CONNECTICUT DEPARTMENT OF TRANSPORTATION'S TRUCK ESCAPE RAMP (TER) – AVON, CT

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ABSTRACT

During 2008, the Connecticut Department of Transportation (ConnDOT) completed a Truck Escape Ramp (TER) in Avon, Connecticut. By incorporating multiple advanced technologies, the design solution addressed an urgent safety need while minimizing disruption to the surrounding businesses and residences. Existing conditions included a small site located in a mixed-use, upscale neighborhood; topographical constraints; a major arterial corridor with limited alternate routes; a steep, winding grade terminated by a signalized intersection; and, an accident history with two major runaway vehicle incidents during the previous three years.

The TER design solution to stop runaway vehicles consists of a proprietary vehicle arrestor system to stop runaway vehicles; a Mechanically Stabilized Earth (MSE) wall system to support the TER above existing land contours; a complete concrete wall for safety and debris retention; and, an automatic sub-surface pavement heating system to prevent snow and ice accumulation and subsequent removal during winter storm maintenance. This paper discusses the role of these various TER components, along with its accelerated construction schedule and the performance of the TER to date.

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BACKGROUND

U.S. 44 was designated as such in 1935 and incorporated into the National Highway System, traversing Avon (Talcott) Mountain, a traprock ridge in the Metacomet range located in central Connecticut. The subject section of highway was formerly known as the Old Talcott Mountain Turnpike and was first constructed in 1798. The modern-day U.S. 44 is part of the National Highway System in Connecticut, and serves as a critical link in the region's roadway network, facilitating passage for both passenger and commercial vehicles between Hartford and northwestern Connecticut.

During July 2005, a tri-axle dump truck experienced both vehicle and operator error while descending the grade and crashed into 18 other vehicles waiting at the intersection, killing 4 people and injuring 19. At that time, a series of safety improvements were proposed by a Governor's task force and later implemented by ConnDOT. However, during September 2007, a tractor-trailer experienced both vehicle and operator error and crashed into a furniture store near the intersection, injuring the driver. After this incident, Governor M. Jodi Rell issued a temporary ban on this grade for all vehicles over 13 tons. An emergency declaration authorizing the construction of a TER was authorized on October 1, 2007, with initial construction completed by February 21, 2008. Final construction cost was approximately $2.8 million for the initial project, and an additional $0.4 million additional cost for the sub-surface heating system.

EXISTING CONDITIONS

The site is located in an upscale suburban neighborhood about ten miles west of Hartford, CT. The ramp is located adjacent to a historic inn, with a brook bounding the west end of the ramp and the inn's parking lot running along the north side. The location is on a major arterial corridor, with a 2006 Average Daily Traffic (ADT) volume of 19,600. In this area, westbound U.S. 44 descends almost 300 vertical feet in about 1.5 miles, with grades ranging up to 10%. The highway was comprised of 2 lanes in each direction with little or no shoulder and a double yellow line. No median or barrier was present, and passing was allowed in both directions. Near the grade bottom is a signalized intersection with CT 10 and Nod Road, at which the westbound direction widened to 2 thru lanes and left-turn lane.

DRAGNET® TRUCK ARRESTOR SYSTEM

The design of the new TER is based on the DRAGNET® Truck Arrestor System (TAS), a proprietary system manufactured by Entwistle Corporation. It is designed to stop a vehicle using a series of mechanical energy-absorbing spools and stainless steel nets. These nets are connected to spooled-tape energy absorbers mounted in precast concrete barriers on either side of the TER. The energy absorbers use a patented "metal bender" principle for absorbing energy. As a truck enters the ramp and pulls the net, the spooled tape attaching the net to the side wall is pulled over a series of offset pins, bending the tape backwards beyond its strength point. This bending actions is the principle mechanism for absorbing the kinetic energy of the runaway truck. The chambered spooled metal tape and offset pins make up the absorber, and with so few moving parts the absorbers are virtually maintenance free.

The size and number of nets in this type of TER depends on the length and grade of the ramp, as well as the entry design speed and vehicle weight. The Avon TER system is designed to stop an 80,000 lb truck traveling at 60 mph, although systems for stopping heavier and/or

faster vehicles have been supplied by the company. The Avon TER is comprised of five nets, with net #1 positioned 5' feet past the gore area attenuation system, and nets #2 through #5 positioned at 55', 65', 75' and 85', respectively, from the same location. Net #1 is comprised of two metal tapes (one mounted in a pocket in each side wall) and a stainless-steel net. It is purposely designed with less stopping resistance so that a lighter and/or slower-moving vehicle may enter the truck ramp and be stopped with acceptable decelerations. Nets #2 thru #5 are comprised of four metal tape cartridges (two mounted in separate pockets in each side wall) and designed with higher stopping resistances to accommodate both a heavier and/or faster vehicles. Each net is comprised of stainless steel cable and fittings, as well as a center stand to maintain the desired height of the net above pavement so overtopping does not occur.

