Trinity ET-PLUS Guardrail Terminals - Revelations From Real-Life Impacts

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Considerable publicity has centred around the functioning of the ET-PLUS guardrail terminal manufactured by Trinity Highway Products (THP) of Dallas Texas. The ET-PLUS is a piece of roadside hardware that is placed at the end of a guardrail and is meant to reduce the injury consequences if a vehicle strikes it (See Figures 1 and 2).

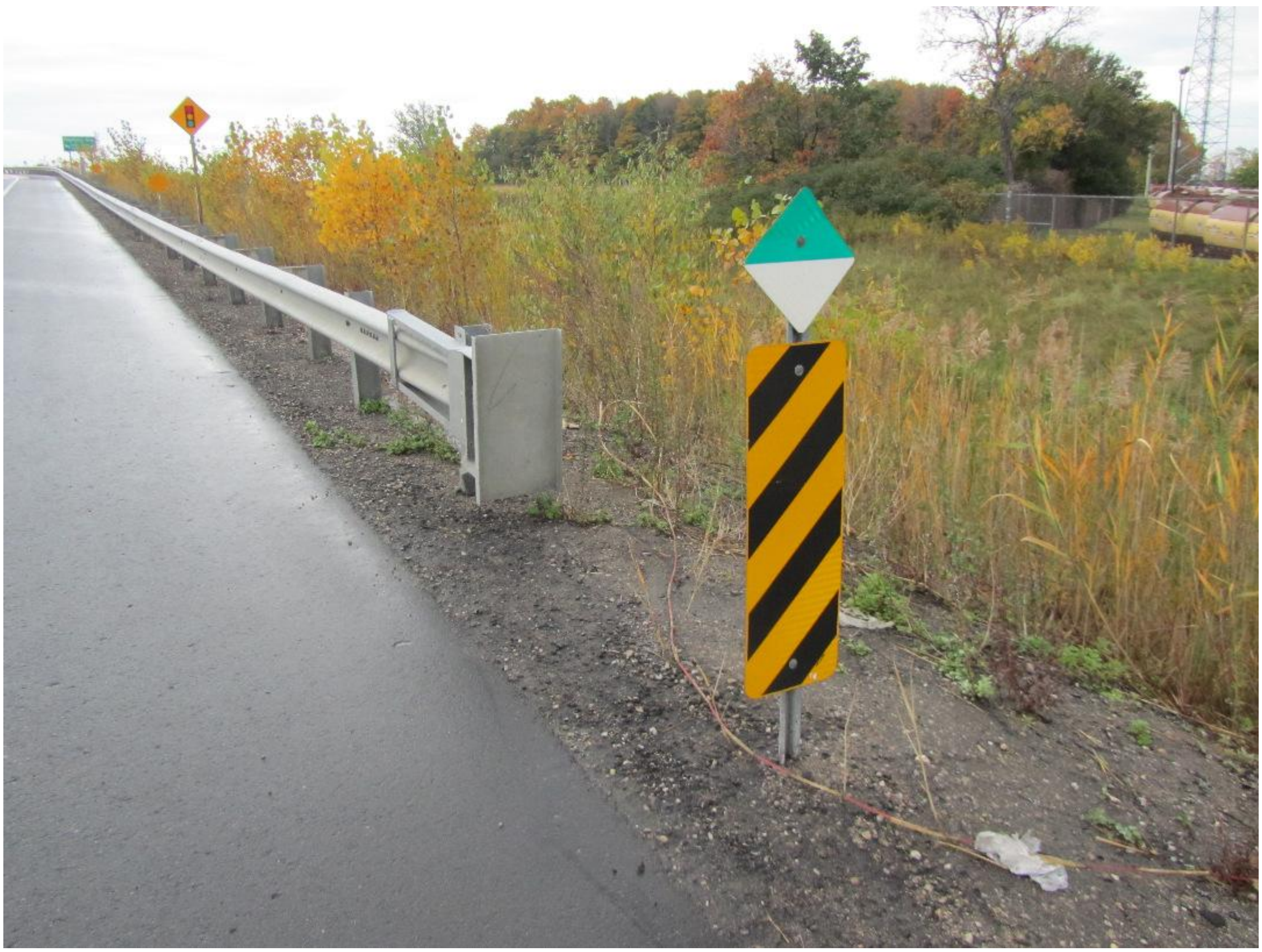

Figure 1: View of a typical ET-PLUS guardrail terminal located on the eastbound exit ramp from Highway 401 to Highbury Avenue in London, Ontario.

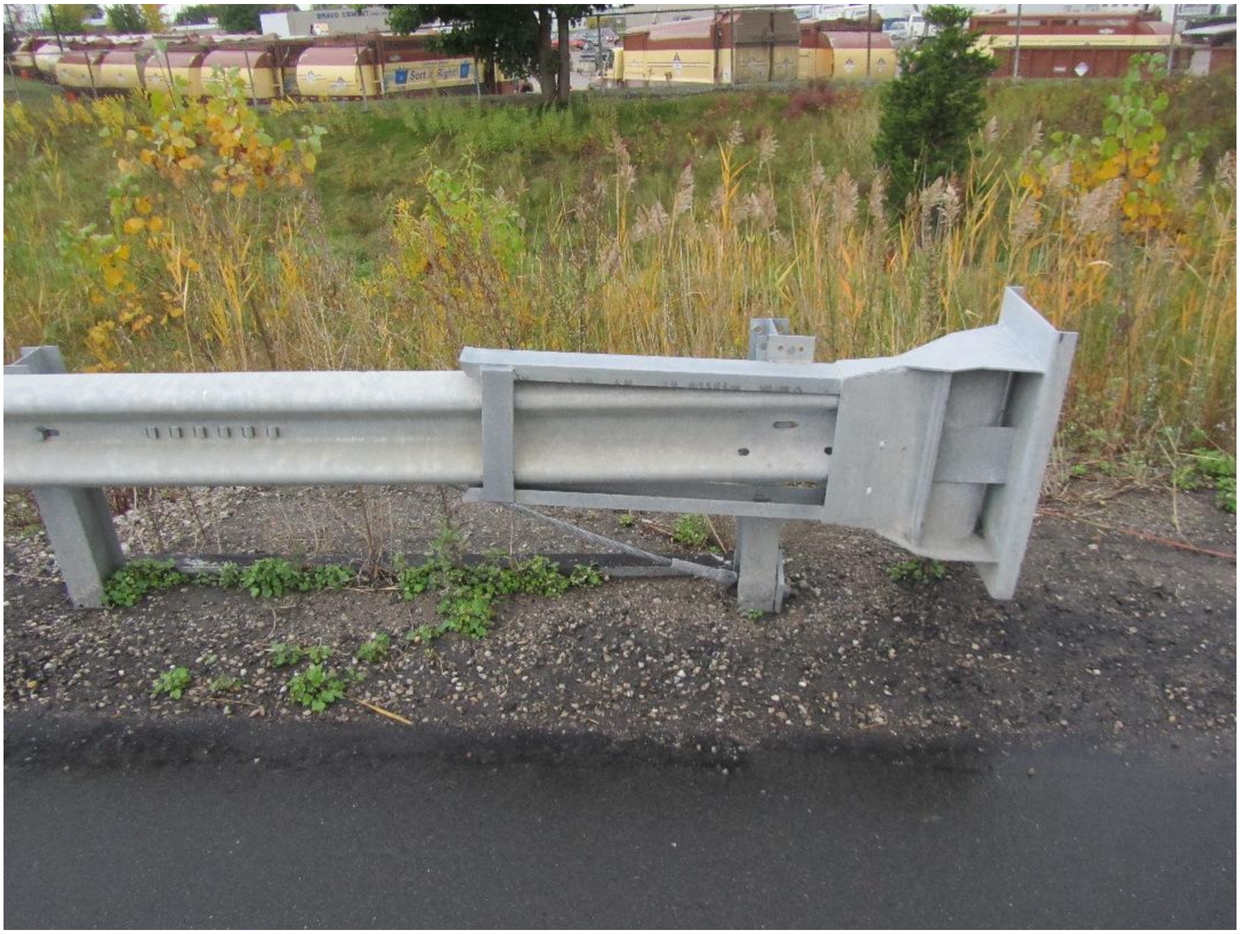

Figure 2: Side view the ET-PLUS guardrail terminal showing the plate (head) on the right and the channel attached behind it. The end of the guardrail fits within the channel.

The terminal has a large plate (head) which is meant to be struck by a vehicle. A channel behind the plate is used as a guide within which the end the guardrail is designed to fit. The impact of the plate causes it to be displaced so that the plate and channel ride along the guardrail. This is accomplished because the guardrail slides within the terminal channel and is squeezed into a narrow opening within the head. This squeezing causes the guardrail to become flattened and then is extruded out the side of the head. It is this motion, along with the flattening of the guardrail, that results in the dissipation of the kinetic energy that is introduced into the system as a result of the vehicle impact. Such dissipation of kinetic energy is a desirable action because it should lead to a controlled deceleration of the impacting vehicle and consequent reduction of injury to the vehicle occupants.

Figures 3 and 4 show an example of an ET-PLUS terminal on Dingman Drive in London, Ontario that was struck and sustained damage. Figure 3 shows a top view where the end of the flattened guardrail can be seen extruding from the side of the terminal head. Figure 4 shows the same terminal from a ditch-side view and we can also see a small portion of the guardrail as it has passed through the head and become flattened by its squeezing action.

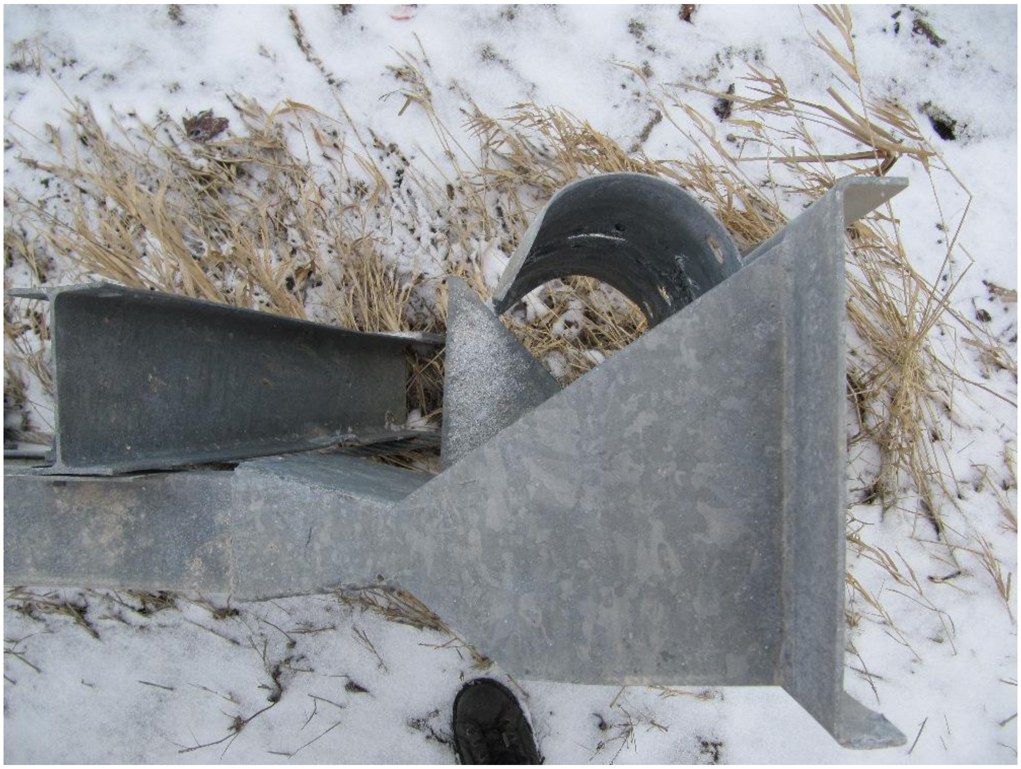

Figure 3: Top view of the ET-PLUS terminal showing how a minor impact has caused the head and channel to be displaced along the guardrail. Consequently the end of the guardrail has been squeezed out the side of the head.

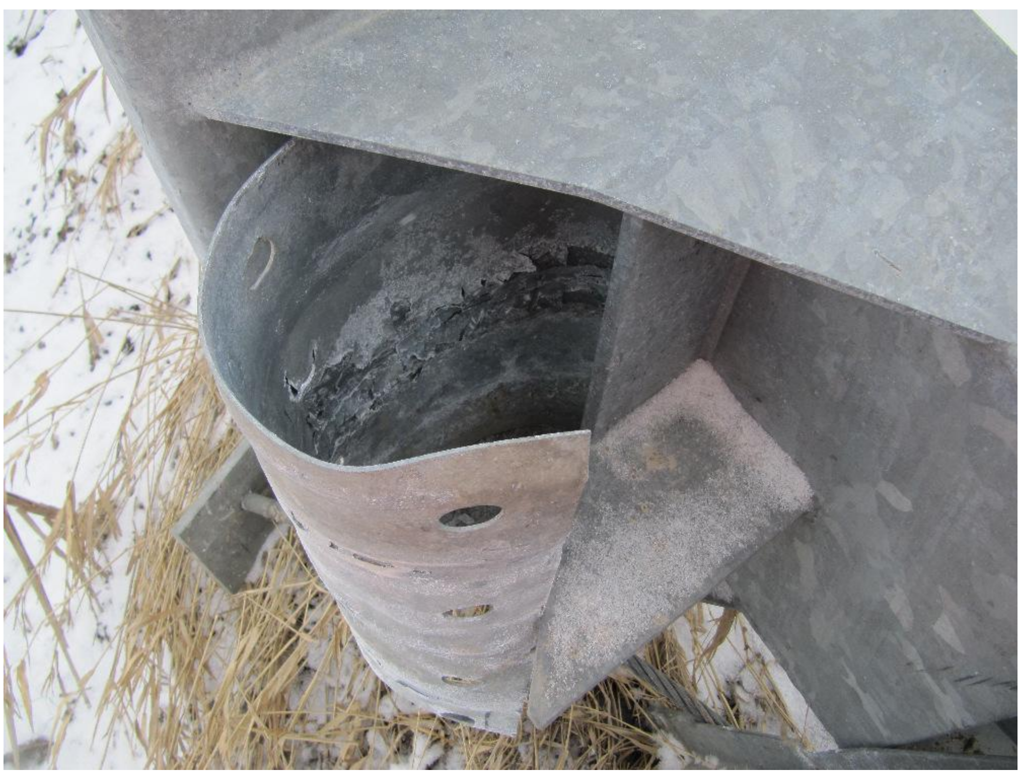

Figure 4: Ditch-side view of the end of the guardrail as it has been squeezed and deformed from passing through the narrow opening in the head.

The functioning of the ET-PLUS terminal has been criticized because of reports that the guardrail becomes jammed within the channel and head rather than passing through in the manner in which it was designed. The predecessor of the ET-PLUS, the ET-2000, contained a larger channel opening in the head which, on face value, would be expected to allow the guardrail to pass through with less chance of jamming. Research reported in a University of Alabama in Birmingham (UAB) study claimed that the ET-PLUS had a poorer performance record in real-life impacts than the ET-2000. This finding was also accompanied by revelations that Trinity Highway Products (THP) had made these adjustments to the ET-PLUS without informing the U.S. Federal Highway Administration (FHWA), like it was required. This resulted in a law suit against THP in which a federal jury found THP liable for defrauding the U.S. federal government. THP is now in the process of appealing that verdict.

