for an estimated 0.1 ac ithin the right-of-way limits which are not surfaced. The foll g types and rates shall be used for seeding (native).

COMMON NAME	BOTANICAL N		POUNDS PLS/ACRE
Blue grama	*Bouteloua gracilis "H*	a	1.5
Little bluestem	*Schizachyrium scopa* "Pastura"		2.0
Sand dropseed	*Sporobolus cryptand*		0.7
Prairie sandreed	*Calamovilfa longifolia* "Goshen"		3.0
Prairie coneflower	*Ratibida columnaris*		0.3
Blue flax	*Linum lewisii*		0.5
*Oats	*Avena sativa*		3.0
*In the event of fall seeding, substitute Oats f inter Wheat at the same rate.			
		TAL	24

B. SEEDING APL ATION: *Hand broadcast seed mix at double the rate and r 25 inch*

the seeding.

F. RESEEDING (RATIONS/CORRECTIVE STABILIZATION
Prior to final acce e.

1. Seeded a shall be reviewed during the 14 day inspections by the Eros ontrol Supervisor for ba ils caused by surface or wind erosion. Bare areas caused b face or gully erosion, blo way mulch, etc. shall be regraded, seeded, mulched and ha ulch tackifier (or blank plied as necessary.
2. The Contr shall maintain seeding/mulch/tackifier, sod, mulching deco , mow to control weeds or herbicide to control weeds in the seeded areas until Final A tance.

9. PRIOR TO F AL ACCEPTANCE

A. Final Acceptar hall be in accordance with subsection 208.061.

208	Concrete Washout Structure	Each	1
208	Stabilized Construction Entrance	Each	1 if needed (included in the cost of the work)
208	Sediment Removal and Disposal	Hour	10 if needed
212	Seeding (Native)	Acre	0.1 (paid for as erosion control force account)
212	Soil Conditioning	Acre	0.1 (paid for as erosion control force account)
213	Mulch Tackifier	LB	20 (paid for as erosion control force account)
700	Erosion Control	FA	1

1. BMP cleaning and maintenance shall be p or as 208 Sediment Removal and Disposal Hour.
2. It is estimated that 1 concrete washout st ures will be required on the project.
3. It is estimated that 1 stabilized constructi entrance(s) will be required as directed to minimize le tracking control, if the contractor stays on the paved roadway. If not, then a stabilized constructi ntrance shall be installed at the Contractor's expens
4. Maintenance of seeded areas shall be pai as Erosion Control Force Account.

Print Date: 3/26/2009	Sheet Revisions	Colorado Department of Transportation
File Name: 01579DES_SWMP'S.dgn	Date: / Comments / Init.	425 B Corporate Circle, Golden, CO 80401
Horiz. Scale: 1:1 / Vert. Scale: As Noted		Phone: 720-497-6961 FAX: 720-497-6951
Unit Information / Unit Leader Initials		Region 6 Central Engineering PDJ

As Constructed	WASTE TIRE NOISE WALL STORMWATER MANAGEMENT PLAN	Project No./Code
No Revisions:	Designer: J. Christopher	C 0062-024
Revised:	Detailer: R. Amack / Structure Numbers	SA 17198
Void:	Sheet Subset: SWMP / Subset Sheets: SWMP-3 of 3	Sheet Number 17

