EXPERIMENTAL GUIDERAIL END TREATMENT

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ABSTRACT

This report documents the design and construction of the eccentric loader terminal and the extruder terminal for w-beam guiderail. The objective of the study is to develop design guidelines and construction procedures for these terminals at high accident locations where the standard breakaway cable terminal is restricted by the lack of recovery area. The study includes monitoring the design, construction, repair and accident performance of the terminals.

Four eccentric loader terminals were constructed on typical rural highway sites. Although the contractor was unable to understand the post offsets and orientation from the plans for the first two eccentric loader terminals, the second two terminals were constructed according to the plans by pre-bending the guiderail and orienting the posts to the pre-bent rail. The contractor designed a special shoe for the post driver to drive the posts and steel tubes with attached soil plates.

Four extruder terminals were constructed on a highway through pine lands and marsh where recovery area is limited. The terminals were constructed according to the plans without errors.

The complete study will document the accident performance and repair costs in a final report.

INTRODUCTION

The objective of this study was to develop construction procedures and design guidelines for the use of the eccentric loader terminal and the extruder terminal for straight (no flare) w-beam guiderail at high accident locations.

The study includes monitoring the design, construction, repair, and costs of the terminals on highway safety projects. As a lesser emphasis, the accident performance will be compared with the crash test results. Since the successful crash testing was conducted under ideal field conditions (i.e. flat terrain, and controlled impact conditions), the roadside installations provide data for construction, site conditions, and accident conditions which vary from the tests.

Background

The implementation of a new or improved roadway safety feature does not always require an extensive evaluation or testing program. Careful research of published literature and an evaluation of the results from other agencies is frequently sufficient. Such implementation requires an assessment of a number of issues such as performance, design details, constructability, and maintainability of the proposed safety feature, and requires input from many disciplines. The New Jersey Roadside Safety Features Committee was established to provide this type of assessment.

The interdepartmental task force is organized to expedite the evaluation of proposed safety features. The committee uses a multidisciplinary approach to resolve implementation issues regarding the safety features and issues specifications and guidelines for their use.

The implementation of new guiderail end treatments has predominated recent committee activities because of a concern for reduced accident severity on the Department's Breakaway Cable Terminal. The committee selected the one and one-half foot (45 cm) flared eccentric loader terminal and the extruder terminal for implementation and evaluation.

The new end treatments were selected with the following criteria:

1. Meet national safety standards for small cars;
2. Perform safely when installed on a tangent section;
3. Provide attenuation for small cars impacting the guiderail end;
4. Simple to construct; and
5. Designed for urban and rural areas.

TERMINAL DESIGN CONCEPTS

Breakaway Cable Terminal (BCT)

The first standard guiderail Breakaway Cable Terminal was installed on New Jersey highways in the spring of 1976. The BCT was developed to reduce the severity of end-on impacts without vaulting or ramping the vehicle.

