

Spill Clean-up Recommendations for Emergency Escape Ramps (EERs): Western Mountain DOTs' Perspectives

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Steep grades and runaway trucks have the potential of severe and fatal crashes. The use of an emergency escape ramp (EER) accommodates the control of runaway trucks by slowing and stopping them. Fuel or hazardous material (hazmat) spills may result from rollover or jack knife after trucks enter the EER. The objective of this research is to understand the clean-up processes and the remediation techniques after trucks enter ramps, and the auditing/verification processes after the clean-up. Additionally, this study presents a set of recommendations to improve spill clean-up processes and remediation techniques after trucks enter EERs. The recommendations are developed by using the combined method of literature review, phone interviews with staff from western state Departments of Transportations (DOTs), emergency responder companies, and hazmat personnel from Colorado DOT unit as well as exploratory analysis. The implementation of the recommendations will benefit DOTs and freight carriers through improved driver safety and freight security, and the general public through less hazmat discharge into the natural environment.

Key Words: Emergency escape ramp, Truck escape ramp, Runaway truck ramp, Fuel spills, Clean-up, Maintenance.

Introduction

Emergency Escape Ramps (EERs) have proven to be an effective method to control and stop runaway vehicles by transferring the vehicles' energy through gravitational deceleration, rolling resistance or both (Abdelwahab, & Morral, 1997). The need for EERs has been established in previous studies. According to Lill's study (1977) conducted for the American Trucking Association, 16% of truck crashes nationwide and 41% of the mountainous state truck crashes were downgrade crashes. Eck (1983) found that 18% of crashes were identified as runaway truck crashes from fifteen downgrade highway sections in West Virginia. Witheford (1992) describes that many ramps in the US are utilized once a week or more.

Depending on the energy dissipation method, different terminology is used by various agencies such as emergency truck ramps, runaway truck ramps, truck escape ramps, escape lanes, arrester beds, and gravity ramps. In this study, the American Association of State Highway and Transportation Officials' (AASHTO) Green Book (2011) definition of EERs is used as an accepted definition to include all types. The AASHTO's Green Book defines the need for EERs on long, descending grades and topographic locations where excessive speed poses a risk. Improving a highway through construction of an EER often requires adjusted grades and new alignments for providing a safe deceleration and stoppage of runaway trucks at locations away from the main traffic flow. Moreover, the AASHTO's Green Book provides the details about the design of these EERs. The first emergency truck ramp in US history was designed and constructed in 1956 in California (Witheford, 1992). In the twenty years following the completion of the first ramp, more than 60 ramps were constructed by 20 different states (Williams, 1979).

Preliminary data from operation reports provided by Colorado Department of Transportation (CDOT) indicate a high number of incidents for EERs in a mountain state, averaging over 150 incident reports per year since 2007. The reports can be related to signage problems, disabled vehicles on approaches, ramp closure due to weather or maintenance, wildlife, or to a truck in the ramp, but the high number of incidents reveal a significant usage, maintenance and operational record for EERs in this mountain state. One of the problems identified by state engineers is that most of the emergency truck ramps along Interstate Highway70 (I-70) have the approach on the right side with an angle of departure into the arrester bed. The arrester bed materials cause a rapid deceleration of the tractor while the trailer section continues its forward momentum over the travel distance between the tractor and the trailer. The differential forces along with the departure angle between the tractor and trailer increase the probability of a left rollover or jack knife.

Hazmat and aggregate contamination of the soil in the EERs have not generally been included in prior research. Moreover, clean-up, remediation, and auditing/verification processes after the clean-up have little discussion in extent research literature. Transportation of hazmat has a critical importance and fuel spills can be a threat for public health and safety as well as the environment. Additionally, many of the EER incidents resulting in jack knife and rollover experience fuel tank punctures on the EERs. Subsequently, the objective of this research is to better understand the clean-up processes and costs, remediation techniques after trucks enter the EERs, and auditing/verification processes after the clean-up from the perspective of DOTs. To accomplish this objective phone interviews were conducted with the following three groups: 1) western state DOTs, 2) emergency responder companies, and 3) CDOT's hazmat personnel. The combination of exploratory analysis of these interviews along with the extensive literature review served as the foundation for the recommendations presented in this paper.