In the interim, the FHWA has also required that the ET-PLUS be re-tested for compliance to the NCHRP-350 standard which determines whether it can be installed on roadsides in the U.S. Recent reports indicate that the ET-PLUS passed those re-tests and much comment has been made in the media that the ET-PLUS would appear to be of a safe design.

However, a passing grade in several controlled tests, under ideal conditions, cannot be used to determine how the apparatus will perform in the real world, under less than ideal conditions. Thus, an obvious requirement should have been that the FHWA also conduct a survey of the functioning the ET-PLUS in real life conditions. Yet, no such data has ever been revealed, nor has the FHWA demonstrated that such testing was ongoing in the years that the ET-PLUS was being installed on North American highways. The only publicly available study is what was reported by the UAB researchers, noted above.

At present, there continues to be a lack of information about the performance of ET-PLUS terminals in real life collisions. In fact, when these terminals have been impacted, there has been no publicity and the systems are quietly replaced and taken away without being seen again.

Despite these unusual actions, Gorski Consulting has managed to locate several instances where the impacted and damaged ET-PLUS terminal has not yet been replaced and this is the subject of the current article. Three instances of these real-life impacts will be presented.

ET-PLUS Impact #1: Eastbound Highway 401 Exit Ramp to Highbury Avenue, London, Ontario

Figures 5 and 6 below show the site of the impact as eastbound traffic would approach the area along the exit ramp from Highway 401 to Highbury Avenue in London, Ontario.

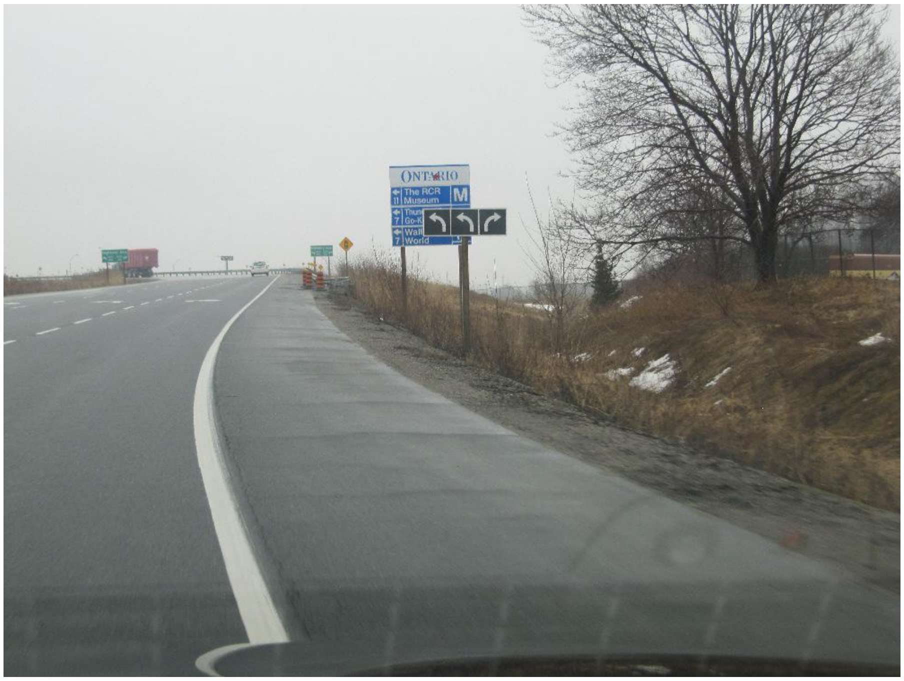

Figure 5: View looking along the exit ramp toward the impacted ET-PLUS guardrail terminal.

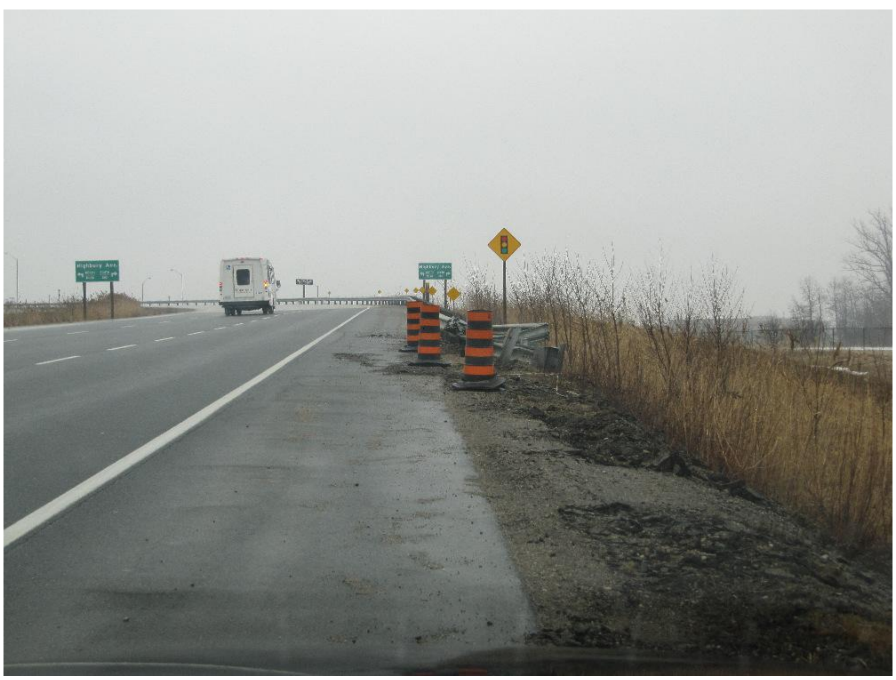

Figure 6: Overall view of the impacted ET-Plus terminal.

This evidence was identified on March 24, 2015 and the impact likely occurred within the previous 24 hours. Judging by the extent of damage, along with other evidence, the impacting object was likely a large truck. This interpretation is also supported by the extensive damage to the guardrail system suggesting that a large amount of kinetic energy was dissipated, as shown in Figure 7.

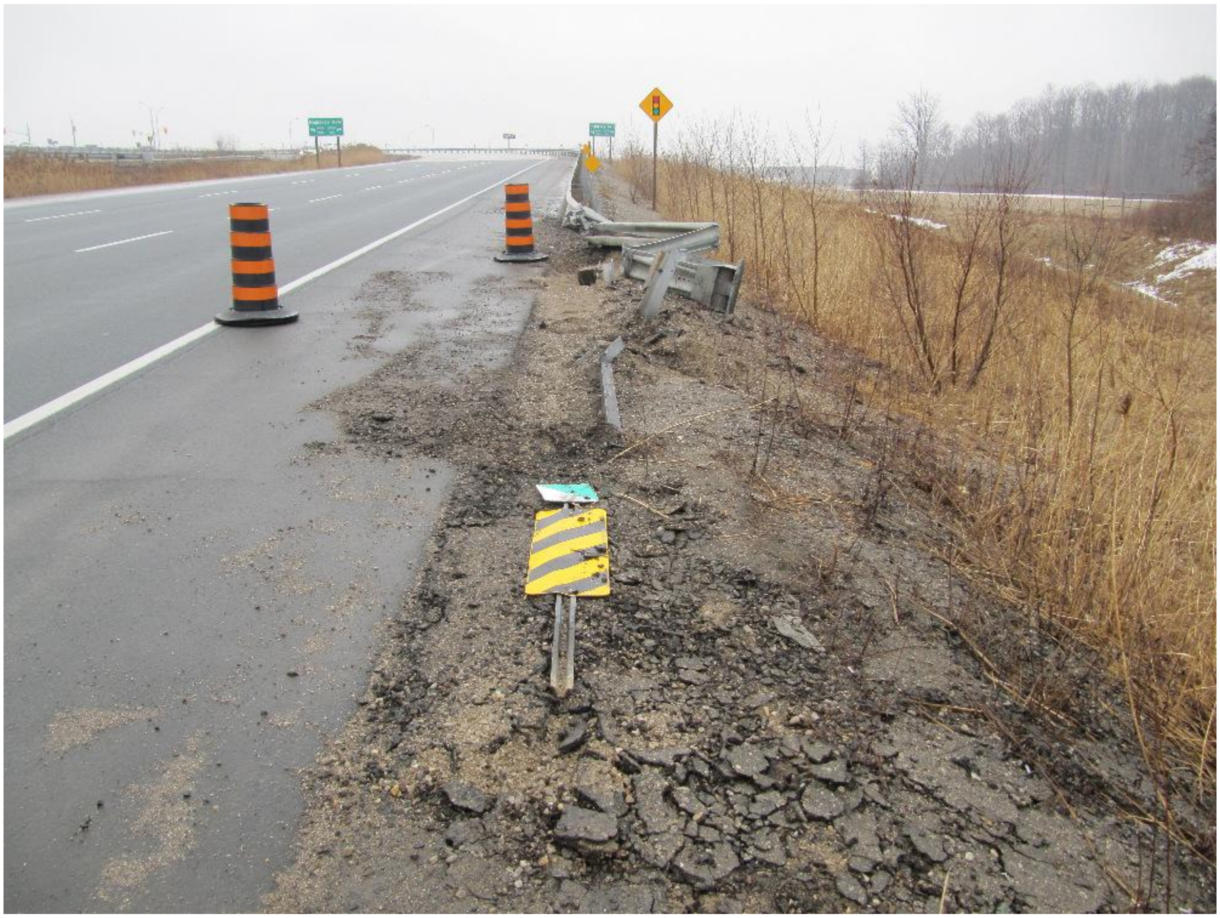

Figure 7: Overall view of damaged ET-PLUS terminal including a substantial length of guardrail.

In the foreground of Figure 7 one can see the yellow/black hazard marker post that was located just in front of the face of the terminal plate (head). The original position of the head would have located very close to the resting position of the hazard marker yet we see that the head's damaged position is a substantial distance away, confirming that the system was carried that distance as a result of the post-impact motion of the vehicle.

We have some good evidence about the pre-crash status of this ET-PLUS terminal and guardrail because this was one of the installations surveyed by Gorski Consulting on October 14, 2014, or about 5 months before this impact. Figures 1 and 2 above are the actual photos of this system from October 14th, before it was damaged.

Figure 8 is another view of that installation from October 14, 2014. One concern is that the horizontal angle of the channel of the ET-PLUS is at a substantially different angle than the guardrail that is inserted into that channel.

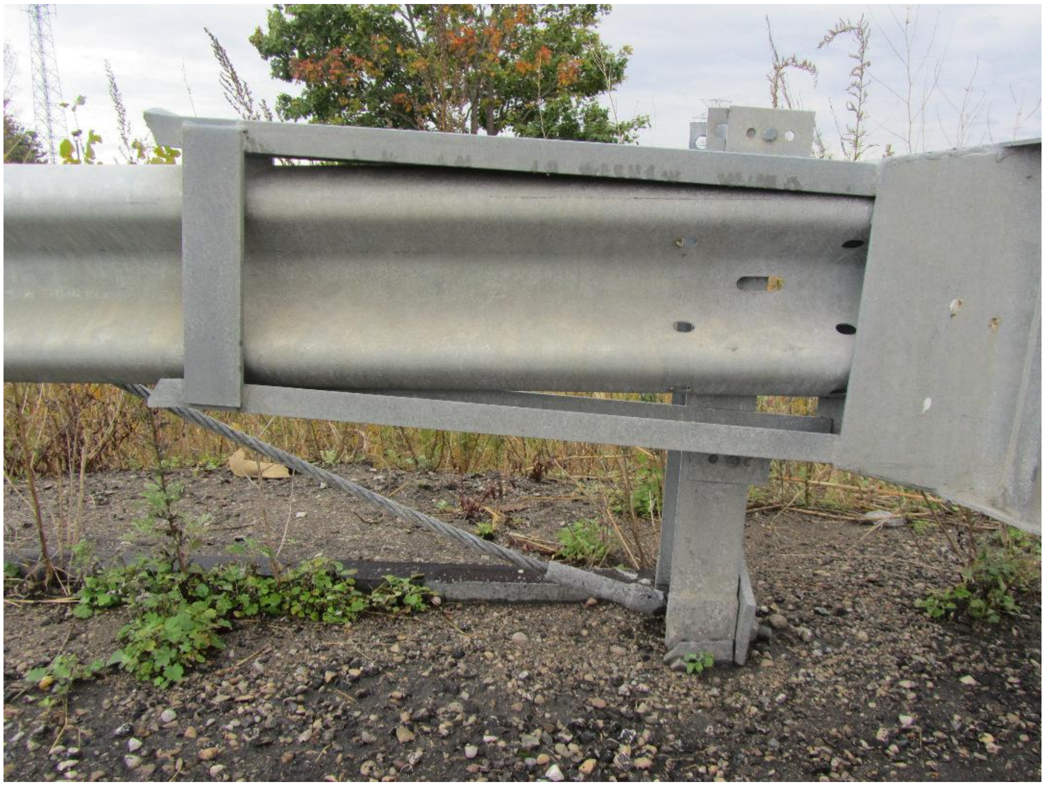

Figure 8: Note the substantial difference in the horizontal angle of the head and channel of the ET-PLUS versus the angle of the guardrail.

This is a common occurrence that we have observed in a majority of the installations that we have surveyed. It is as if the weight of the head of the terminal causes it to lower over time while raising the rear end of the channel. It is unlikely that this is the manner in which the system is set-up during the controlled tests that the ET-PLUS passed during its recent compliance testing. This is why it is important for certifying agencies such as the U.S. FHWA to conduct studies of the performance of the ET-PLUS in real life collisions because such differences could affect how the system performs in those real life collisions.

Figure 9 shows that at the time that the system was inspected on October 14, 2014, the base of the terminal head was located about 6 inches (15 centimetres) above the gravel shoulder.

The measurement in Figure 10 confirms the 4-inch width of the channel. What is also apparent in Figure 10 is the large gap between the top of the channel and the top of guardrail, which confirms the differing horizontal angles of the two.

Meanwhile Figure 11 shows that the bottom edge of the guardrail is resting on the bottom edge of the channel.