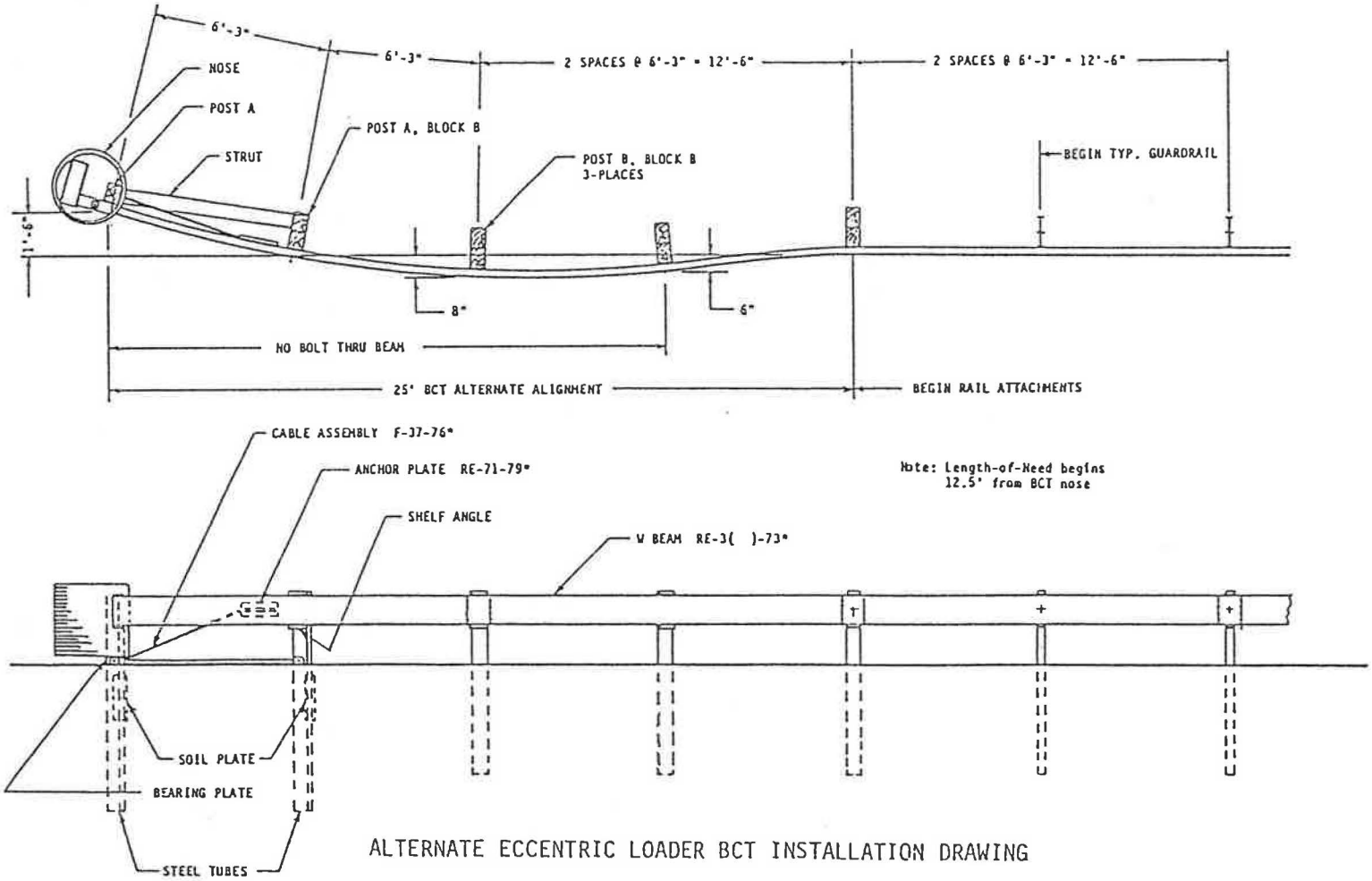

FIGURE 1 Eccentric Loader Terminal Detail.

The New Jersey in-service evaluation of the BCTs (*1*) indicated that the terminals performed satisfactorily with median size vehicles when installed with a four foot (1.2 m) flare. In locations where the space for recovery and installation were limited by side walks and limited right of way, the BCT was installed without the flare. Such installations stiffen the rail section and cause excessive damage to small vehicles. The standard BCT consists of two 6x8 inch (15x20 cm) wood posts in concrete footings, a buffer end section with two steel diaphragms, and a cable from the w-beam rail to the first post. Upon end impact, the posts breakaway, and the rail is bent away from the impact.

Initially, maintenance forces reported problems removing the broken posts subsequent to an accident. To resolve this, the felt paper wrapping of the posts was replaced with a wax impregnated cardboard construction tube. This design failed when the wood posts were loosely installed in oversize tubes. Another problem occurred when the concrete footing was poured in a cone shaped hole. In this case, the footing and post was pushed out of the hole on impact.

Eccentric Loader Terminal (ELT)

In an effort to correct some of the above problems, the Southwest Research Institute (SwRI) developed and crash tested the eccentric loader terminal to reduce small car impact severity and to eliminate the post replacement problems (*2*). The basic design features of the terminal are an eccentric connection in the nose that introduces a bending moment on the w-beam and wood posts which are installed in steel tubes to facilitate removal.

The ELT design is similar to the standard BCT with the nose removed and replaced with a vertical section of corrugated steel pipe surrounding a structural steel lever (see Figure 1). The parabolic offset reduces the buckling strength. The offset is accomplished with a one foot, six inch (45 cm) flare at the first post. The second post is constructed at the line of the front of the guiderail at the steel posts. By offsetting the third and fourth posts by eight inches (20 cm) and six inches (15 cm) respectively from that line toward the road, the column strength is reduced in the rail. To further reduce the strength of the rail, the bolts are removed from these posts. The fifth post is constructed in-line with the front of the guiderail. The ELT must be set back eight inches (20 cm) from the edge of the shoulder to accommodate the forward offset.