The physical dimensions of the ramp are much less than those of a stone-based TER. Unlike a conventional TER, this ramp has up to a 6.5% **downgrade** in the deceleration area. The interior of this ramp is approximately 330' long and 20' wide, and is surrounded on both sides by 56" precast concrete walls, which act as protective barriers as well as trapping detached vehicle parts. The mainline of U.S. 44 westbound was widened for approximately 1000' prior to the ramp to accommodate the exit lane and gore area. The TER, however, is closely aligned with the mainline, and the additional right-of-way (ROW) required widened the original ROW by no more than 50'.

MECHANICALLY-STABILIZED (MSE) EARTHEN WALL

Due to the proximity of the inn's parking lot and the brook to the TER, and the necessity to reduce the downgrade of the TER, a fill was needed to attain the desired vertical profile. The final TER profile required that grade be raised up to 19' above existing grade line. The ramp's length, downward slope and location on a steeply-sloped embankment required some type of structural embankment support to allow construction while eliminating slope intrusion into the surrounding brook and parking lot. Design personnel chose a Mechanically Stabilized Earth (MSE) wall that utilizes precast concrete wall panels with an ashlar stone masonry formlined finish. Atop the MSE embankment is a precast concrete barrier wall constructed behind the precast concrete coping at the top of the facing panels. This barrier wall bears on the retained fill, but functions independently of the MSE wall to resist overturning and sliding forces that would be induced by a TL-5 truck (124 kip horizontal force applied 42" above the pavement). This barrier wall was precast at a local plant a short distance from the project site, a process that facilitated coordination between the fabricator and contractor and reduced transportation costs. Mild weather during the installation of the precast barrier allowed for the barrier footing to be cast-in-place, with the barriers then chemically anchored to the footing. It should also be noted that the end barrier wall was cast-in-place, which ties together the end wall with both side walls.

SUB-SURFACE PAVEMENT HEATING SYSTEM

This type of TER performs optimally with little or no snow pack accumulation in the net area, lest the bumper height of a runaway vehicle may not have correct vertical placement to be ensnared by the nets. While the TER nets are removable to allow snow removal or other type maintenance activities, it required both time, manpower and traffic protection to perform these operations. Plowing might also lead to deeper snow accumulations in and around the sand-barrel attenuator area, posing a vaulting risk. Plows would leave windrows against the barrier walls that must be removed, and the ramp's 20' inside width greatly confined operations of front- or

skid-steer loader snow removal operations. If icing had first occurred during the snow event, the ramp's downgrade exacerbated traction and footing problems for snow removal forces. Also, while snow-removal operations were active or the nets were being removed or installed, the TER was unavailable for use. This ramp closure required three maintenance vehicles with crash attenuators maintenance trucks be stationed prior to the ramp, and signage directing vehicles to the TER to be disabled.

The TER's short length and confined end treatment area made it a viable candidate for a snow-melt system. Although a system was proposed during the initial design meetings for the TER but rejected, initial experiences in clearing snow led to reconsideration and a system was added approximately four months after initial opening. The addition of the heating system eliminates any noise and vehicle exhaust associated with the snow removal task. The sub-surface heating system maintains near-bare pavement conditions during snow/ice events, melting snow at up to 4 inches per hour to accommodate heavy New England snowstorms. The system extends into the ramp's entry area and has the ability to melt plow windrows leftover during mainline plowing operations. The snow-melt system was supplied and installed by Warmzone Premier Radiant Heating and uses multiple temperature / moisture sensors to determine when it should be activated. The electrical service into the panel is a newly installed 480 volt / 3-phase / 400 amp service, with the total design load calculated to be 328 amps. Estimated power usage at full operation is 260 kW. The system automatically activates when a temperature/moisture sensor indicating the conditions for freezing precipitation are present, and remains on throughout the duration of the weather event. Due to the power requirements of the heating system, the start sequence is spread over nine separate zones, with a brief time delay between zone activation so as not to overload the electrical service. A light tower on top of the system's control cabinet indicates to passing DOT vehicles the system status – green is off, yellow is active, and red indicates a malfunction.