Literature Review

EERs have different types of design and construction, and according to these types, maintenance and operation practices vary. The literature review showed that types of EERs are identified under two main categories including the geometry and the technology used in them. The use of high rolling resistance substrate and gravitational force consist of the characteristics of geometric EER category. In addition to that, technology category is mostly identified with dragnet systems. Within this context, the literature review of this study identifies the types of EERs with the categorization of the AASHTO's Green Book (2011) dragnet systems, and hazmat and aggregate contamination. Additionally, this study conforms to the AASHTO's Green Book (2011) categorization for the identification of EER types.

Types of EERs

The AASHTO's Green Book (2011) references three main subcategories in the classification of EERs and arrester beds, classified by the grade, including gravity, sand pile, and arrester bed. In this study, categorization for the identification of EER types conforms to the AASHTO's Green Book (2011).

1. *Gravity EER*

Gravity ramps work by using gravitational forces to slow and stop the runaway truck. Rolling resistance forces do not have a significant role in stopping the vehicle. Additionally, the physical characteristics of gravity ramps are long and steep which is considered costly and inefficient. However, the paved surface of the gravity ramp helps to stop forward motion of the vehicle, it cannot prevent rolling back or jackknifing of the tractor-trailer. Therefore, gravity ramps are defined as the least desirable option in the AASHTO's Green Book (2011).

2. *Sand Pile EER*

Sand pile ramps help to slow down and stop the truck with rolling resistance provided by loose and dry sand. Also, the gravity force on the slope of the surface contributes to the slowing process. Compared to the arrester beds, sand piles are less preferable because of their severe deceleration characteristics and lack of functionality in adverse weather.

3. *Arrester Bed EER*

Arrester beds are specifically designed with a usage of confined or unconfined loose material such as gravel with a certain depth and aggregate size. Arrester beds have three main categories including:
Descending-grade: Descending-grade arrester beds increase rolling resistance by loose aggregate to slow the vehicle in a manner. However, the gravitational effect does not contribute to a reduction in the speed of the vehicle

and the gradient resistance controls the direction of vehicle movement. Because rolling resistance is the only contributor to deceleration, descending-grade arrester bed need to be longer than the other types or arrester bed EERs.

Ascending grade: Ascending-grade arrester beds combine gravitational effect and rolling resistance of the loose material for decelerating and stopping the runaway vehicle. The assistive effect of gravity helps to reduce the length of the arrester bed. Additionally, loose material supports the vehicle to stay in place after it stops. With the effect of all these characteristics, ascending-grade arrester beds are the most preferred option in the AASHTO's Green Book (2011). Figure 1 shows a typical arrester bed in the State of Colorado.

Figure 1: Colorado Loveland Pass confined ascending grade arrester bed EER

Horizontal-grade: Horizontal-grade arrester beds are designed on a flat gradient compatible with the topography. The rolling resistance of the loose materials decelerates and stops the runaway vehicle. The effect of gravity on the horizontal-grade is minimal which makes its length more than ascending-grade arrester beds. However, vehicle roll-back is less likely on a horizontal grade arrester bed EER.

Dragnet Systems

In addition to EER types described in the AASHTO's Green Book (2011), new types of EERs have been developed. A dragnet truck arrester bed consisting of energy absorbers and barrier nets is one of the new types of EERs. Concrete median barriers located on each side of the ramp provide mounting and restraining of the steel cable nets and absorbers. The energy absorbers are embedded in the concrete median barriers and the nets are positioned vertically to the ramp (Cushion & Barrier LLC, 2017). Also, the mechanically stabilized earthen wall consists of precast concrete wall panels with an ashlar stone masonry form lined finish. At the end of the ramp, 15 sand-barrel impact attenuators are installed. While not a compulsory aspect of the design, sand barrel attenuator systems increase the psychological reliability of the ramp for drivers (Hanley, 2010). Compared to other types of arrester beds, a dragnet system requires less distance and less time to stop the runaway vehicle.

Dragnet systems have been located on various locations including near Avon on US Highway 44, Connecticut, US Highway 16 west of Buffalo, Wyoming, and State Route 431 Mt. Rose Highway, Nevada. The damage from the dragnet system to the truck is limited to the front bumper and cab which makes it possible to back the truck up after being stopped. Also, the system helps to decrease the possibility of saddle tank rupture, jackknifing, and overturning. The approximate cost of these projects vary from $3.2 to $4.6 million (Hanley, 2010).