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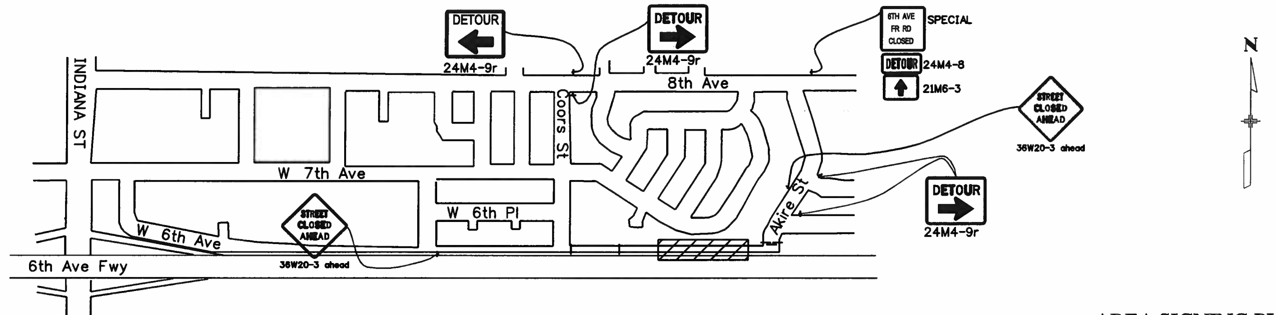
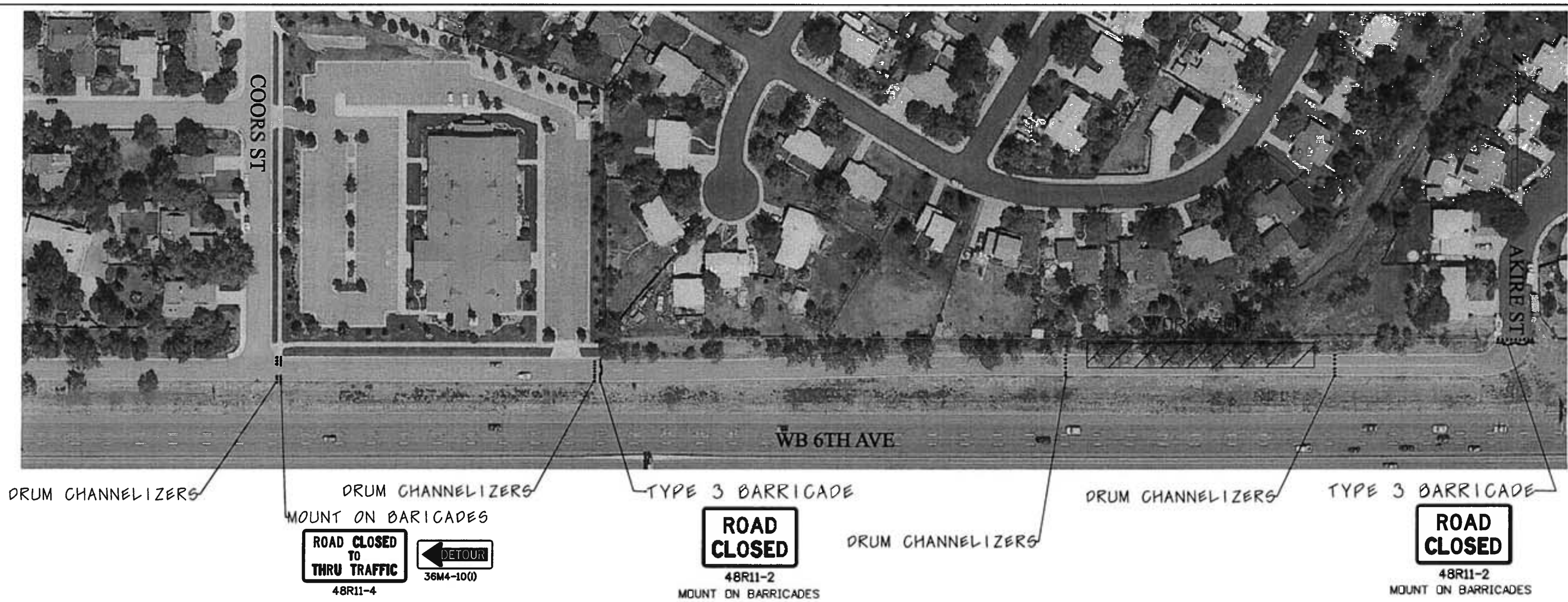


AREA SIGNING PLAN



WORK AREA SIGNING PLAN

Print Date: 3/25/2009		Sheet Revisions	
File Name: 17999Traf_000 DetourPlan01.dgn		Date:	Comments	Init.
Horiz. Scale: NONE	Vert. Scale: As Noted		
Unit Information: 6580	Unit Leader: PJNIII		

Colorado Department of Transportation

2000 South Holly Street
Denver, CO 80222
Phone: 303-757-9511 FAX: 303-757-9907

Region 6 Traffic and Safety LR

As Constructed
No Revisions:
Revised:
Void:

TRAFFIC ROAD CLOSURE SIGNING

Designer:	PJNIII	Structure Numbers	
Detailer:	PJNIII		
Sheet Subset:	TRAFFIC	Subset Sheets:	