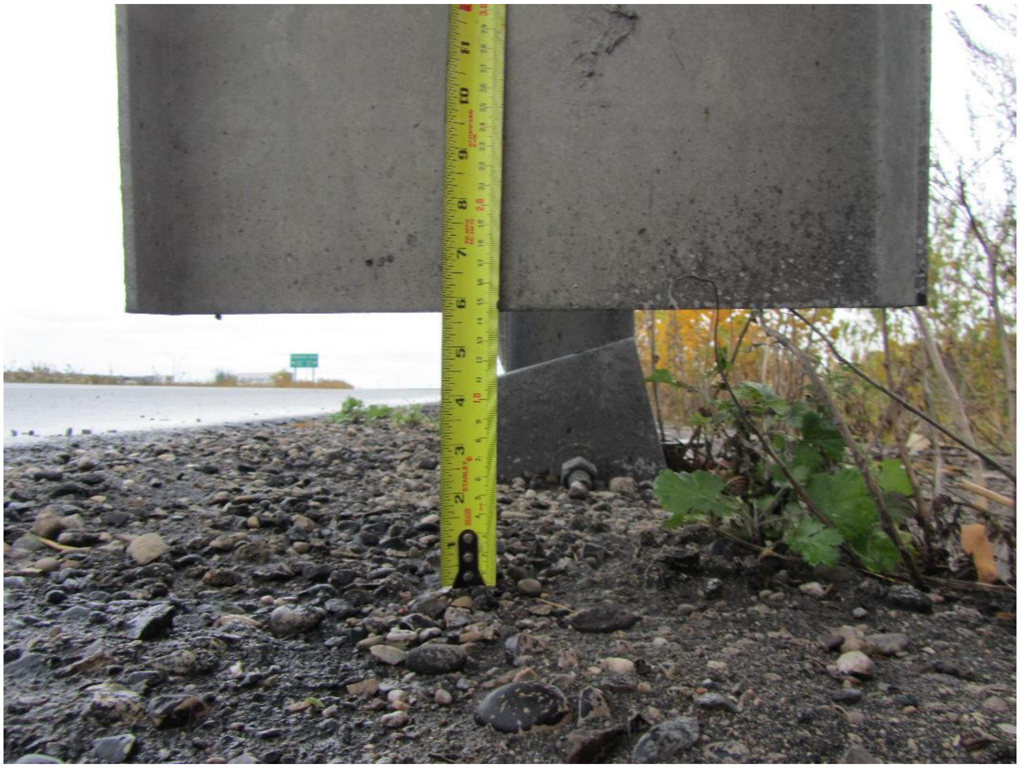

Figure 9: Measurement of the installation height of the terminal head during an inspection on October 14, 2014.

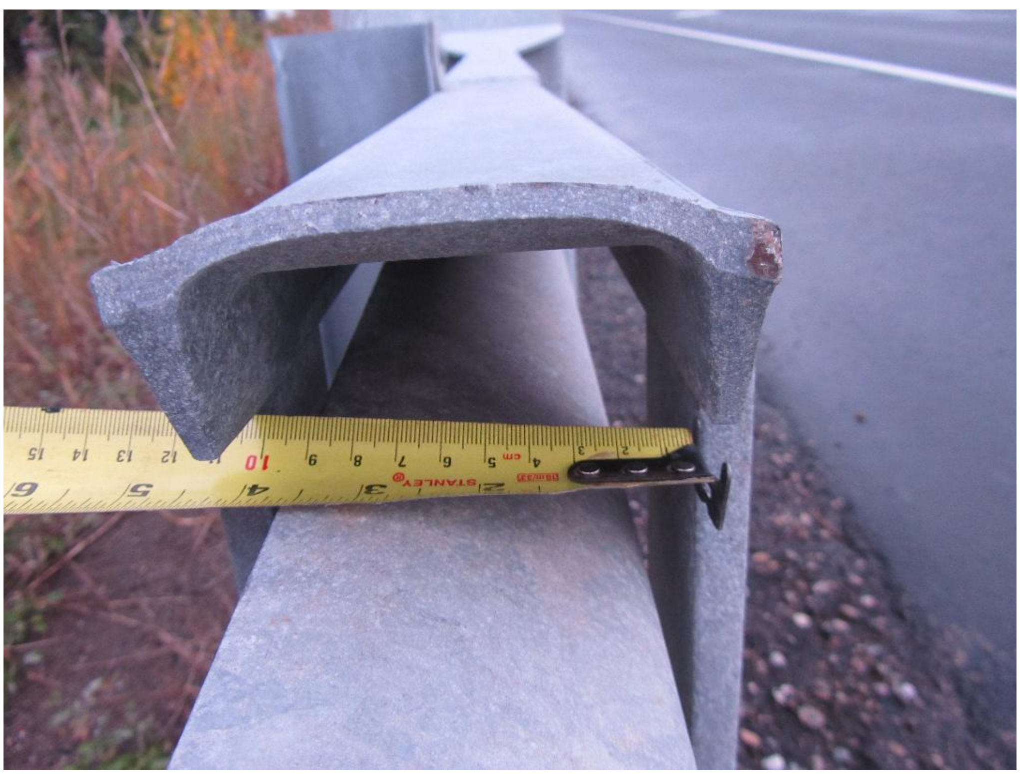

Figure 10: Measurement confirming the 4-inch-wide channel of the ET-PLUS terminal (Photo taken on October 14, 2014).

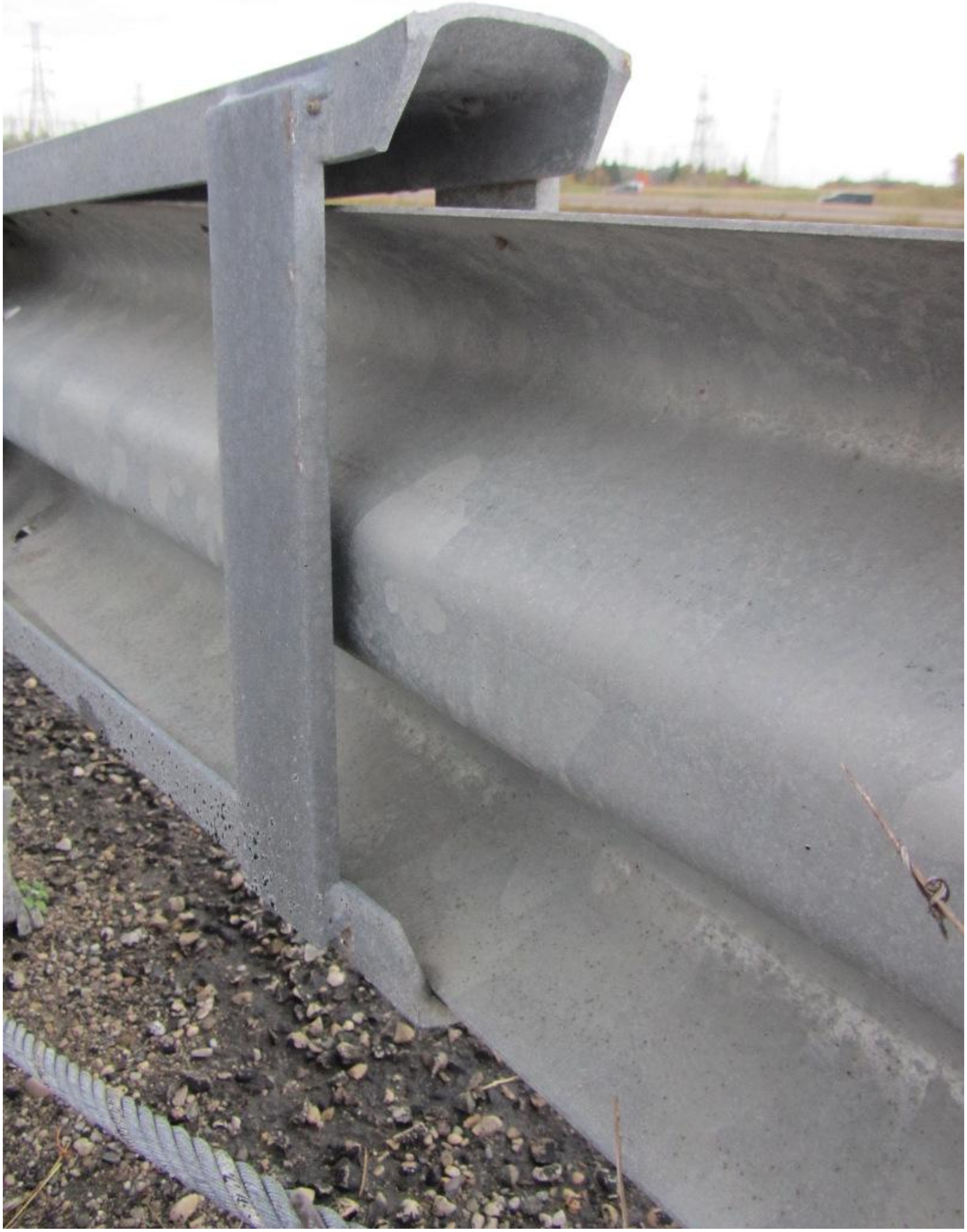

Figure 11: View of the ET-PLUS terminal on October 14, 2014. Note that the substantial difference in the horizontal angle of the terminal and guardrail causes the bottom edge of the rail to rest on the bottom of the channel while there is a large gap at the top.

Figures 12 and 13 show that the position of the rear edge of the channel was measured to the rear portion of the anchoring bracket that anchors the rail to a slip-fit vertical post near the terminal head.

Figure 12: Measurement taken to locate the channel and head with respect to the guardrail.

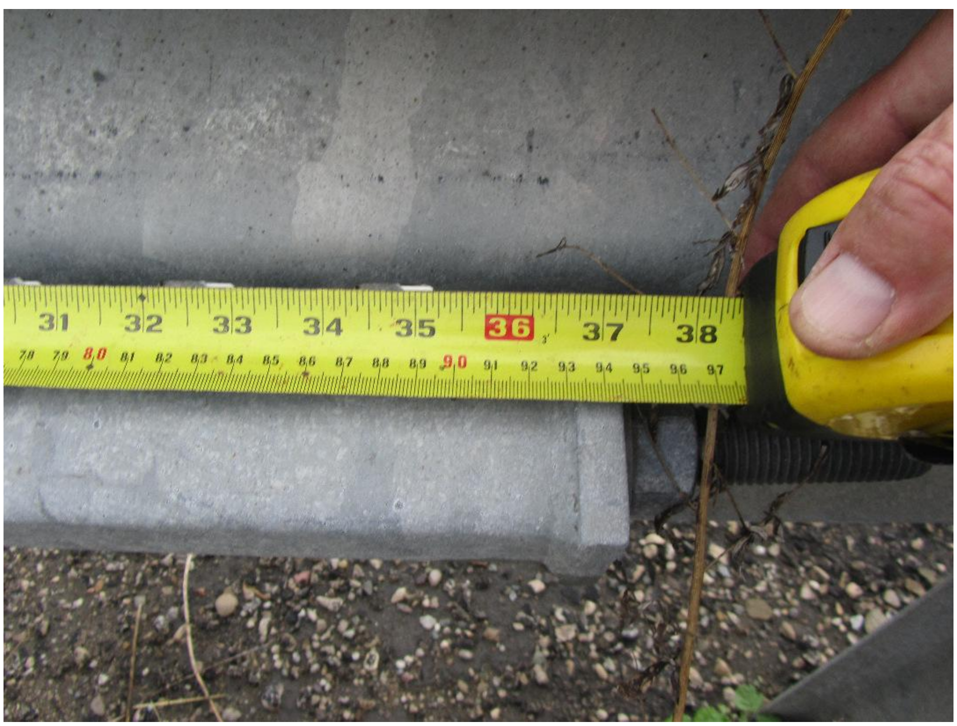

Figure 13: View showing that the measured distance to the rear edge of the anchor bracket is about 37 inches.

Figure 13 demonstrates that this distance is about 37 inches. This distance usually differs by one or two inches from installation to installation. It can be used as a general estimate of the length of guardrail that was squeezed through the narrow opening of the terminal head in this real life collision.

Figure 14 shows an overall view of the buckled guardrail along with the terminal head and channel. One can note that a length of the rail passed through the head, was flattened, and is seen extruded out the side of the head.

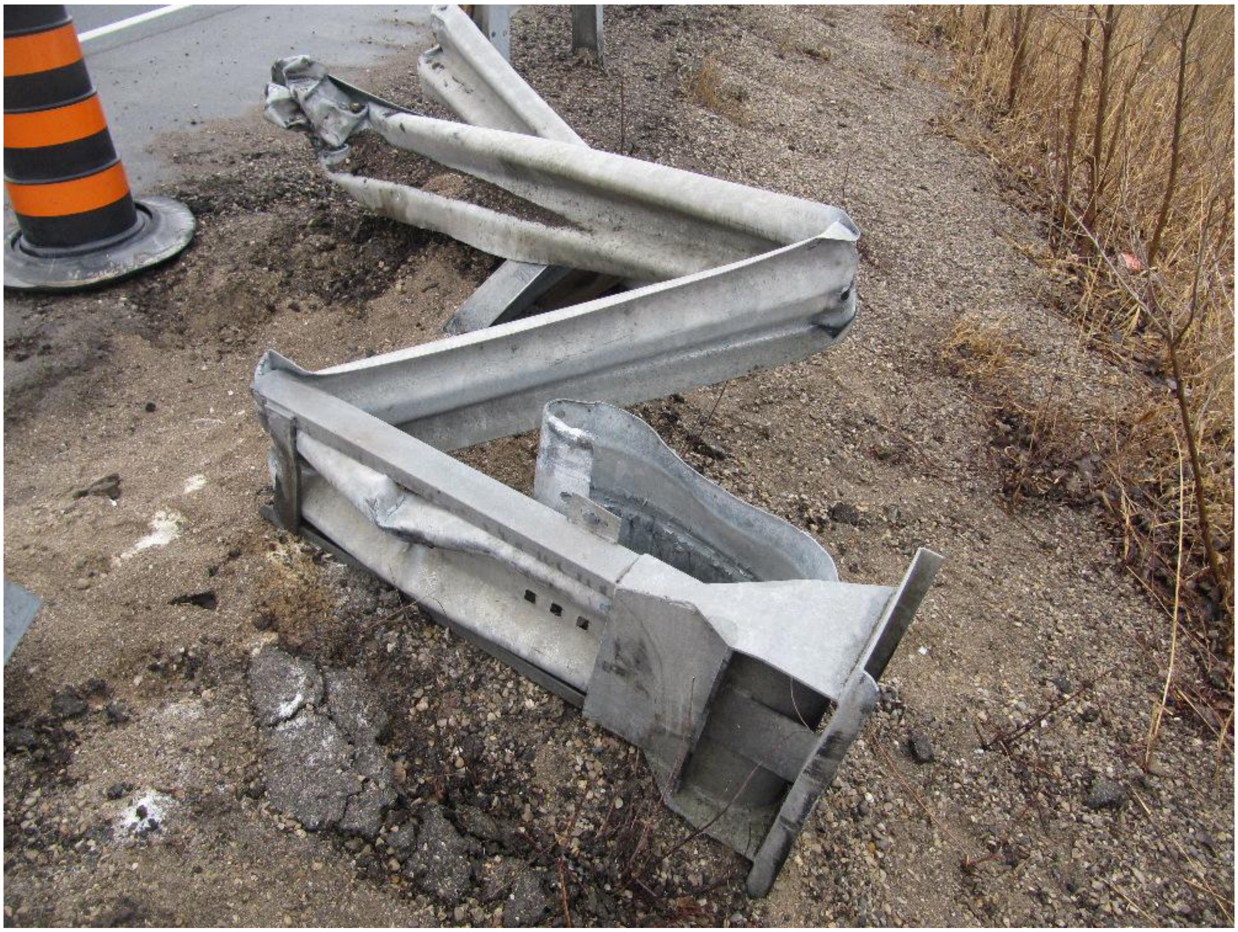

Figure 14: Overall view of buckled guardrail and a short length of rail that has been extruded out the side of the terminal head.