Aggregate Contamination and Hazardous Material

The synthesis of National Cooperative Highway Research Program (NCHRP) pointed out compaction and fines contamination of the arrester beds decreases the effectiveness of EER performance. CDOT reported the effects of melted snow and rain on the sub-surface drainage system and water infiltration. Especially free drainage water from the mountains carries the fines into arrester beds which causes aggregate contamination (Witheford, 1992). According to the FHWA (2009) there are two types of spill: 1) vehicular fluid spills and 2) hazardous materials cargo spill. The same study mentioned that some states recognize that incidental spills do not have the same threat as larger cargo tank spills. They have adjusted laws and policies to permit quick and proper containment of minor spills.

The Arizona DOT (2003) stated that the contamination of arrester beds come from four main sources: 1) existing ground, 2) surface, 3) vehicles, and 4) gravel decay. The following suggestions were provided for each source of contamination: a) paving the bottom and sides of the arrester bed basin is recommended to prevent contamination of the aggregates from existing material (fines migration), b) an adequate drainage system for roadway and arrester bed is recommended to prevent surface contamination, c) contamination caused by vehicles is defined as unpreventable, so no specific preventive recommendation were stated, and d) contamination from aggregate decay over time is largely attributed to weather cycles and the natural breakdown of aggregate material. The usage of high-quality gravel is recommended for minimizing the contamination from aggregate decay.

The design guide of California DOT (Tye, 1986) has a similar summary for the contamination resources which includes 1) the ground under the bed, 2) fines blown or carried from the surface, 3) fuel or cargo spills from arrested vehicles, and 4) degradation of the bed material. For preventing the effects of fuel or cargo spills, surface slopes designed to direct runoff away from the bed was suggested. Another suggestion was the usage of a drainage system to separate and contain contaminants before they are released into watercourses.

The synthesis of NCHRP (Witheford, 1992) reported that only two states had followed the guidelines on periodic replacement of material in arrester beds. One state replaced material every three years. The other state removed, washed, screened, and replaced the bed material. Three states mentioned the use of geotextiles or fabric filter under the arrester bed to control fines migration. Surface controls such as a grate system at the approach, earth berms adjacent to the bed and intercept ditches were the other solutions, which were recommended by different states.

Tye (1986) identified the problem of diesel fuel spills with the suggestion of paving the base with cement concrete and the provision of holding tanks to retain spilled material. None of these studies have specific details related to the suggested systems.

Research Method

In addition to the literature review, the study consists of phone interviews with 1) western state DOTs, 2) emergency responder companies, and 3) CDOT's hazmat personnel as well as the exploratory analysis of these interviews.

The main purpose of the phone interviews with western state DOTs was to better understand the following topics: types and numbers of the emergency escape ramps in their states, their practice of clean-up process and costs, remediation techniques after trucks enter emergency ramps, and auditing/verification process after the clean-up. The study focuses on these western state DOTs because the majority of the EERs are located in this region. The first step of the phone interview process was to collect the name and contact details of the person(s) responsible for oversight of the emergency escape ramps from the DOTs. As a second step, the researchers followed up with the DOTs' personnel via email and scheduled the phone interviews. An interview instrument with a total of 12 questions was used for the structured phone interviews, which normally lasted approximately 30 minutes. As a result, out of eleven DOTs, six of them participated in the phone interviews and two of them participated with written responses. Four of them had one participant and the remaining four had more than one participant. Three DOTs did not participate in the study. A total of 17 people from eight DOTs participated in the study. The DOTs' participants have backgrounds in operations and maintenance (14), construction (2), and design of EERs (1).

Phone interviews were also conducted with three emergency responder companies. The companies were selected based on their current work with DOTs and current experience cleaning-up EERs. The main focus of these phone interviews was to better identify their current practices of clean-up and remediation techniques after trucks enter EERs. The company representatives were contacted via email and the phone interviews were scheduled. Each company participated in the interview process with one participant. The questions on these interviews have a purpose of providing detailed information pertaining the drivers' way of contact with their companies, the typical incidents that their company deals with in EERs, the average time and cost of for the clean-up processes of spill incidents, and their suggestions to improve the design and clean-up processes on EERs. These interviews lasted approximately 20 minutes.