Two areas of note were included in the ramp heating design. First, the TER's drainage outlet was also heated as to allow melting runoff from the ramp to flow freely to the catch basin. Second, a portion of the exit lane approaching the ramp was heated, since this was both a critical driver decision area for ramp entry. This allowed for a smooth transition from a possible pack snow condition on the mainline of U.S. 44 to the heated ramp's bare pavement before the ramp throat was entered. It is anticipated that this design will provide uninterrupted ramp availability due to weather.

CONSTRUCTION

Several residences were located in the direct proximity of the proposed ramp, two of which were taken through eminent domain before construction began. In addition, small amounts of land from several other residences' front yards were required for the TER's exit lane and gore area. The accelerated construction schedule saw construction begin in October 2007, and the ramp was initially opened in February 2008, with the final paving lift being delayed until spring 2008. During this time, a project scope change was made to include the sub-surface heating system. The heating system was installed and final paving lift installed during the summer 2008.

As an additional safety measure, a 15 sand-barrel impact attenuation system was installed at the ramp end. Although not required by the TER design, its inclusion may play an important

psychological role for drivers entering the TER, since it is visible from the exit lane and visually shields the concrete wall at the end of the ramp.

MAINTENANCE

Maintenance of the DRAGNET® system is simple and straight-forward. Normal operation requires virtually no maintenance, only to make sure the ramp stays clear of debris and an annual test of the heating system. If a runaway vehicle event should occur, the runaway vehicle is extracted either under its own power or by tow vehicles. Then the expended metal tapes and tape cartridges are detached from both the nets and removed. Replacement tape cartridges are carried as stock in the Department's inventory or available from the manufacturer. New cartridges are reattached to both the net and side wall for each of the affected nets, and the system is ready for use. Total time for complete turnaround is anticipated to be under a day. Approximate full-cost replacement is about $90,000 per event, with less cost if not all nets are deployed. The heating system is billed on a special demand electric utility rate that charges a low fee during the non-heating season, and a higher kW/hr fee the rest of the year. Although each activation of the system may cost several hundred dollars, the savings in traffic protection costs alone if the ramp were to be mechanically cleared more than offset this charge.

PERFORMANCE

The Avon TER was placed into service February 21, 2008. To date, there have been no incidents involving this system. The snowmelt system has functioned as designed, including melting 14" of snow that fell in a 72-hour window during the winter of 2008-09. The heating system has also been activated during several non-snow ice events, including a freezing rain storm and a freezing morning fog. Heating the pavement leading to the ramp entrance has also worked well, as the heating system is powerful enough to melt the snowplow windrow that typically occurs when a snowplow transitions across the ramp entrance.

It is the intent of ConnDOT to continue to monitor and document events and provide periodic reports on its operation and other similar TER's to determine performance characteristics over time. Most recently, the Ontario (Canada) Ministry of Transportation performed a successful full-scale, live-driver test of a TER installed in North Bay, Ontario with a 60,000 kg truck travelling at 90 km/hr. Results of that test can be viewed at www.highway11northbay.com on the Internet.

CONCLUSION

To ConnDOT's knowledge, this is the first full-scale installation of this technology in the eastern United States, and the first heated TER in the world. The final cost of the TER was approximately $3.2 million. Although this TER may seem to be an expensive design alternative, the design solution integrates well with the neighborhood and site constraints; preserves existing traffic flows without usage restrictions, allows all-weather availability and requires minimal additional maintenance.