Figures 15 and 16 show further views of the rail and its relationship to the head and channel. In particular, Figures 14 and 16 show a set of holes in the rail near the back of the terminal head. These holes are what the teeth of the anchor bracket fit into. The last hole would have been near the end of the anchor bracket or about 37 inches to the rear of the channel. The length of the channel from its rear edge to the rear edge of the head is about 36 inches. So the rail has travelled less than (37+36) 73 inches or less than 2 metres through the head. This is not a long distance given the overall extent of energy dissipated by the long length of buckling of the rail.

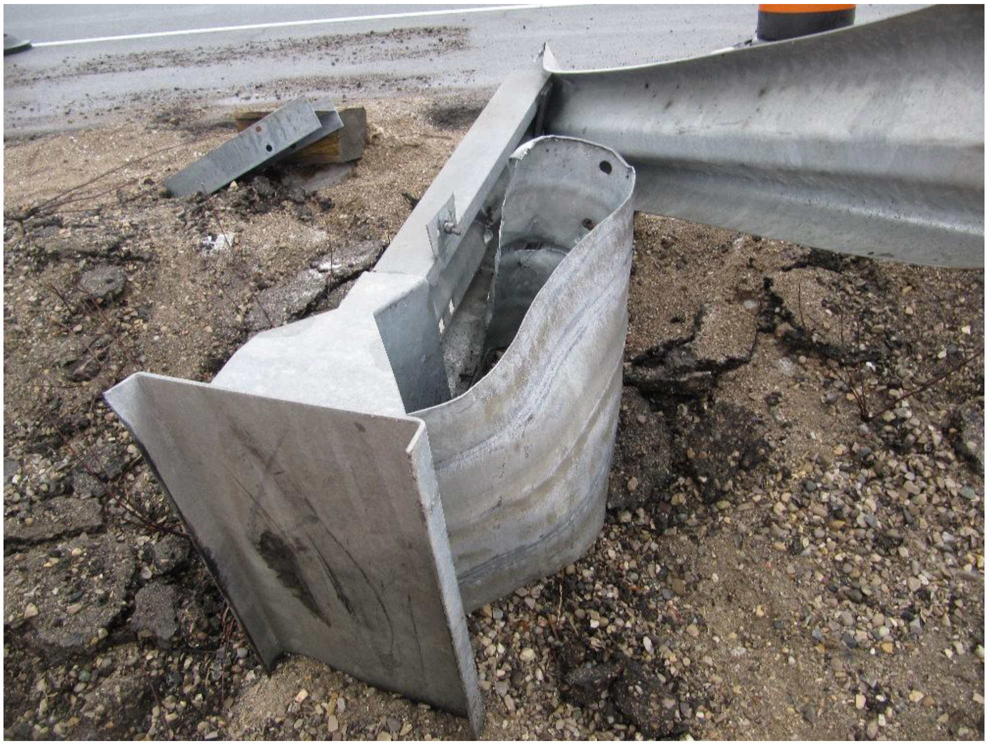

Figure 15: View of the terminal head and the short distance of rail that was extruded out of its side.

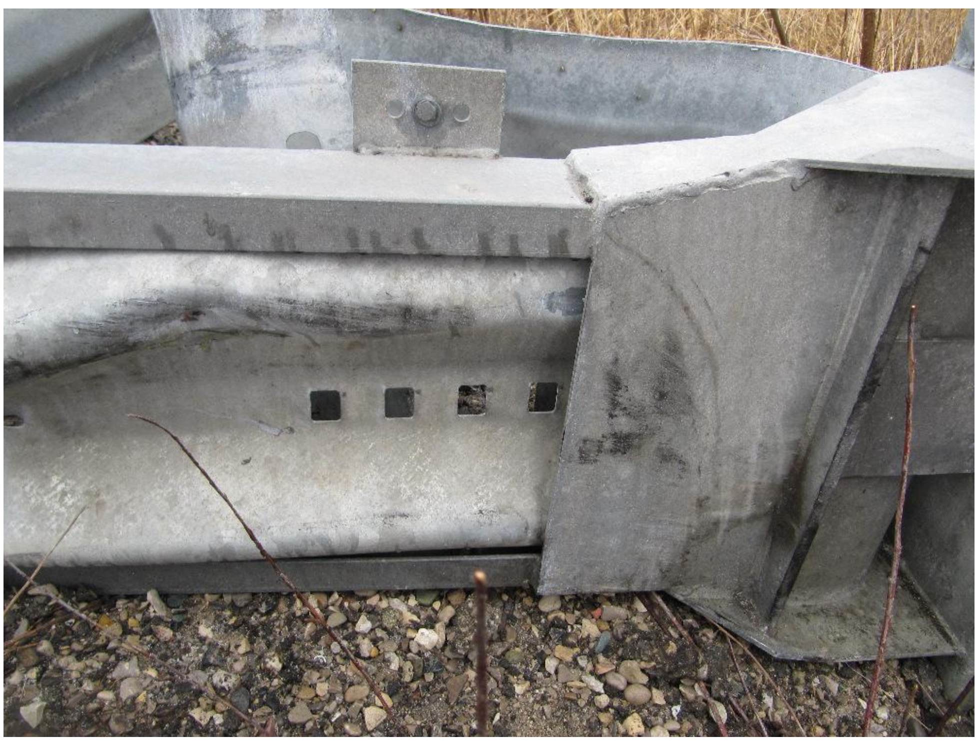

Figure 16: View of anchorage holes in the rail where the teeth of the anchorage bracket would have fit. This indicates the extent of travel of the rail through the head as a result of the impact.

The question that needs to be answered is why there was only a short length of rail which passed through the terminal head when clearly there was much more energy available to be dissipated as demonstrated by the long length of buckled rail. A large truck such as a tractor with a semi-trailer is one of the objects used in the controlled compliance testing (NCHRP-350). One might conclude that this installation was unable to manage the huge energy of such an impact.

There is evidence that the rail was buckled and may have jammed within the channel. Figures 17 and 18 show that the rail is buckled at the location where it rests within the channel.

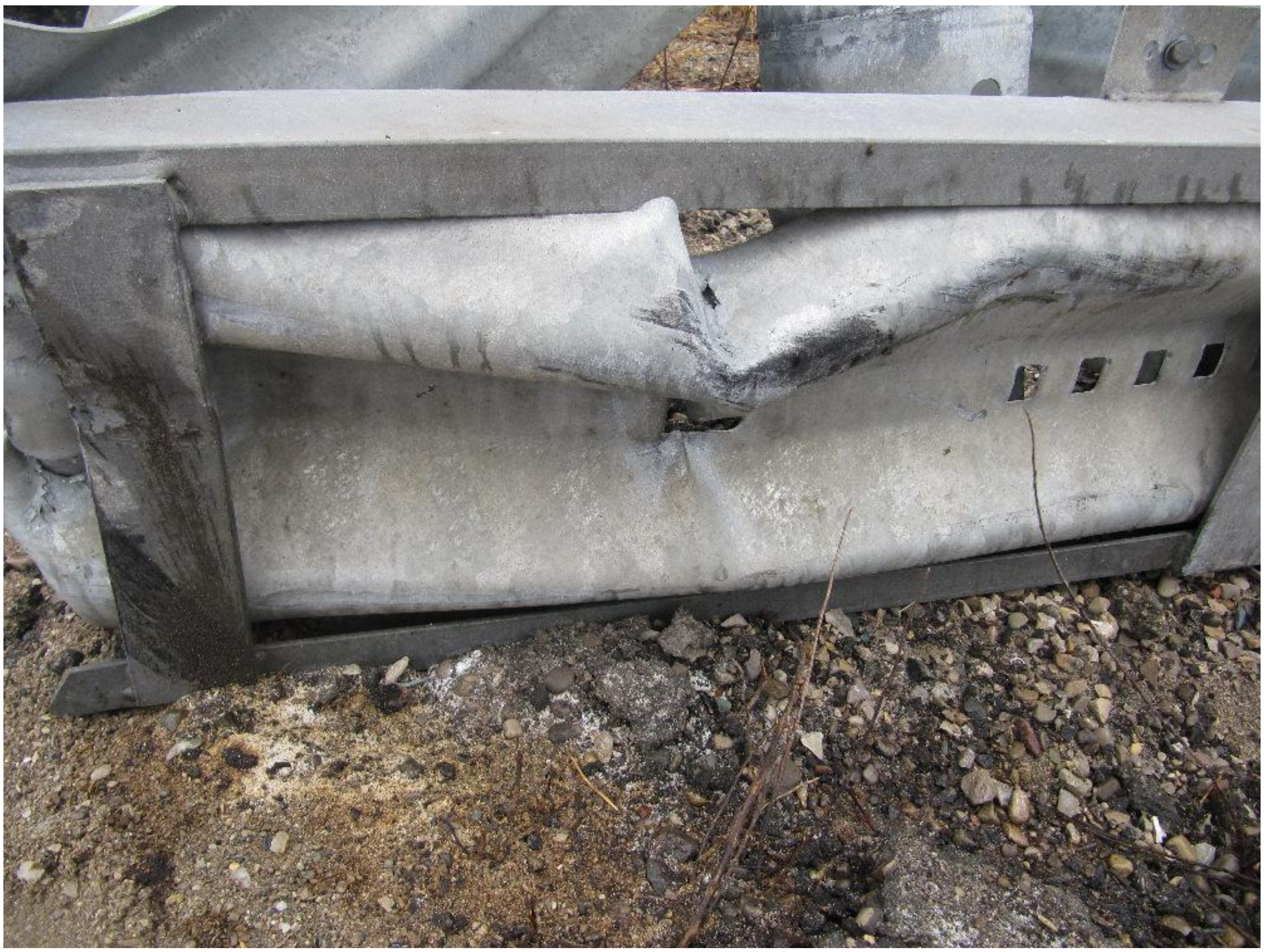

Figure 17: View of buckling of the rail while resting within the channel.

Clearly, the rail has buckled at the rear edge of the channel as the rail is beyond a 90 degree angle with respect to its original orientation. Some study would be required to evaluate when, and how, this buckling occurred and whether this can be solely related to excessive energy of the large striking vehicle. Given that the collision occurred at the curve of an exit lane it is unlikely that the terminal was struck at highway speed.

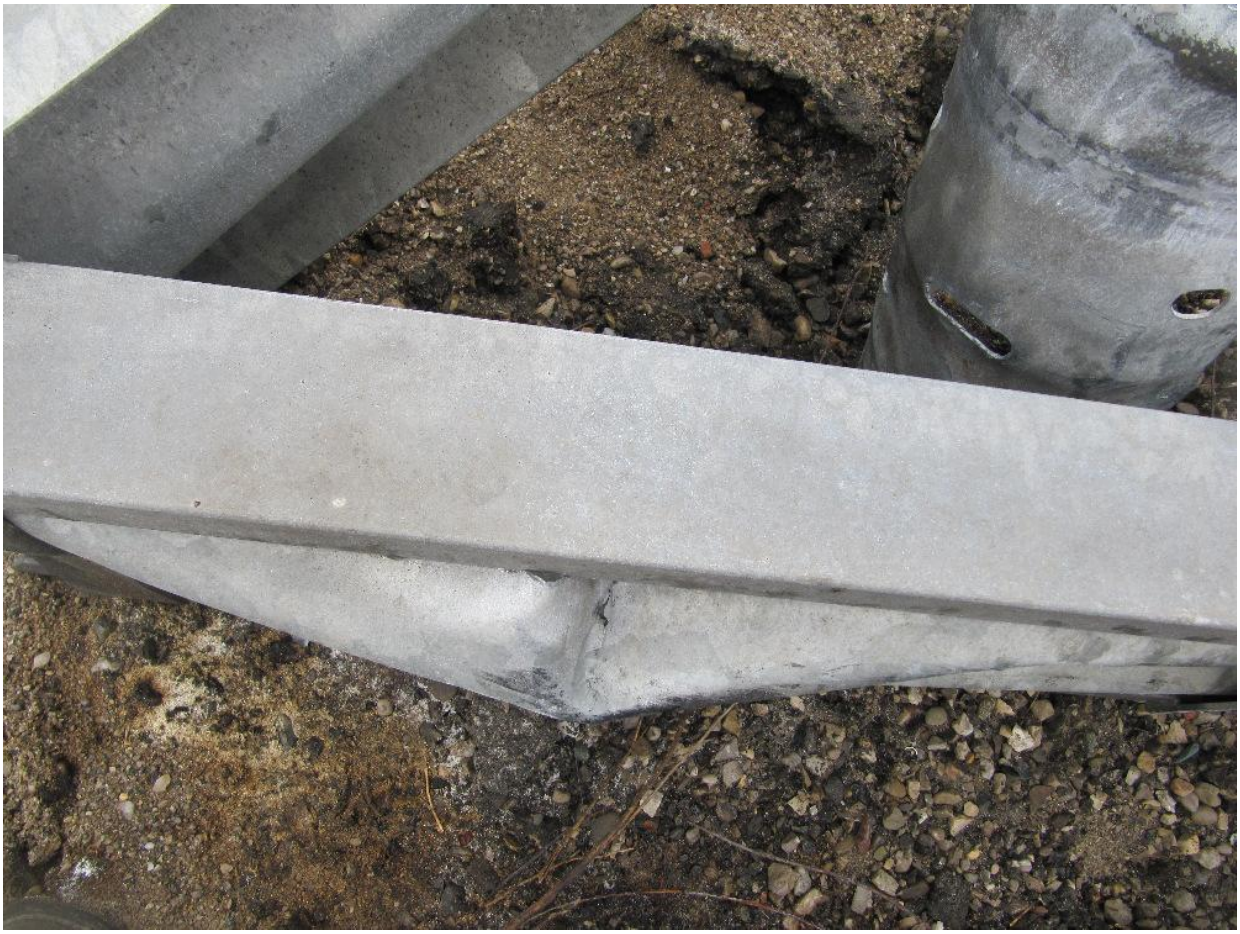

Figure 18: View looking down at the guardrail within the channel showing how it is deformed and is protruding out of the side of the channel.

This conclusion is also borne by the fact that there is no evidence of post-impact travel of the striking vehicle past the buckled guardrail. So it would suggest that the vast majority of the vehicle's kinetic energy was dissipated by the guardrail system. Even though the energy dissipation is large it does not equate, in our opinion, to a very high impact speed of the large truck. Given this lower impact speed it becomes questionable why the terminal head was not capable of passing the rail through its opening.

There has been considerable discussion from various sources that the rail buckles within the channel of the ET-PLUS when struck in real life scenarios that are similar to the controlled tests of NCHRP-350. Therefore the finding in the present case is not one to be overlooked. This impact by a large truck may not confirm that there was a problem with the ET-PLUS however it also does not confirm that the system would have performed properly either if it had been struck by a vehicle of a smaller mass. It would seem that the possibility of improper jamming of the rail within the channel/head would need further study. This is why we need to look at the terminal's performance in real life impacts rather than relying solely on the results of controlled tests to determine its safe functioning.

ET-PLUS Impact #2: Northbound Wellington Road East Guardrail on South Side of Overpass to Highway 401, London, Ontario

Figure 19 shows a view, looking north, along Wellington Road in London, Ontario, at a location just south of the overpass to Highway 401. On the right roadside there is a guardrail where an ET-PLUS guardrail terminal was struck and became detached from the rail.