Project No./Code
C 0062-024
SA 17198
Sheet Number 18

TABULATION OF TRAFFIC ENGINEERING ITEMS

ITEM NO.	ITEM DESCRIPTION	UNIT	PROJECT TOTALS
210-00810	RES GROUND SIGN	EA	2
✠627-00005	EPOXY PVMT MKG	GAL	8
630-80335	BARRICADE (3 M-A) (TEMP)	EA	8
630-80341	CONST TRAF SIGN (A)	EA	10
630-80342	CONST TRAF SIGN (B)	EA	16
630-80344	CONST TRAF SIGN (SPECIAL)	SF	41
630-80360	DRUM CHANNEL DEV	EA	100
630-80380	TRAFFIC CONE	EA	50

SCHEDULE OF CONSTRUCTION TRAFFIC CONTROL DEVICES

CONSTRUCTION SIGNS

SIGN CODE	LEGEND	DIMENSIONS	PANEL SIZE A	PANEL SIZE B	PANEL SIZE C	PANEL SIZE SF
36W20-3	STREET/CLOSED/AHEAD	48"X30"		4		
48G20-10	XYZ / CONSTRUCTION / THANKS YOU / 555-555-5555 ♦	48"X48"		2		
48W20-7a	FLAGGER SYMBOL	48"X48"		2		
48R11-4	ROAD CLOSED/TO/THRU TRAFFIC	60"X30"		4		
48R11-2	ROAD/CLOSED	48"X30"		4		
36M4-10(L)	DETOUR "ARROW" ♦	48"X18"	2			
24M4-9R	DETOUR "ARROW" ♦	30"X24"	2			
24M4-9L	DETOUR "ARROW" ♦	30"X24"	2			
24M4-8	DETOUR ♦	24"X12"	2			
21M6-3	"ARROW" ♦	21"X15"	2			
* 48G20-11	"CONSTRUCTION INFO" ♦ ●	4'X4'				32
* SPECIAL	"6TH AVE FR RD CLOSED" ♦	36"X36"				9
		SIGN TOTALS	10	16		41

SHEET NOTES

★1. SEE STANDARD S-630-1 OF THE "COLORADO STANDARD PLANS" FOR TYPICAL PLACEMENT OF THE CONSTRUCTION TRAFFIC CONTROL DEVICES

*2. CONSTRUCTION TRAFFIC SIGN (SPECIAL) PAID BY SQUARE FOOT

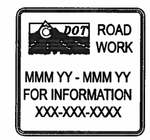
♦3. STENCIL BLACK ON REFLECTIVE ORANGE

4. ROLL-UP TYPE SIGN SHALL NOT BE ALLOWED ON INTERSTATE, FREEWAY, OR EXPRESSWAYS

●5. LOCAL NUMBERS ONLY SHALL BE USED ON THE CONSTRUCTION INFO SIGNING AND NO NUMBER WITH EXTENTIONS SHALL BE ALLOWED.

✠6. IT IS ESTIMATED THAT 4 GAL OF YELLOW AND 4 GAL OF WHITE EPOXY STRIPING WILL BE REQUIRED TO RETURN THE FRONTAGE ROAD TO ORIGINAL CONDITION

CONSTRUCTION INFO SIGN



G20-11

Legend – Black (Non-Refl)
Background – Fluorescent Orange (Refl)

24"X24" SPECIAL

Legend – Black (Non-Refl)
Background – Fluorescent Orange (Refl)

Print Date: 3/25/2009			
File Name: 17999Traf_001Tab of Traf Items01.dgn			
Horiz. Scale: NONE	Vert. Scale: As Noted		
Unit Information: 6580	Unit Leader: PJNIII		

Sheet Revisions

Date:	Comments	Init.

Colorado Department of Transportation
2000 South Holly Street
Denver, CO 80222
Phone: 303-757-9511 FAX: 303-757-9907
Region 6 Traffic and Safety LR

As Constructed
No Revisions:
Revised:
Void:

TABULATION OF TRAFFIC ENGINEERING ITEMS

Designer: PJNIII
Detailer: PJNIII
Sheet Subset: TRAFFIC
Structure Numbers
Subset Sheets:

Project No./Code
C 0062-024
SA 17198
Sheet Number 19

APPENDIX E
Post-construction Interview Sheets

6th Avenue Frontage Road Waste Tire Noise Wall

Questions for NP&G Innovations (Tire Tie Manufacturer)

1. Cost per tie worked out to be approximately $250 each, delivered. What was the approximate cost per tie, without shipping costs included?