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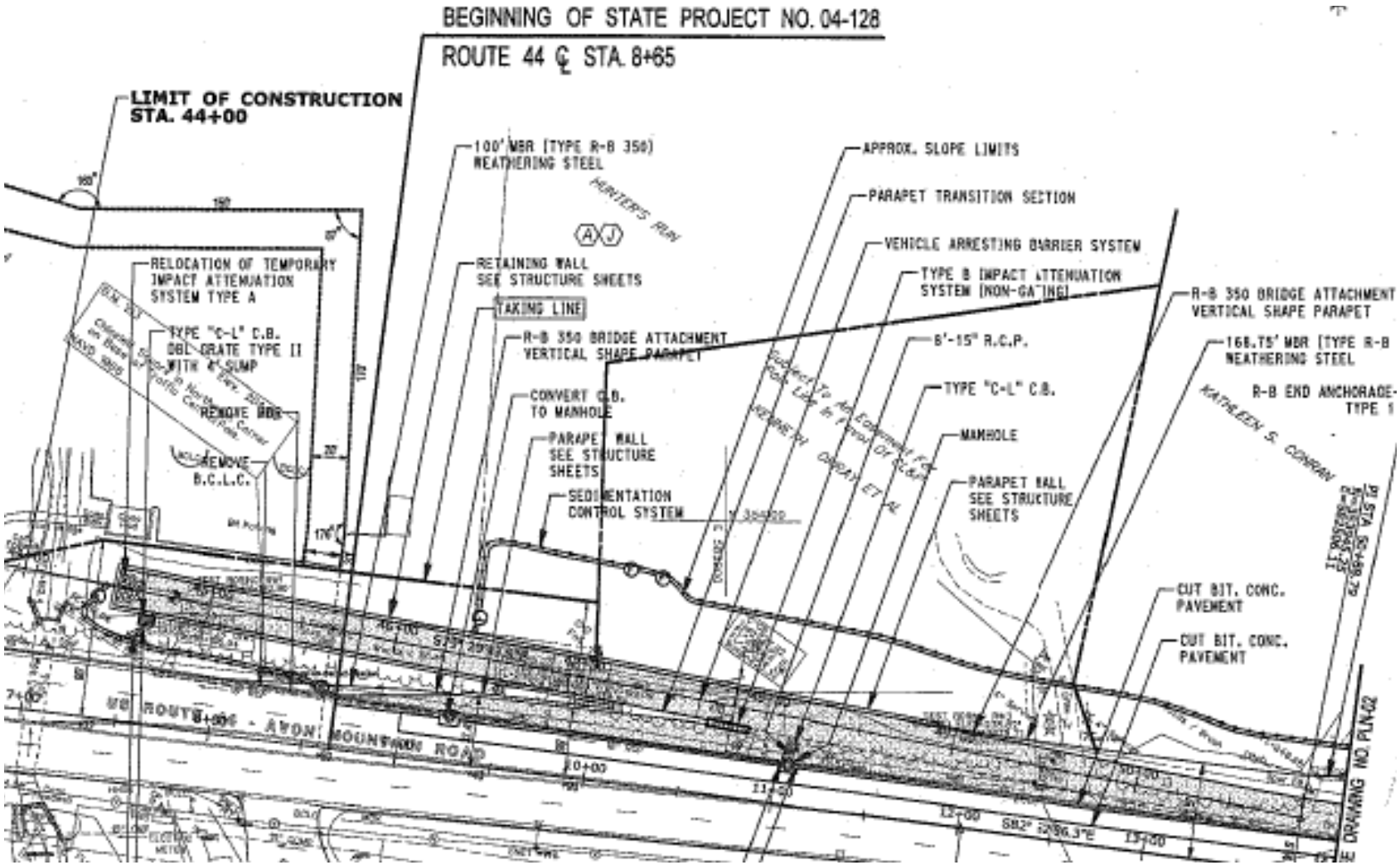
SUPPORTING NEWS ARTICLES

Construction Of Avon Mountain **Ramp** Begins
Construction Of Avon Mountain **Ramp** Begins. The construction of a runaway **truck ramp** on Avon Mountain began on Monday. One lane of Route 44 was closed Monday morning as crews prepared to begin construction....
Article: http://www.wfsb.com/news/14636888/detail.html

Runaway **Truck Ramp** Opens In Avon
Runaway **Truck Ramp** Opens In Avon. A runaway **truck ramp** on U.S. Route 44 in Avon opened on Thursday, a day earlier than scheduled. State transportation officials said the **ramp** was opened Thursday in anticipation...
Article: http://www.wfsb.com/news/15359057/detail.html

Figure 1: Plan View of Avon, CT Truck Escape Ramp (TER)



Photograph 1 – Throat of TER

Photograph 2 – Installation of Stainless-Steel Arrestor Nets #2-#5

Photograph 3 – Arrestor Net #1 Connection to Mechanical Brake

Photograph 4 – Crash Barrel Installation at TER Terminus.

Photograph 5 – TER Terminus on Mechanically-Stabilized Earthwall (MSE)

Photograph 6 – Heating Cable Installation

Photograph 7 – Completed TER (U.S. 44/CT 10/Nod Rd. Intersection in Background)

Photograph 8 – Deployed DRAGNET® TER (Courtesy Wyoming DOT)

Photograph 9 – Truck Escape Ramp during Night Snowstorm

Photograph 10 – Truck Escape Ramp after 14” of snow in 72-hour period