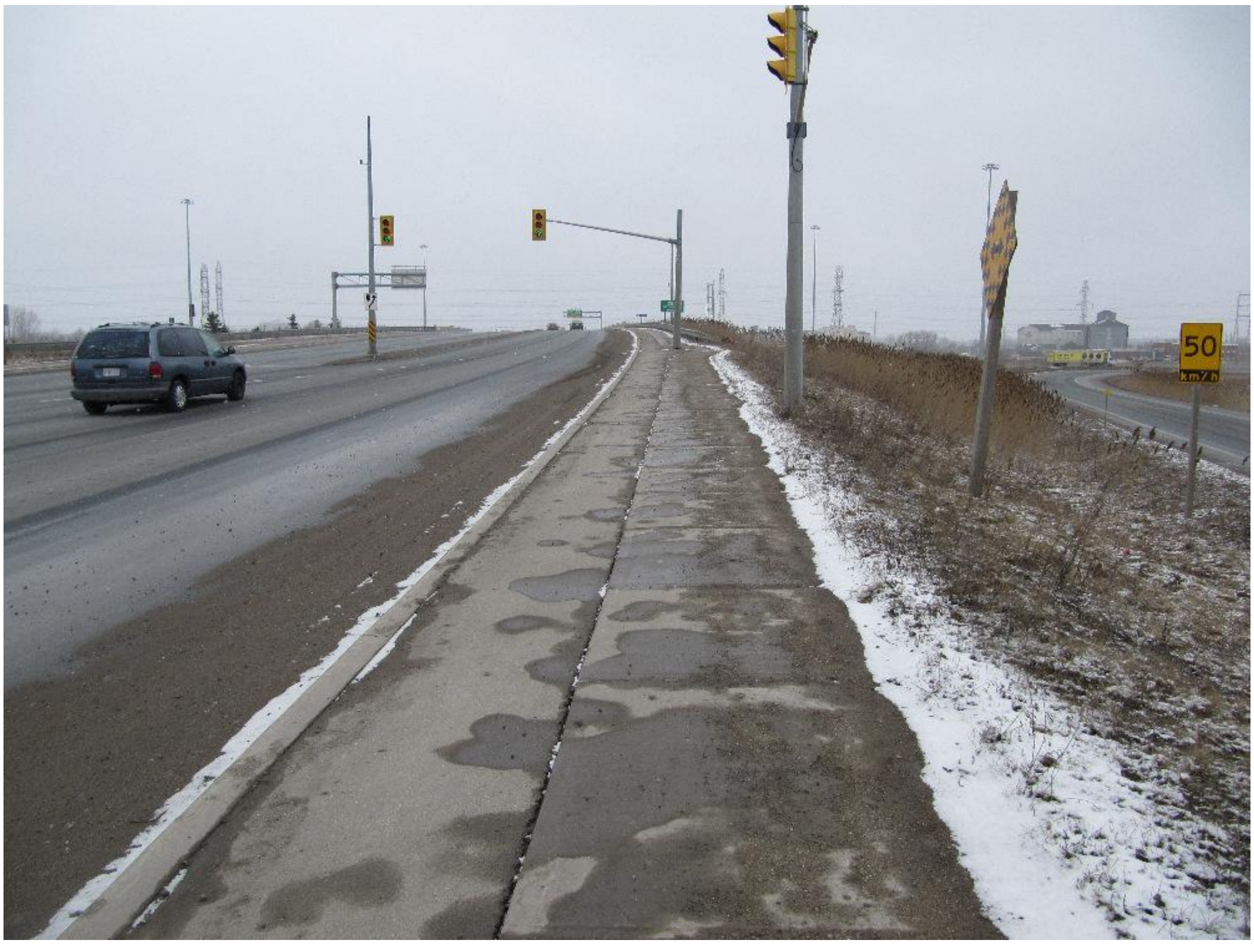

Figure 19: View, looking north, along the east edge of Wellington Road toward the overpass of Highway 401 in London, Ontario.

As we come closer to this area, Figures 20, 21 and 22 show that the end of the guardrail has been bent away from the roadway. This may not be solely related to the impact as it a common procedure of road works personnel to bend the rail away from traffic as a way of preventing a possible harpooning of a striking vehicle. The ET-PLUS terminal can be seen in Figure 21, lying in the brush at the right edge of the view.

This finding is interesting as it demonstrates the ease with which the terminal can become separated from the rail.

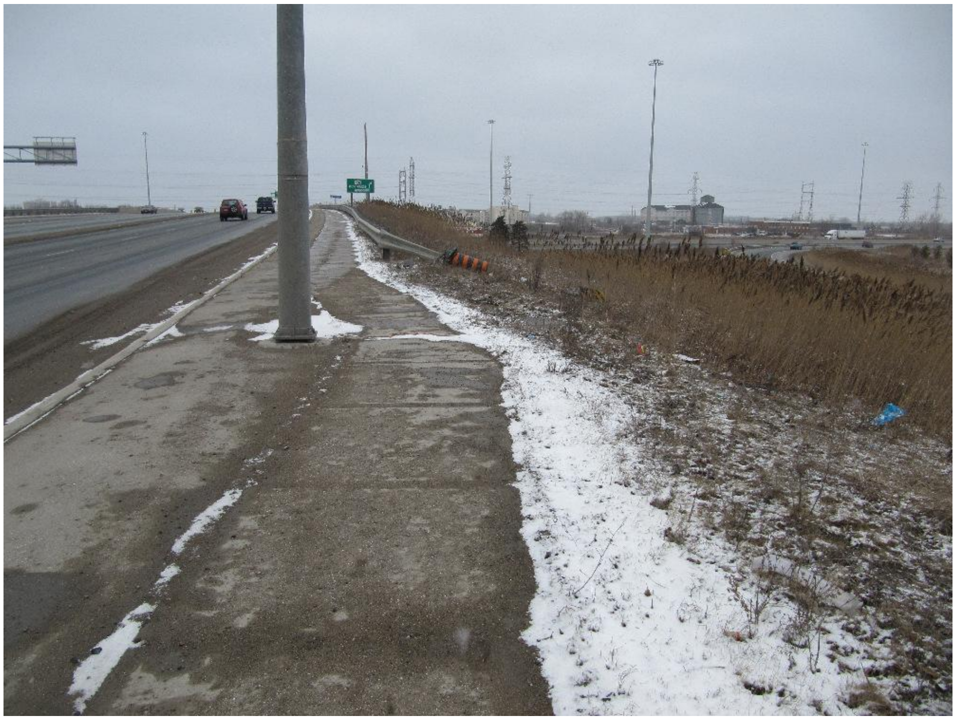

Figure 20: View, looking north, toward the damaged guardrail end on the east side of Wellington Road.

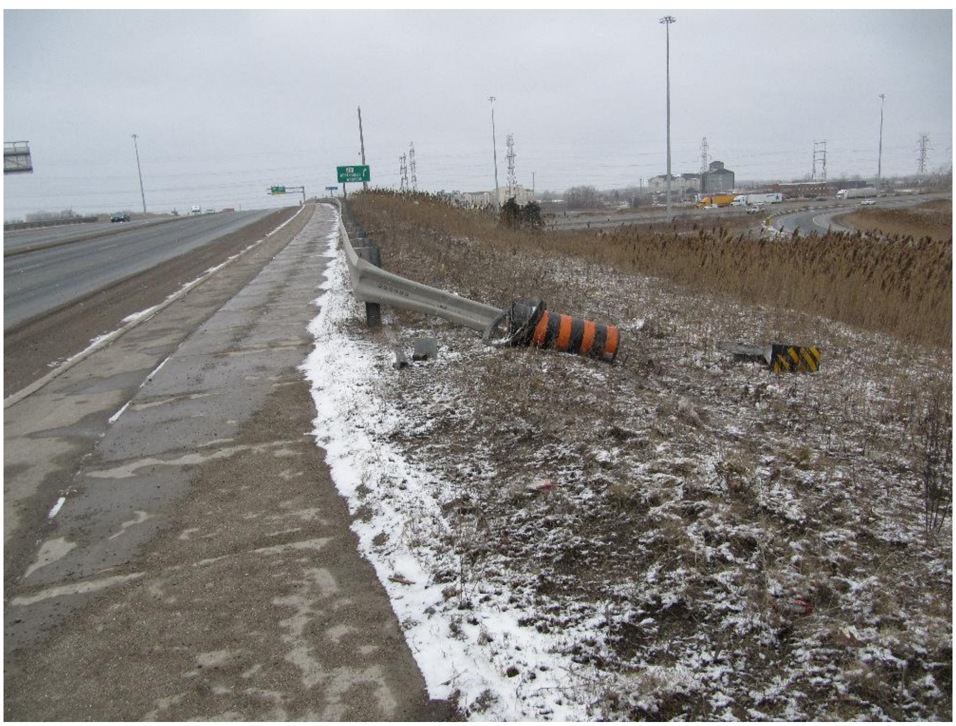

Figure 21: Closer few of the damaged guardrail end.

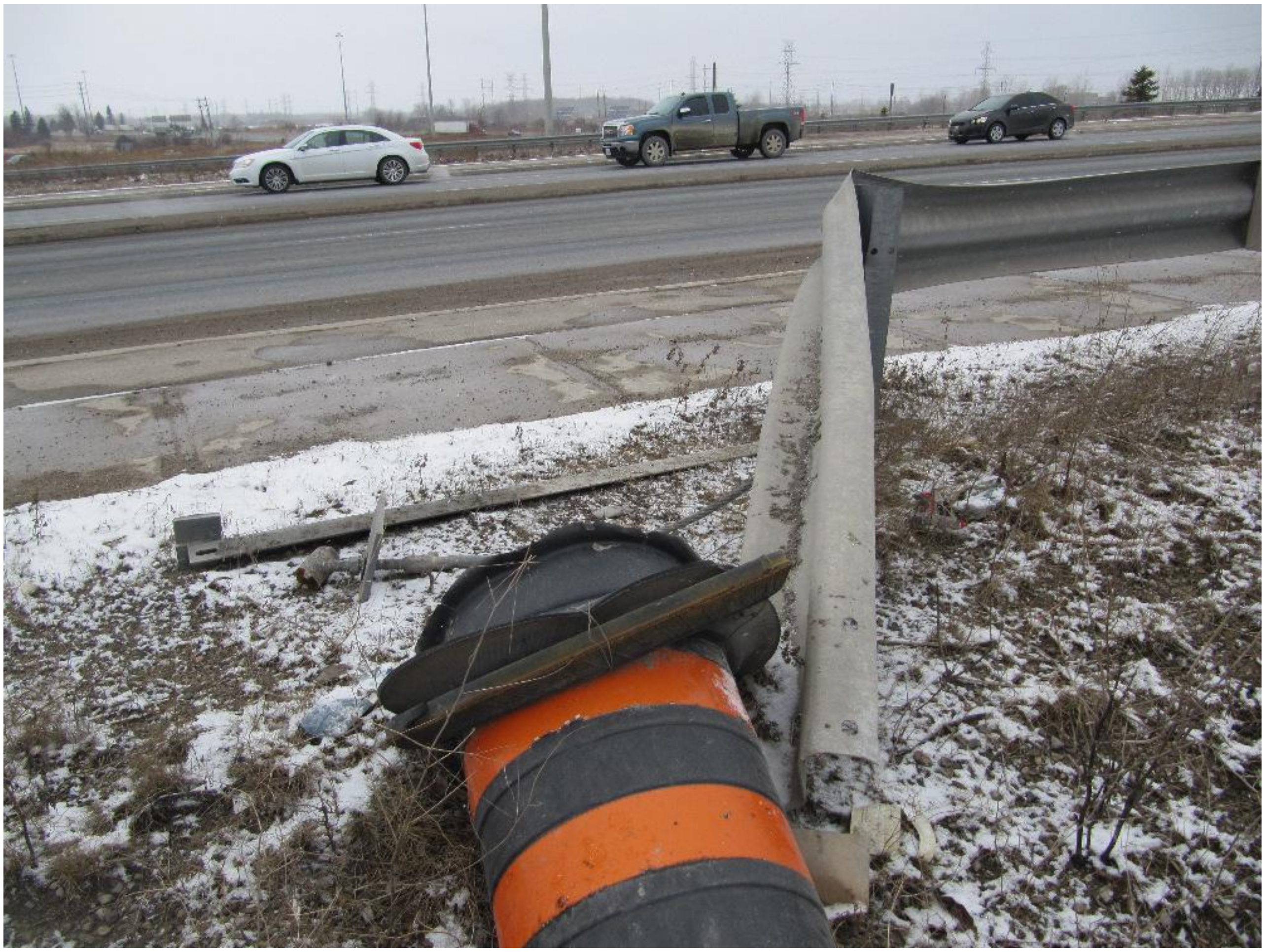

Figure 22: View showing that the end of the guardrail has been bent at it anchorage post however there is little evidence of additional damage to it.

As can be seen in Figure 22, the guardrail itself shows only minor evidence of deformation. In fact the rail is simply bent at the anchorage post.

Figures 23 through 26 show views of the detached ET-PLUS terminal lying in the brush. Again, there is no evidence of any deformation to its structure. The only evidence of damage is that the black covering of the head (plate) shows some tears that are visible in Figure 26.

It is likely that the terminal and guardrail were struck at a large angle with respect to the length of the rail. The impact force would therefore contain a substantial lateral component that would not normally exist at higher speeds in highway situations. In most instances it may be beneficial to have the terminal separate allowing an impacting vehicle to push it freely along the rail. However, when this freedom causes the terminal to actually fall off the end of the guardrail then there is the possibility that a striking vehicle could become harpooned by the exposed end of the guardrail. The issue is that the head and channel should stay attached to the guardrail and ride along the guardrail but not become detached from the guardrail, as shown in this example.

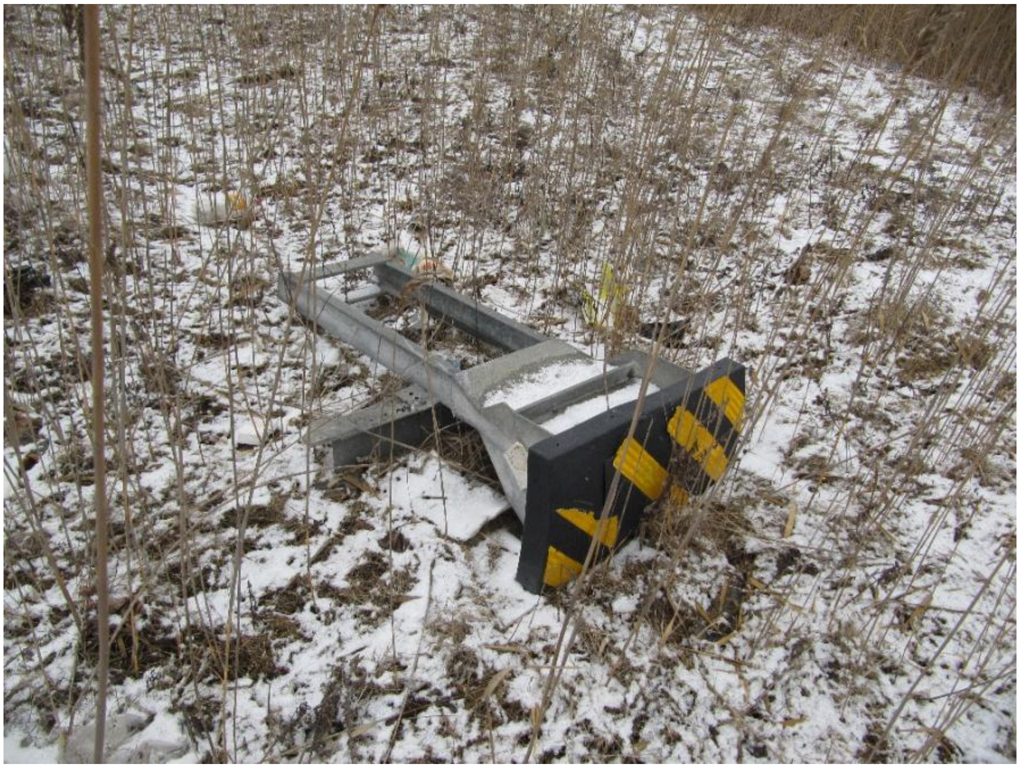

Figure 23: View of detached ET-PLUS terminal lying in the brush near the damaged guardrail.