   Cost of Tire Ties was $275 each at the shop. Shipping was paid for by the contractor, Jalisco International. Each tie took about 6 hours to fabricate. Subcontractors were used to complete the steel frame fabrication. Each frame cost about $100. Future versions of the tie will have roll-formed steel frames, which will reduce the cost to $30 to $40 each. The treads are currently provided from a supplier in Chicago. The tire laminating is done in-house. The target price for full tire tie production is $100 each.

2. Have you assembled a laminated tire section without a steel frame to test its structural integrity? Do you think such an assembly is feasible, or would you always consider including a steel frame in a section developed for applications other than rail ties, such as sound wall panel segments?

   A frameless assembly is possible, and has been considered, but has not been assembled or tested to date. Laminations would be adhered using epoxy, stacked as needed to develop the proper section depth.

3. An efficient stackable noise wall panel section would be approximately 4"x12", with panel lengths approximately 10'-0" long. Are these dimensions achievable for your current fabrication setup, or would you need to modify the dimensions? Would re-tooling for the optimum shape be a significant expense?

   Standard car tire treads are about 6.7 inches wide; a target width that can be accommodated by just about any tire would be 6.1 to 6.2 inches. Adjusting this unit dimension into other usable widths could be investigated, but developing such a shape would add labor. Most tread lengths are between 92 and 96 inches; adding length to attain 10'-0" sound wall segments would require splicing. Sections 6" wide and 8'-0" long seem to be optimal, without adding significantly to labor. The depth could be developed as needed, and there are no apparent limitations. Additional adhesive information for developing the laminated sections can be investigated with help from Lord Corporation.

4. How large of a shop would you estimate would be required to effectively mass produce Tire Ties or a similar product?

   A 20,000 square foot shop is anticipated for the initial Tire Tie facility. Approximately 60 to 70 employees would be on-site. This would allow for a little over 200,000 ties per year to be fabricated, or around 2 million linear feet per year. In the long-term, a facility of up to 160,000 square feet would be the goal.

5. How many linear feet of this product do you think you would have to sell annually for you to seriously consider developing a noise wall specific product? Have you considered a price target for such a product?

   Production length would have to be similar to that for Tire Ties (2 million linear feet). A target price point would be about $100 per plank. Approximately 23 tires are currently used in each Tire Tie. In the anticipated sound wall panel section being considered, approximately 14 to 16 tires would be applied. Use of the sidewalls would be considered for a sound wall panel section; sidewalls are not currently used in the Tire Tie product. This would raise the amount of tires used to approximately 85 to 95%.

6. What environmental clearances have you needed to consider in setting up your current facilities? Do you see these clearances as an obstacle for setting up a similar shop in another location, e.g. Colorado?

   Having under 1,000 tires stored on-site is the preferred situation, to avoid EPA thresholds for small quantity generator status. The adhesives used in assembly have been proven through testing to be benign when cured. A new shop would not be considered in New York State, due to several governmental and environmental constraints on developing the product. States with economic development programs, such as Mississippi and Virginia would be more likely areas for setting up a shop. It is anticipated there would be fewer environmental obstacles in these locations, where there is a greater priority on business development.

7. Based on your understanding of the trends in used tire supply, do you foresee any availability issues that will affect the long-term development of Tire Ties or similar products?

   There are over 300 million waste tires available every year, so the supply is not expected to dwindle. Currently, 60% of waste tires are burnt at power plants. Potential classification of tires as solid waste would change the current way waste tires are handled. Retrofitting of existing burning facilities, including addition more robust scrubbers, would be required, and could result in a significantly larger number of unprocessed waste tires.

8. The application of airplane tires on the ties for our wall provided an aesthetic continuity. Do you believe airplane tires would be readily available for mass production of a noise barrier product, or would you expect that the aesthetic would need to be compromised by using another finish? Are there other finishes you would consider applying to provide a smooth, consistent look between all the panel elements?