Extruder Terminal(ET)

In the continuing effort to correct the spearing problem, Texas Transportation Institute developed and crash tested the extruder terminal for the end of straight w-beam guiderail (*3*). The primary objectives of the ET development were to perform safely when installed on a tangent, and to provide ease of installation and maintenance. The design concept (see Figure 2) of the terminal involves an extruder device placed over the end of w-beam guiderail. When impacted head-on by a vehicle, the extruder forces the w-beam through a circular arc away from the vehicle. As the w-beam is deformed, impact energy is dissipated and the impacting vehicle is decelerated at an acceptable rate.

The extruder terminal captures the end impacting vehicle and safely decelerates the vehicle to a stop rather than redirecting the vehicle away from and behind the guiderail end, reducing the need for a large recovery area as required by the eccentric loader terminal. Furthermore, the ET is installed on a tangent section which reduces the required area for the flared end.

RESEARCH METHODOLOGY

Site Selection

Four eccentric loader terminals and four extruder terminals were constructed on existing and new guiderail installations. The location criteria was the need for a guiderail end treatment on a tangent guiderail sections where the potential for accidents was high and the installation of the standard BCT was not practical. In such installations, the area adjacent to the guiderail did not permit the four foot (1.2 m) flare, and the recovery area was inadequate for vehicle redirection.

Monitoring and Data

The monitoring effort for the guiderail terminal installations includes:

1. Technical support for the preparation of construction plans and design criteria such as site review, layout and preparation (curb removal, tree removal, etc.);
2. Construction inspection for critical elements in accordance with the plans, and technical support for construction; and

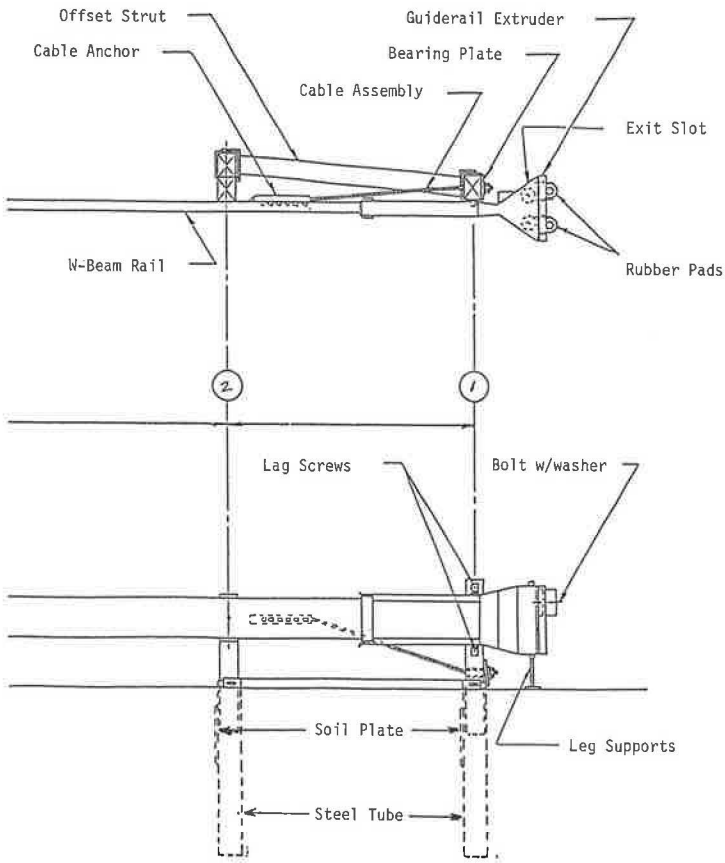

FIGURE 2 Extruder terminal detail.

3. Technical support for maintenance and repair of the terminals after an accident. During the study, the following data were collected:

1. Location.
2. Site description.
3. Pictures of all units during construction.
4. Measurements of the critical elements.
5. Notes on construction problems.
6. Time of construction and repair.
7. Initial and repair costs.
8. Accident histories and information.

TERMINAL CONSTRUCTION

Eccentric Loader Terminals

The eccentric loader terminals were constructed at two sites on Route 33, Hightstown and on two sites on Route 206, Columbus which met the location criteria.

Route 33, Hightstown

In September 1991, two eccentric loader terminals were constructed at the leading end of guiderail preceding a head wall in the eastbound and westbound lanes of the rural, two lane roadway with an AADT of 10,800.

The eastbound ELT was constructed 90 feet (27 m) from the existing headwall on a flat area of brush and small trees which were off the right of way and were not removed (see Figure 3). This site is typical of many rural highways in New Jersey where limited right-of-way does not permit the construction of the standard flared BCT.