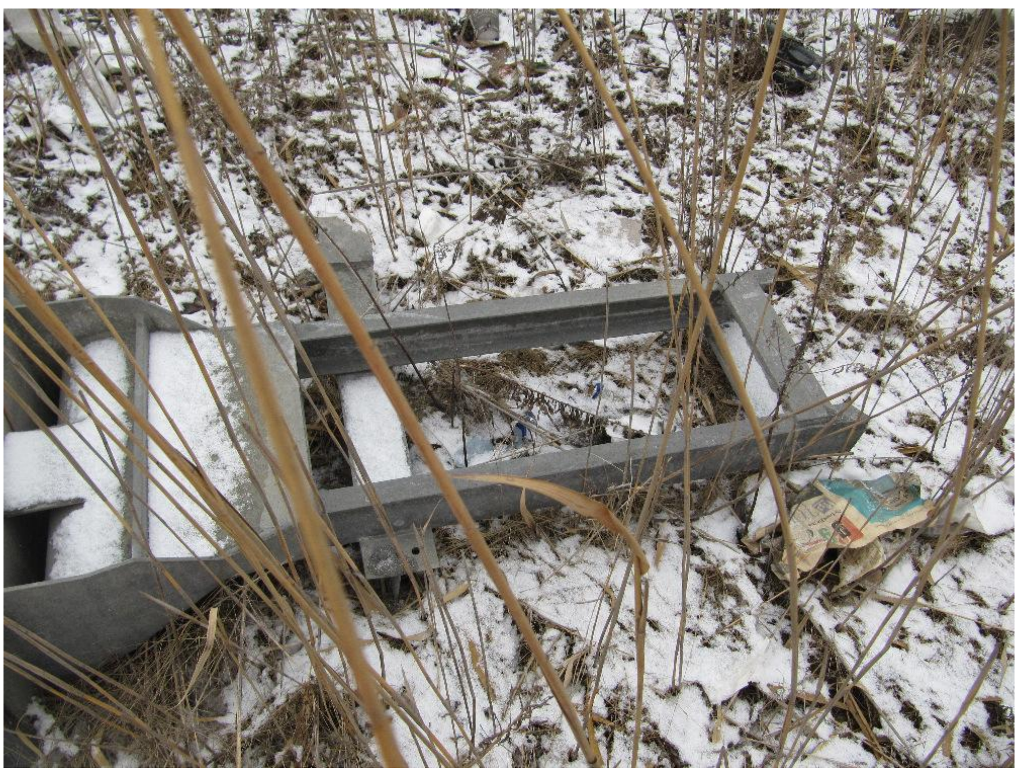

Figure 24: Note the lack of any structural deformation to the terminal.

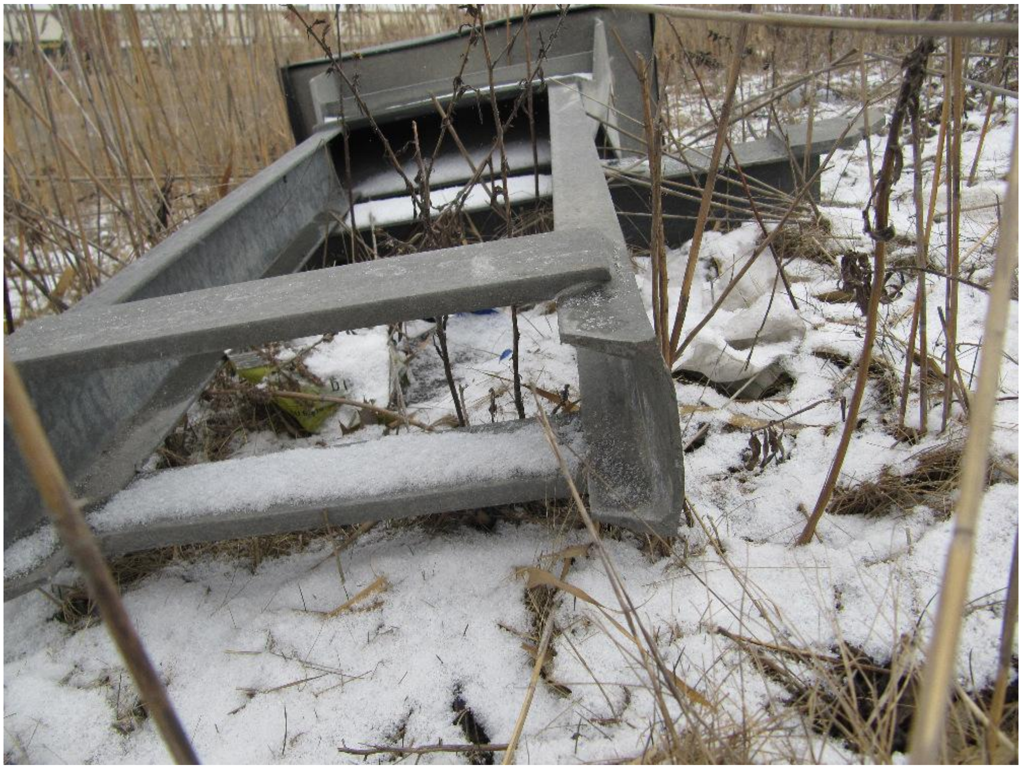

Figure 25: View of the length of the channel of the terminal indicating a lack of structural damage.

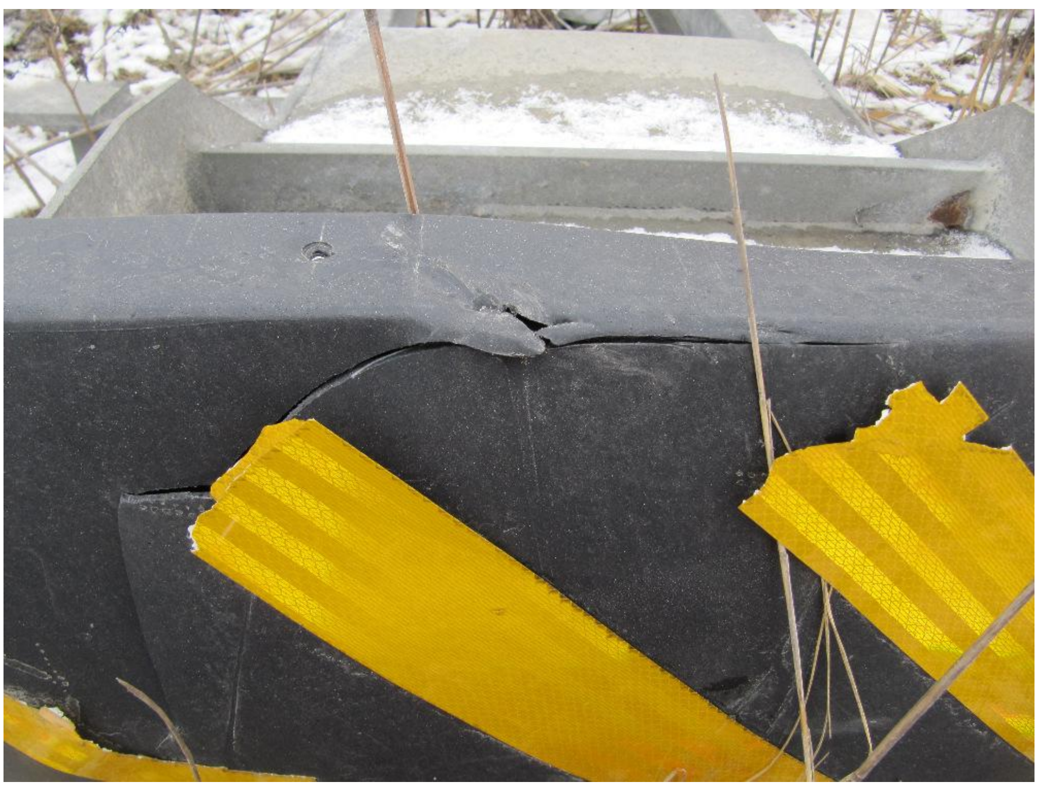

Figure 26: View of the minor tears to the cover of the head (impact plate) confirming that an actual impact occurred to the unit.

ET-PLUS Impact #3: Dingman Drive West of White Oak Road in London, Ontario.

The final example of a real life impact to a Trinity ET-PLUS terminal takes us to Dingman Drive on the southern outskirts of London, Ontario. This installation was located on the south side of the road just west of White Oak Road.

Figures 27 and 28 show eastward views of the terminal and guardrail. Upon initial inspection one might believe there was no damage to this installation.

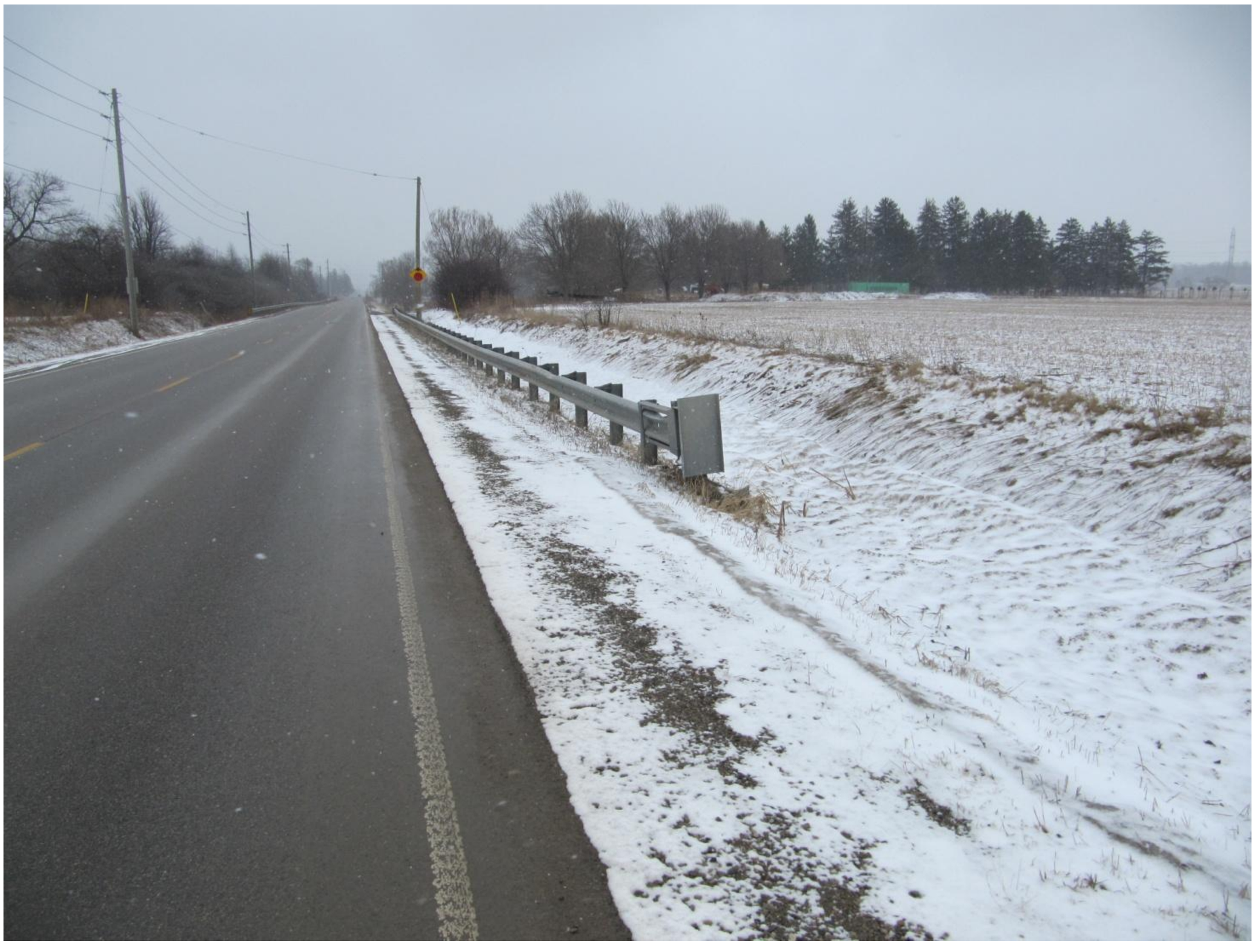

Figure 27: View, looking east, at the south guardrail on Dingman Drive, just west of White Oak Road in London, Ontario.

Even looking from a short distance the guardrail appears to be straight and undisturbed. The head (impact plate) of the ET-PLUS terminal also appears to be upright and positioned fully onto the end of the rail.

However as we come closer to the terminal, as shown in Figure 29, we can see the ground-based anchorage bar lying in the grass ahead of the terminal head. Normally this anchorage bar lies behind the terminal when the system is undamaged. So, already, this is an indication that the terminal has been pushed back along the rail.

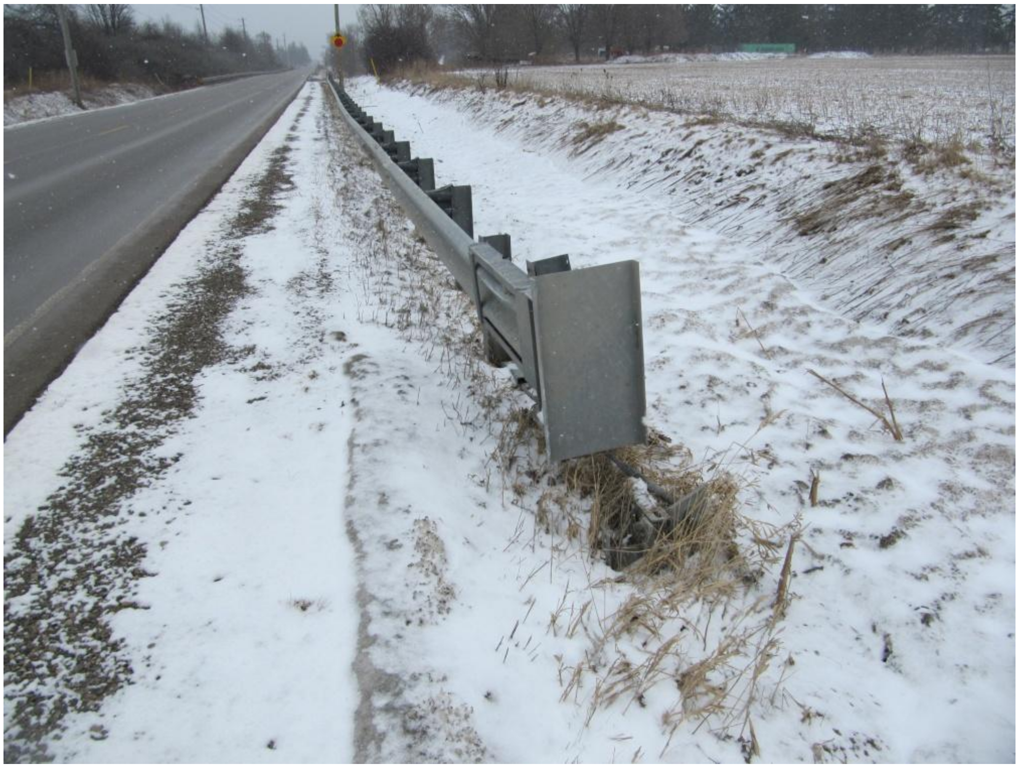

Figure 28: View of the ET-PLUS terminal and guardrail initially suggests there is no damage to it.