   NP&G added the airplane tires to the Tire Tie surfaces to provide a little better aesthetic than a regular car tire tread. This deviated from the specification, which asked for a standard production tie, but was recognized as a good addition to the project. Airplane tires are only one ply, which create some trouble in applying them on the Tire Ties. Airplane tires typically have less than 1,000 miles on them, due to the rigorous landing stresses. But the low level of *use keeps the surfaces with relatively low amount of scuff marks or discontinuities.*

Alternate finishes used on the ties include Herculiner (truck bed liner material), which was applied to rail ties being delivered to India. DAP urethane roofing caulk has been used to fill gaps on ties to provide more consistent surfaces in preparation for experimental applications of urethane on the ties. The urethane can be formed a bit to provide an improved finish to the ties.

9. Have there been any instances of Tire Ties catching on fire? Do you have any concern about the Ties catching on fire in our application? We discussed this, and didn't feel it was too big of an issue.

   No fires have been reported for any ties in service. However, ties made from other materials have been shown to be unreliable in the case of fire, including timber and plastic ties. (A video was supplied from NP&G demonstrating an attempt to catch a tie on fire. Even when doused with some gasoline, the tie did not exhibit a tendency to burn).

10. Delivery of Ties was slower than desired. Was this the first big order of Ties? What delays were encountered, and what could have increased your production rate?

    This was considered a special order, with a request for an unprecedented number of ties, and with consideration for this particular application (e.g. the consideration for a more aesthetically pleasing product taken on by NP&G itself). The scheduled production length was actually close to that proposed for the project (94 calendar days vs. 90 calendar days quoted to the Contractor). Approximately 6 to 8 ties per day were able to be fabricated, but help from outside the plant was required.

11. Can you create a product that interlocks better so that gaps between the Ties are eliminated?

    A tongue and groove configuration of the tire panel sections can be provided, and has already been considered (but not built). The groove depth under consideration would be ½". The alignment of the tires in the laminated configuration is flexible.

12. Do you have any other thoughts or suggestions on how you can apply your technology in developing noise wall panels?

    Configurations for lighter Tire Ties have been developed, which was provided on the Tire Wall project. Typical production Tire Ties weight over 400 lb. For the 6th Avenue tire wall, the ties only weighed around 360 lb each. It is estimated that the tie weight may be able to be reduced to under 300 lb each. Heating the ties in an oven can help reduce the tie weight.

To address potential rusting problems from the steel on the Tire Ties, a phosphorus finish was supplied on the ties shipped to India.

Questions for Jalisco International (Noise Wall Contractor) and Jeff Hargrove (CDOT Construction Supervisor)

Responses provided by Jeff Hargrove (CDOT Region 6) 8/4/10:

13. How were the Tire Ties delivered (comment on how bundled, packaged, etc.)?

    The Ties were delivered on 2 trucks to Jalisco International's yard. The Ties were set on wooden palettes, simply stacked, and tied down on the delivery trucks, uncovered.

14. Were there any problems with the Tire Tie delivery/unloading/storage? Were any of the ties damaged when they arrived?

    The delivery of the Ties was delayed twice. The schedule at the start of the project was for a 90 day delivery from the award date. When the Tie fabricator realized it wasn't going to be paid prior to delivery, the delivery was delayed until a payment agreement was settled with CDOT. Jalisco International, the Contractor, ended up fronting a portion of the Tie cost, to have the fabricator start its work.

    The delivery date was later pushed back, with sickness to several of the shop employees being cited as the reason.

    No problems were encountered with delivery. No Ties were rejected. No significant damage was reported.

15. How were the Tire Ties stored on-site prior to installation? Were any protective measure taken?

    The Ties were stored on palettes, uncovered at Jalisco's yard and on the job site. No extra protective measures were used.

16. Do you have any recommendations for how to store the Tire Ties on future projects to keep them clean/in-tact/protected from damage?

No specific recommendations. There were no weather delays on the project, so no new or innovative procedures were developed.

17. Did you find the Tire Ties to generally have the dimensions expected for the project? Were the Ties difficult to modify for proper fit?

    Attempts were made to set about 6 Ties, as they were, without modification. None of the first 6 Ties fit between the posts. Portions of the ends of these ties were cut off to allow the Ties to fit between the posts. At that point, every Tie had their ends cut to some level to fit the post layout. The cuts typically needed to be applied to only one or two tire laminations, and an average of ¼" was required to be cut. Cuts were done on each end of a majority of the Ties.