The ELT was constructed from a string line placed behind the steel posts. Starting with the first wood post after the steel post on the existing w-beam rail, the post spacing and offsets for the wood posts were measured from this string line. As the contractor interpreted the plans which use offsets from the front of the rail, mistakes were made in the placement of the wood posts from the string line. This resulted in the incorrect forward offset and incorrect orientation of the posts to

the w-beam rail (i.e. posts were perpendicular to the string line and not perpendicular to the bent rail as shown in the plans). As a consequence, the contractor was unable to bend the rail to fit the offset posts. Also, the buffer end and anchor cable were improperly attached to the rail.

The site of the westbound ELT is a slight depression with a steep berm (abandoned railroad bed) about 20 feet (6.2 m) behind the terminal which was constructed 270 feet (83 m) from the existing headwall (Figure 4).

The westbound terminal was constructed similar to the eastbound terminal where the contractor's string line was laid behind the steel posts. However, with this second terminal, an attempt was made to change the contractor's construction procedures. Instead of constructing the terminal from the first wood post after the steel post of the guiderail, as done in the first installation, the contractor drove the buffer end steel tube first, and took offsets from that post to the existing steel post of the guiderail. These measurements were not made correctly and resulted in the incorrect forward offset of the bent rail (Figure 4). Similar problems were encountered with bending the rail at the buffer end.

The eastbound and westbound terminal required five hours and three hours respectively for six workers to construct. As a reference, the standard BCT takes two workers about thirty minutes to construct. (Subsequent to the construction of the Route 206 terminals, the contractor reconstructed the two Route 33 terminals.)

Route 206, Columbus

The two eccentric loader terminals were constructed at the leading end of the existing guiderail in the northbound lanes. The roadway has an AADT of 21,000.

In October 1991, the southern ELT was constructed on the northbound four lane divided portion of the highway (see Figure 5). The terminal was constructed on a one foot (30 cm) high berm which was about ten feet (3.1 m) from the edge of the shoulder on an existing guiderail. The recovery area is a 4:1 downward slope to a flat clear area.

Using the previous experience as a bases, the contractor constructed the eccentric loader with pre-bent rail and angled posts as shown in the plan. The post offsets were made from a string line which was placed in front of the steel posts to eliminate the need to calculate for the difference between depth of the wood and steel posts. The first post after the steel post of the existing guiderail was driven first; then, the steel tube of the buffer end was offset from the string line and driven. The posts and steel tubes were driven with a special shoe to accommodate the soil plate (see Figure 6). The orientation of the other posts were accomplished by temporarily constructing the bent guiderail and driving the posts perpendicular to the that rail after measuring the offsets directly from the plans. After the wood posts were bolted to the steel tubes, the rail was temporarily attached to permit two workman to hold the buffer nose while a third worker attached the assembly. The cable assembly was installed to complete the construction.

The northern ELT was constructed on the northbound four lane undivided portion of the highway. The terminal was constructed on a slight berm which rises two feet (60 cm) behind the guiderail with a gradual upward slope (see Figure 7). Using the same construction procedures as the previous ELT, the northern terminal was constructed without problems and according to plans.

The contractor reduced construction time to two hours with four workers for each terminal.

Extruder Terminals

The extruder terminals were constructed at four sites on Route 322, Weymouth (see Figure 8). At these sites, the existing tangent guiderail sections required end treatments and the limited right-of-way precluded the use of the standard flared BCT.

In this area, Route 322 is a rural four lane undivided highway through pine lands and cranberry bogs. The roadway is constructed on a tangent and has an AADT of 11,200. The existing 500 foot (154 m) sections of guiderail were constructed to redirect errant vehicles away from culverts and marshy areas.

The ET is constructed from a string line placed along rear of the existing guiderail posts. No offsets or angled posts are needed to construct the terminal. However, on guiderail constructed at the immediate edge of the shoulder, the terminal must be set back from the curb by eight inches (20 cm). This was done to offset the extruder component away from possible damage by snow plows which follow the shoulder edge.

For the first two terminals, the contractor dug the post holes with an auger, placed the steel tubes and posts in the holes and backfilled the posts. Since the soil in this area is sandy, it was easier to drive the steel tubes with a cap to protect the top of the tube. The soil plate was attached to the tube before driving. However, the contractor lacked the special shoe used on the eccentric loader project. When the tubes were in place, the posts were bolted in the tubes. The strut and cable assembly were constructed by two workers before the w-beam rail was bolted to the posts. The extruder end was lifted by three workers and lag screwed to the first post (see Figure 9).