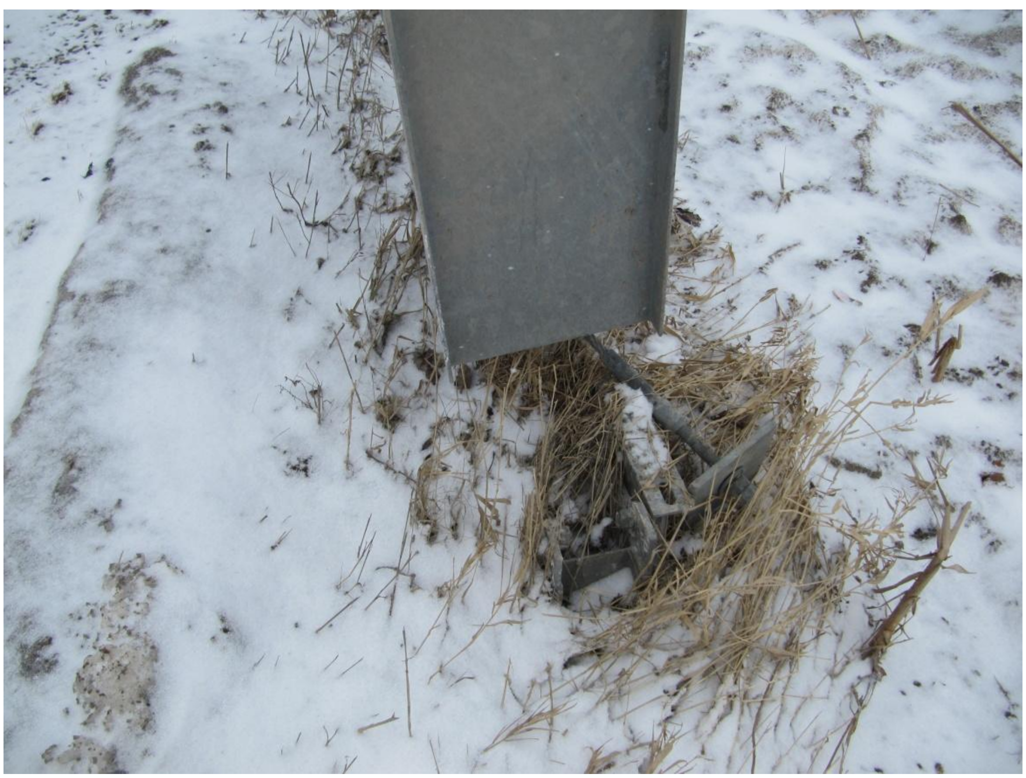

Figure 29: View of the anchorage bar that normally lies beneath and behind the terminal head. Since the head is behind the forward end of the bar it clearly indicates that the terminal has been pushed backwards.

As we move around to look at the installation from a ditch-side view (Figure 30) it becomes obvious that the terminal was impacted and sustained damage. A small length of the end of the guardrail is seen protruding out of the side of the terminal.

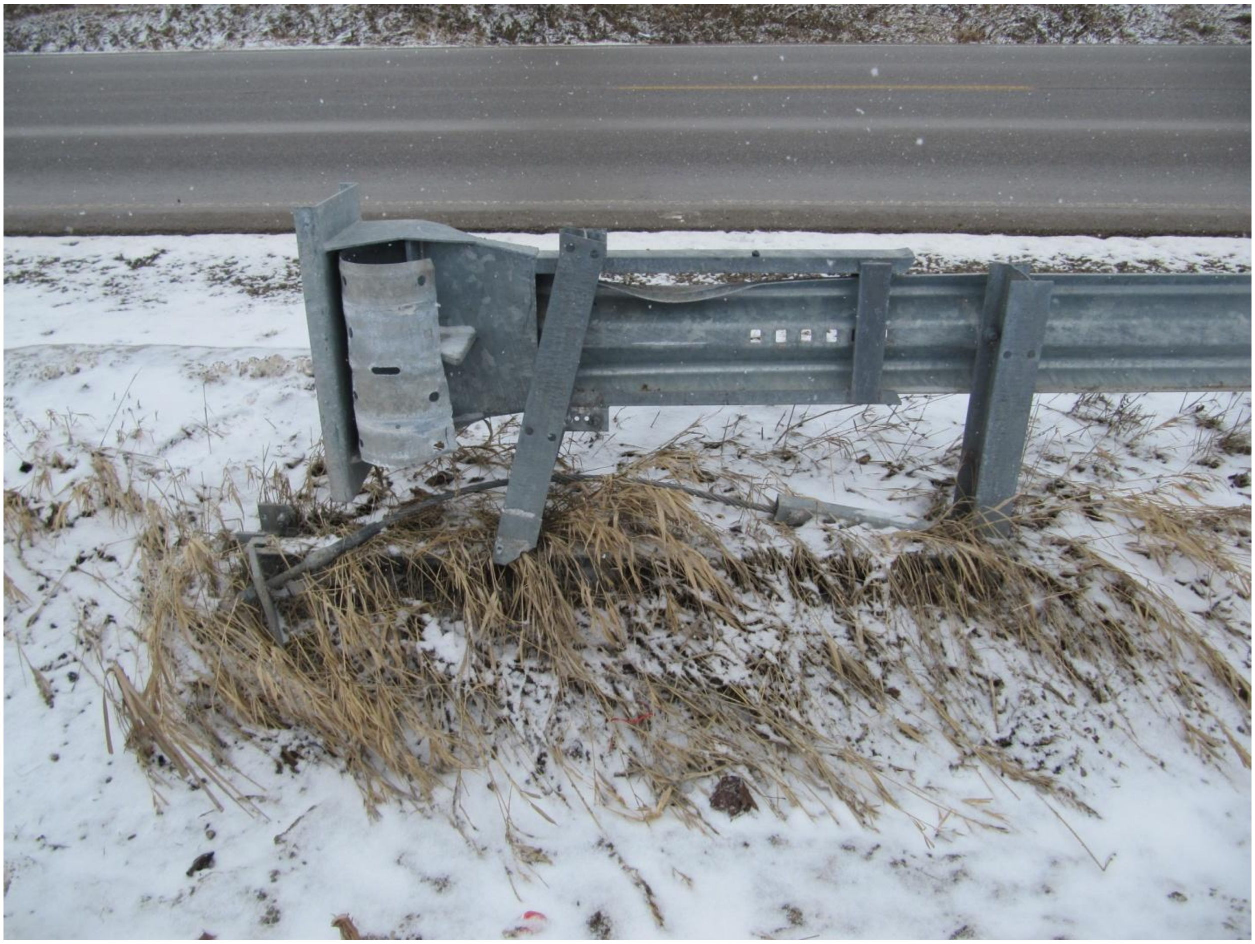

Figure 30: A ditch-side view of the terminal indicates that a small length of the guardrail has passed through the terminal head and has been extruded out of its side.

Close-up views of the terminal have already been shown in Figures 3 and 4 near the beginning of this article. Those figures provide a good indication of how the guardrail is flattened as it passes through the narrow channel of the head. This process of deformation causes kinetic energy to be dissipated and this is what causes the striking vehicle to ride down the collision in a controlled manner. However, if the rail becomes jammed along the channel or inside the head then it cannot pass through and it does not perform the action of energy dissipation that it was designed to do. More importantly, critics have argued that when the rail becomes jammed , it folds over itself and creates a spear that harpoons the striking vehicle. Thus it becomes important to study the results of real life collisions with these terminals to capture any evidence that supports or disproves this argument.

In our example there is an unusual deformation in the top edge of the rail at the location where the rail is within the channel of the terminal, as shown in Figure 31.

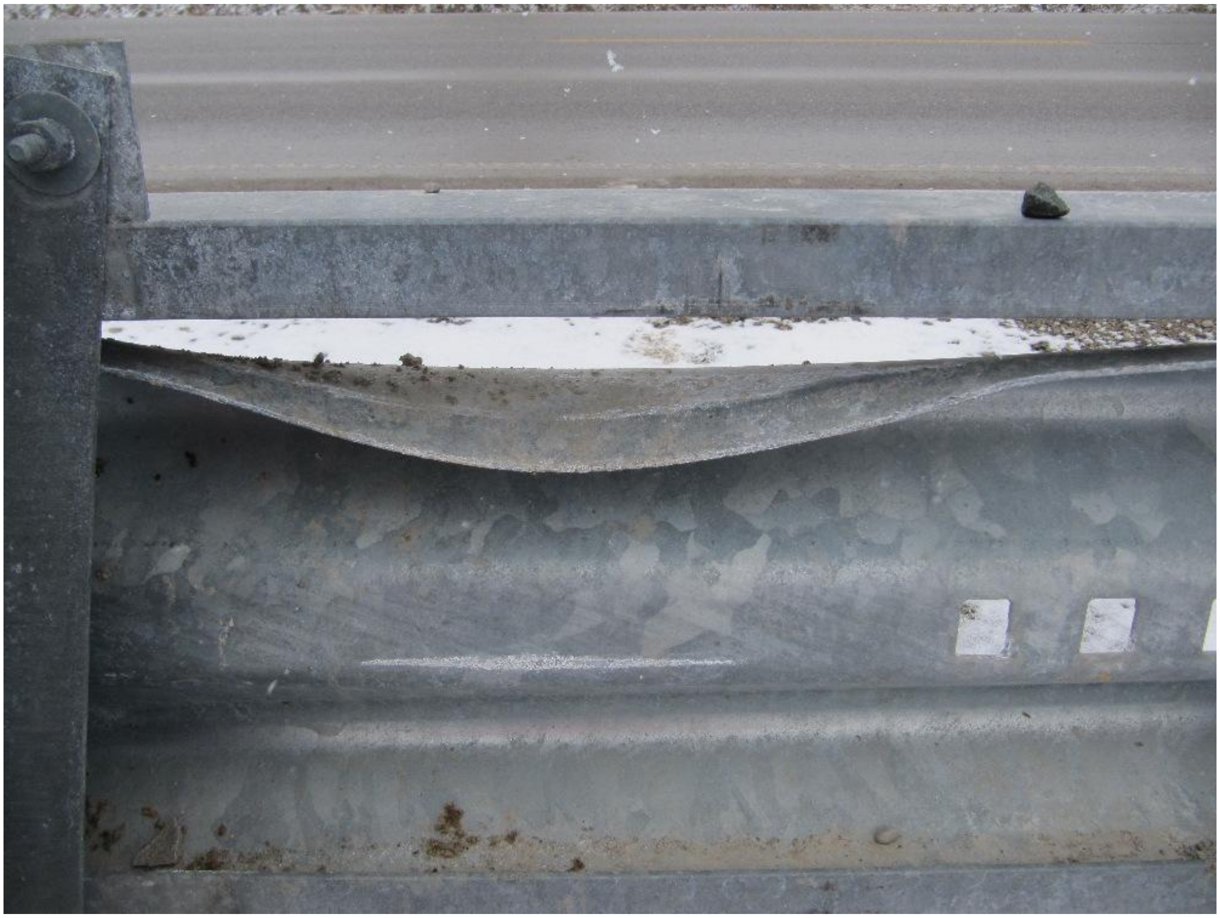

Figure 31: View of an unusual deformation to the top of the guardrail in the vicinity where it is encompassed by the channel of the terminal.

Looking directly below this dent in the rail is a small, light-coloured scrape on the side of the rail.

Similarly, when we look at the other side of the rail, in Figure 32, we can see another longer scrape that extends from the rear vertical bar of the channel all the way to the terminal head. As this portion of the rail has not reached the interior of the terminal head this damage cannot be the result of the designed, narrowed channel that is supposed to flatten it and extrude it out the side of the head. The only logical conclusion is that this damage must have occurred from the rail's contact in the vicinity of the rear end of the channel. As the top of the rail is bent downward the only logical conclusion is that there must have been contact between the top of the rear edge of the channel and the rail. This contact could be from the rail being lifted up or by the rear end of the channel moving down. Since the head and channel would become loose once they began their rearward motion the most logical belief is that the rear edge of the channel came down onto the top of the rail.

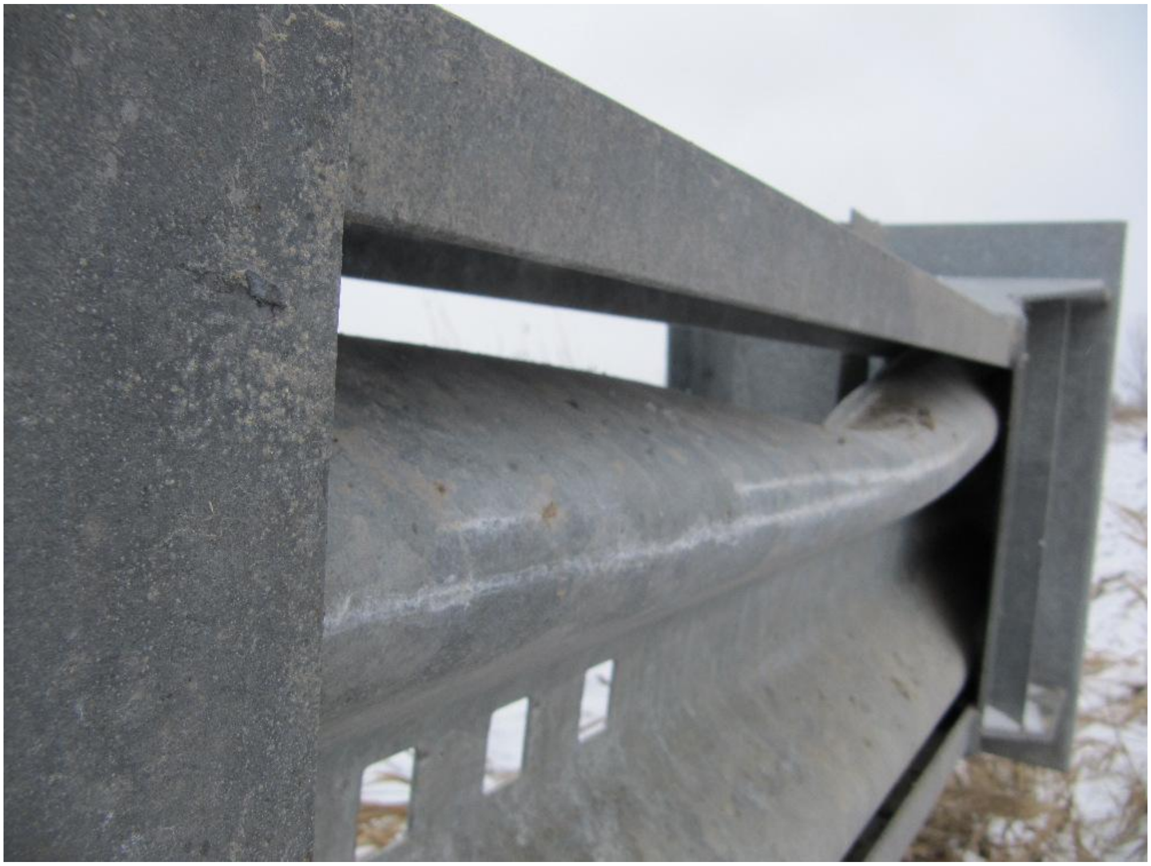

Figure 32: View of a light-coloured scrape on the rail that extends from the rear vertical bar of the channel through to the terminal head.