    The cutting added approximately $1200 to the project cost, which accounted for 2 laborers cutting the Tie ends with a saw. The result was having just about all the Ties being set between the posts, while touching the posts. The original design had assumed that up to a ¼" gap may remain at the ends of the Ties, based on expected fabrication tolerances from the fabricator. However, very few gaps were attained during the installation.

    The steel posts were set vertically along the slightly sloping Type 7 Barrier. This resulted in having the Ties being very slightly skewed vertically between the posts. This may have contributed to a more snug fit of the Ties between the posts.

    About 20% of the Ties have "wavy" facing on the 6th Avenue Frontage Road side of the wall. This is an indication of delamination of the single layer of tire tread from the steel frame of the tie. The delaminated Ties were general delivered in this condition, but were not rejected – the "better", less delaminated faces were placed facing the roadway side of the wall.

18. How were the Tire Ties installed – using equipment or by hand? Combination of both?

    Ties were lifted with straps and set into place. 4 laborers were required: one to operate the forklift or Bobcat with forklift attachment (both were used), one to set the straps to lift the Ties, and two at the wall to guide the Tie down between the steel posts (one each end of the Tie).

19. Were the Tire Ties easy to install? What would you recommend to help make the Tire Tie installation easier and more efficient?

    Other than the saw cutting mentioned above in question #5, the Ties were pretty easy to install. If the Ties had been supplied within the tolerances specified, the installation would have been very easy.

    Approximately 90 to 100 Ties were able to be placed by one 4-man crew in 8 hours. The total time spent to install the Tire Ties was approximately 24 hours.

Two crews at once were used simultaneously on one day, and one crew used on a second day (24 hours of labor, total, between two crews).

20. How were the Tire Ties painted, and was it difficult to complete the painting?

    Two crews of 4 were used to paint the entire wall in on day (2 Powerwashers, 2 Maskers to cover the pre-painted posts, 2 rollers to paint the concrete barrier, and 2 for applying the stain). The wall received a standard powerwash, and was painted the next day. The ties were sprayed with one coat of stain (from Anchor Paint). The Type 7 Barrier was treated with a standard structural concrete coating, per section 509 of the CDOT specifications. The coating on the concrete was applied by roller. Other than the effort for masking the pre-painted steel posts, the painting of the Tire Ties was straightforward.

    A stain from Anchor Paint was used for the project, with the product characteristics specified on the plans (product data is forthcoming).

    One Tie had accidentally been painted with the structural concrete coating intended for the Type 7 Barrier. This Tie was removed from the project, and stored at a CDOT maintenance yard. The Tie was observed by Bill Marcato at the yard. The structural concrete coating was observed to be performing very poorly on the tie, with many inconsistencies in the finish, and non-uniform spread of the coating. The coating appeared to be cracking in several locations, a condition not noticed on the Tire Ties treated with stain.

21. Are there any maintenance issues you anticipate for the Tire Tie portion of the noise wall, based on your field observations?

    The edges of the Tire Ties have exposed steel that will be subject to rusting. Rust treatment or removal may need to be considered if the condition is not acceptable.

    FHU asked if it was noticed whether the steel had been treated with a clear lacquer finish, which had been proposed by the Tire Tie supplier during fabrication. Jeff said there was no indication that the steel had been treated with any coating.

    The other potential maintenance issue noted was for the stain itself, which in many locations appears to have been absorbed into the rubber on the face of the Tire Ties, leaving a darker finish than was provided at the time the stain was originally applied.

22. Any thoughts/observations about the gaps between the Ties, and can you think of solutions for closing them?

    Closing the horizontal gaps was never considered. The Ties fit reasonably well together, such that there were only a few locations with visible gaps. None of *the gaps appeared to be more than around 1/8" wide. It does not appear that closing the gaps with a separate layer of material will be required.*

23. Do any other applications for the Tire Ties come to mind?

    Nothing came to mind for other CDOT applications.

24. Are there any other comments/recommendations you have regarding the Tire Tie product, its installation, and how it can be used on future noise wall construction applications?

    Nothing specific was discussed.