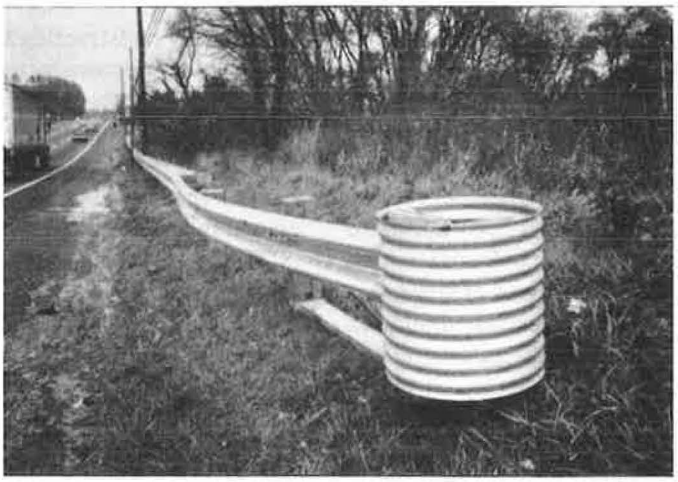

FIGURE 3 Eastbound Route 33 ELT and site.

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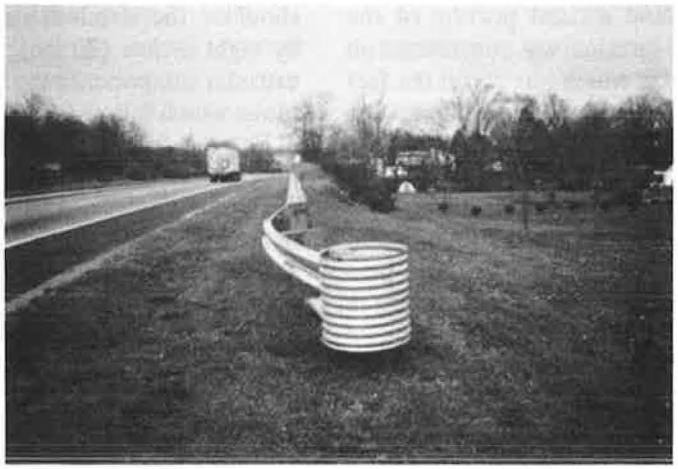

FIGURE 5 Southern Route 206 ELT and site.

FIGURE 6 Special shoe for driving wood posts and steel tubes with soil plates.

FIGURE 7 Northern Route 206 ELT and site.

FIGURE 8 Typical ET and site.

FIGURE 9 Typical three man crew and construction of the ET.

Unlike the eccentric loader where the buffer end component was constructed backwards, the extruder end component and other components were easily constructed from the plans.

The construction of the first two terminals required about two hours each with six workers and the foreman. On the third and forth terminals, the contractor reduced his crew to three workers and required less than an hour to construct each terminal.

COSTS

The bid price for both eccentric loader and extruder terminals was approximately $3000/each. The high bid price reflected the experimental nature of the project and the small number of terminals purchased. The manufacturer estimates that the hardware cost of the eccentric loader terminal is approximately $900 and the extruder is approximately $1700.

The manufacturer notes that the cost of the eccentric loader terminal should include costs for grading the recovery area, and the cost of extruder terminal includes 37 1/2 feet (11.5 m) of the length-of-need which should be deducted from the cost of the terminal.

CONCLUSIONS

This study documents the experimental construction of the eccentric loader terminal and the extruder terminal for tangent guiderail sections. Both terminals reduce personal injury and vehicle damage resulting from impacts of small cars with guiderail ends.

Essentially, the end treatments provide greater safety over the standard BCT where end-on impacts are critical with small cars. This is especially critical in highly urbanized areas such as New Jersey where terrain and limited right-of-way make flared installations impossible.

The Roadside Safety Features Committee selected the eccentric loader terminal for four experimental installations on Route 33, Hightstown and Route 206, Columbus, and the extruder terminal for four experimental installations on Route 322, Weymouth. Although inexperience with the construction plans and procedures caused measurement errors for the offsets of the wood posts and orientation of those posts to the guiderail in the construction of the first two eccentric loader terminals, these problems were solved with the pre-bent w-beam guiderail for the offset posts and a construction string line in front of the steel posts to eliminate measurement errors.

The extruder terminal was constructed without measurement errors. The extruder component was offset from the edge of the shoulder to accommodate snow plows.

The Roadside Safety Features Committee will monitor the terminals for maintenance costs, impact damage after an accident, and vehicle damage from accident reports. After the two year monitoring effort, a final report will be prepared to document the study.

REFERENCES

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