Regardless of the precise mechanism, the deformation of the rail before it enters the narrowed confines of the terminal head should not be viewed as a desirable outcome. If the rail is deformed it may not fit as designed within the narrowed channel and could become jammed.

On numerous occasions we have also found debris within the open channel that could interfere with the sliding of the terminal on the rail. Typically this debris is in the form of gravel as shown in Figure 33. It is believed that in winter months snow plows may throw snow and gravel against the terminal and some of the gravel falls inside the channel. But the precise mechanism by which this deposit is made is unknown. The point is, regardless of the mechanism, the existence of the contaminating gravel is a potential hazard that could lead to the jamming of the system.

Another potential hazard is that the head and channel are frequently observed positioned at a significantly different horizontal angle from the horizontal angle of the rail. The head of the terminal is frequently pointed slightly down while the rear end of the channel is lifted up. This possibly occurs because the terminal is attached to a vertical anchorage post by a single bolt, as shown in Figures 34, 35 and 36. It is believed that the terminal can rotate about this single bolt. If the head is heavier than the channel to its rear then the head could drop down over time due to the force of gravity and the rear end of the channel would be lifted up. When impacted the whole terminal could be forced to rotate such that the head is lifted upward while the rear of the channel is pushed downward so that the rear end of the channel makes contact with the top of the rail, as suggested by the evidence in the above photographs.

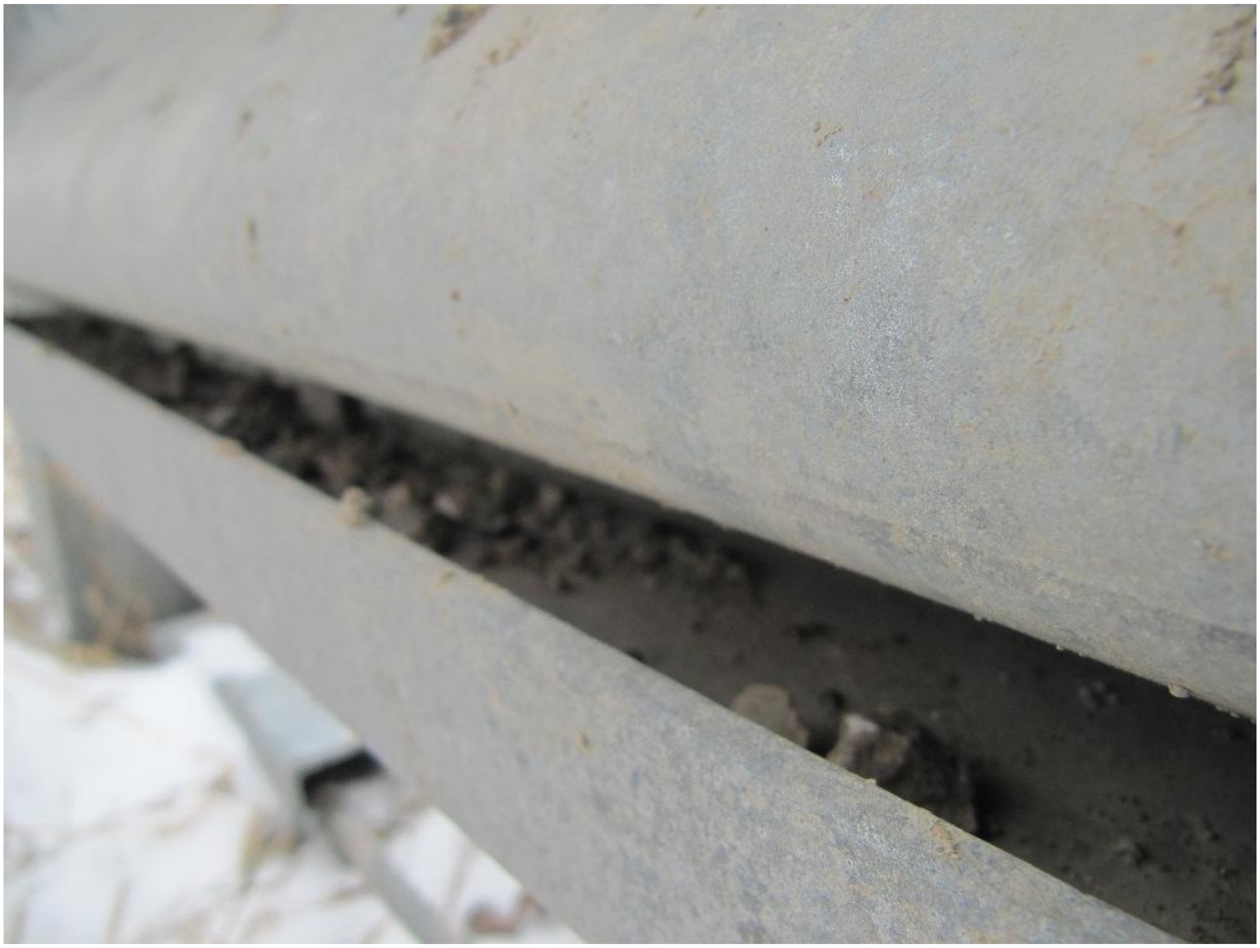

Figure 33: View of gravel resting along the bottom of the terminal channel. Such debris could help in restricting the sliding of the channel and head along the rail or it could become jammed in the narrow opening of the terminal head.

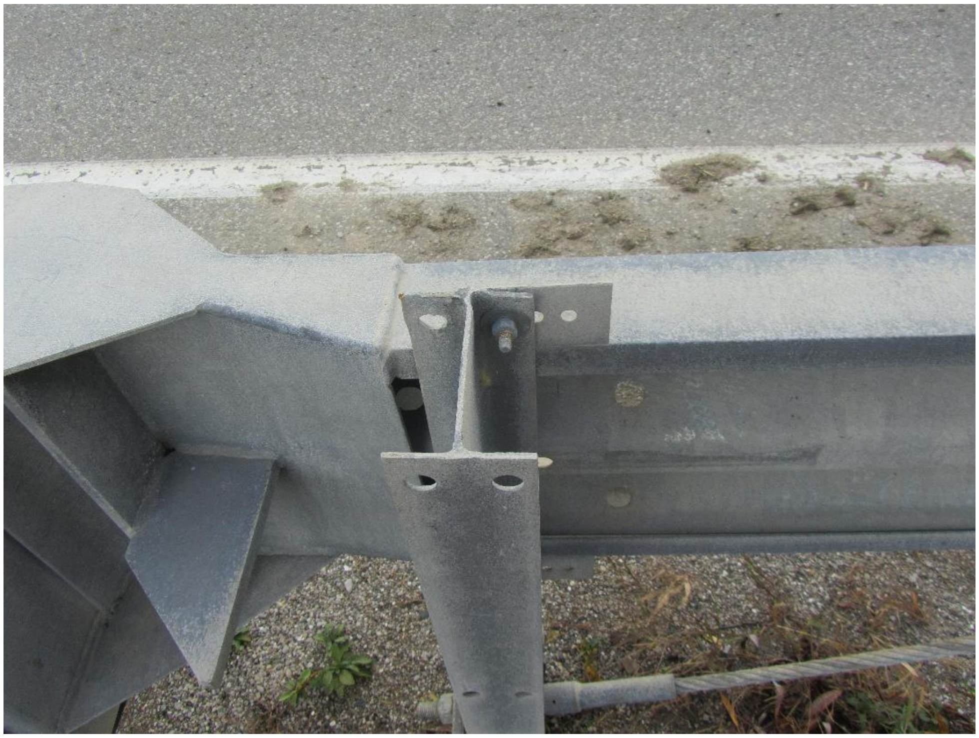

Figure 34: View of an ET-PLUS installation on Ilderton Road near Adelaide Street, north of London, Ontario. This view shows the upper anchorage of the terminal to the vertical anchorage post. A single bolt is the only attachment of the terminal to the post.

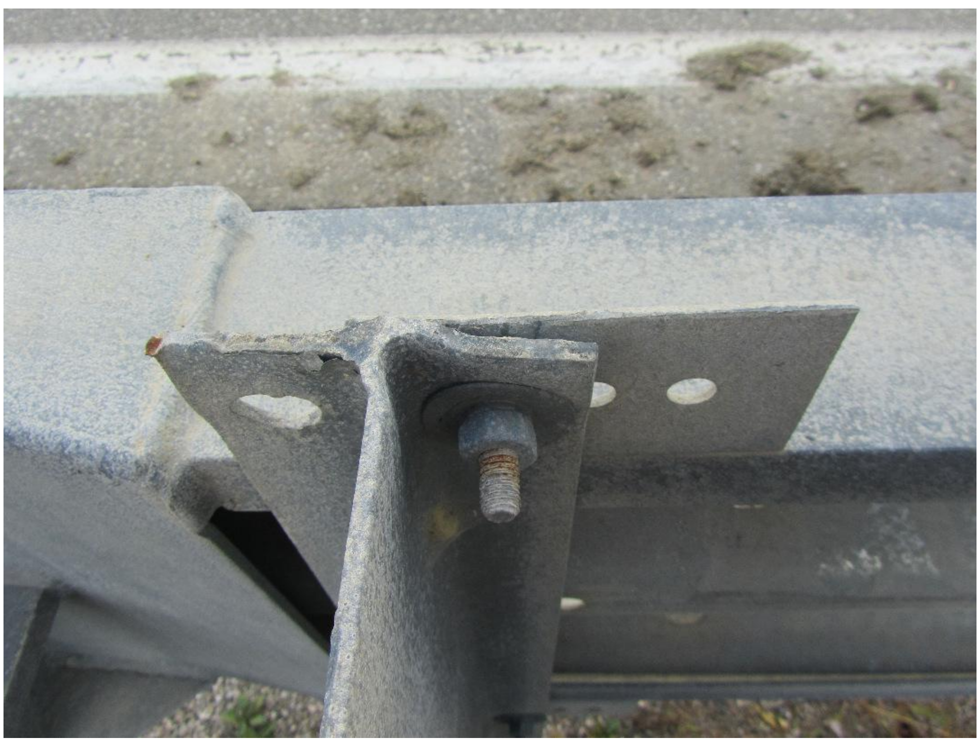

Figure 35: Close-up view of the point of attachment of the terminal to its vertical anchorage post.

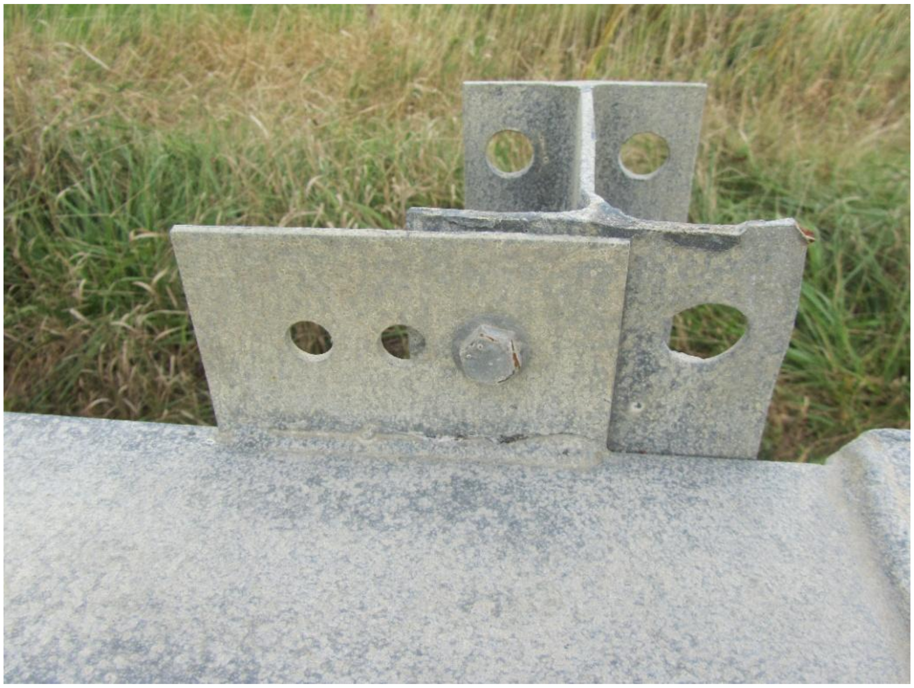

Figure 36: Opposite view showing the anchorage bracket extending from the terminal and how a single bolt attaches the bracket to the vertical anchorage post.

Discussion

Three examples have been reviewed in this article of Trinity Highway Products ET-PLUS guardrail terminal impacts in real-life scenarios. Such evidence is a rarity in the public domain as the performance of these terminals in real life collisions in not being revealed. A large cost is at stake and such situations generally create a panic amongst those who might potentially be liable for that cost. Alternately, there may be nothing wrong, no costs might be incurred and all the panic could be an extremely large waste of human energy. Regardless of the actual truth or outcome, conclusions must be made based on sound, objective evidence. The results of controlled tests, in an idyllic setting, where all real-life confounds are omitted, cannot be used as the sole measure of the safety of the ET-PLUS terminals. Yet this is precisely the focus of the U.S. Federal Highway Administration (FHWA) while failing to reveal how these installations actually perform in the real world.

It has been reported that after a federal jury found Trinity Highway Products liable in defrauding the U.S. government, the FHWA began requesting data from a variety of sources about the real-life performance of these terminals in actual collisions. This action suggests that the FHWA did not maintain an investigation of their own regarding the performance of the terminals on U.S. highways. If so, then this should be viewed as exceptionally negligent. Common sense would make anyone aware that how the terminal performs in several controlled tests is unlikely to be indicative of how they perform in real-life collisions. For the sake of public safety the FHWA should have been compelled to perform investigations of those real-life collisions when such a vast number of them are installed over almost every highway in North America.

There must be an effort to ensure that the consequences of real-life collisions with these terminals are made public and a proper, independent, scientific comparison between the real-life performance of ET-PLUS terminals and other energy-absorbing guardrail end treatments be made available for public scrutiny.

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