Finally, hazmat personnel of CDOT were included to the phone interview process with a focus of their current management practices of clean-up and remediation techniques after trucks enter EERs. Two hazmat personnel were contacted via email and the scheduled phone interviews were conducted with them individually. These individuals were selected based on the experience dealing with this type of situations. Also, CDOT has the higher incidents rate in the western mountain states. The interview questions were similar to the emergency responder companies with a focus of CDOT perspective. In general, the questions were shared with all participants when scheduling the interviews. The researchers considered pertinent providing additional time to the participants before the interviews for the questions asking numerical data such as number of EERs, average clean-up cost and time, which need a preliminary search from the participants.

Results

The results of this study are presented by utilizing the exploratory analysis of the phone interviews with 1) western state DOTs, 2) emergency responder companies, and 3) CDOT's hazmat personnel. The analysis provided the basis for the recommendations for improving the spill clean-up processes and remediation techniques after trucks enter EERs.

The authors would like to emphasize that the information received from the DOTs was limited to the knowledge of the personnel even if the questions were shared by the researchers in advance and provided information did not reflect the statewide or best practice. Subsequently, the responses of the interviewees did not offer any significant differences. Detailed information of removal and replacement practices could not be provided, and it was only reported as depending on the type of material spilled on the ramp. Additionally, the number of incidents regarding the fuel spills were reported less, and the hazmat spills were zero. The general practice of clean-up is to remove and replace the contaminated aggregate, depending on the type of material spilled on the ramp. The dragnet system was reported as an effective and successful system with the advantages of having little damage to the vehicle itself and the prevention of roll over and jack knife. Despite its higher construction cost, the ease and low cost of the maintenance were emphasized as the other benefits of the system

The emergency responder companies and CDOT’s hazmat personnel recommended drainage improvements with a pool on the catch basin, concrete surface of the ramps in terms of easy clean-up purposes, increasing the signage and awareness of driving on the mountain area, and simulations on the driver’s license educations. The three main contacts that the emergency responder companies will use in case of the truck drivers entering the EERs, including the trucker company and their insurance company, law enforcement (state or highway patrol), and CDOT’s personnel. In some cases, the trucker companies get in contact with spill brokers who contact with the emergency responder companies.

Additionally, the emergency responder companies provided that the typical fuel spill on the emergency escape ramp incidents reported is fuel tank puncture. The reportable amount of the fuel spill in the state of x is over 25 gallons; however, any amount of the spill needs to be cleaned up. Depending on the type of spill and its amount, the clean-up steps are as follows: 1) keep the site and its environment safe for ongoing traffic and the public with a flagging crew, 2) prevent the current spill’s contamination of the waterways with absorbent materials both on the ramp surface and drainage, 3) remove the cargo from the truck and then the truck itself, and 4) remove the contaminated aggregate and replacing it with new aggregate.

Moreover, the average time of the clean-up process reported as varying according to the type and volume of the spill by the emergency responder company representatives. If a permit from DOT is required, it can take about a week to get the permit and to finalize the clean-up. The typical cost of the clean-up also depends on the type and volume of the spill and the average cost is around $15,000.

According to the information provided by CDOT's hazmat personnel is not responsible for clean-up of the spills. The main responsible party for clean-up is the truck company. The steps that CDOT follows to clean-up the escape ramp are as follows: 1) According to the location of the incident, the fire department or the State Patrol (SP) is informed as emergency response authority. SP is the initial responder to the hazmat incidents and they have hazmat troupers and certified hazmat people to handle the initial response., 2) SP will get in contact with the trucking company about the need of clean-up and trucking companies contact with the hazmat broker or the emergency responder companies for the initial response of the clean-up., 3) After the removal of the truck and the cargo, the spill is covered and controlled against any case of contamination., 4) CDOT issues a hazmat permit for the clean-up process., and 5) Additionally, the clean-up companies need to be in contact with the insurance companies to confirm their payments.

The general time frame for the clean-up of the spills in the emergency escape ramps reported as depending on the location and the volume of the spill. The clean-up of a tank puncture spill may take two weeks including permit and clean-up process. Cost data is not provided by CDOTs personnel.

The recommendations from the CDOT's hazmat personnel on the design and operation of the ramps can be summarized as follows: containment system for the spills under the ramp, concrete surface of the ramps in terms of easy clean-up purposes, increasing the signage and awareness, additional part on the commercial motor vehicle (CMV) driver's license for the proper brake usage in the mountain areas, increasing the awareness of the drivers driving on the mountain area, and using the simulators on the driver's license process.

Discussion and Conclusion

This paper focuses on the recommendations for clean-up and remediation techniques after trucks enter EERs. Specific recommendations to be implemented by western DOTs include considering a dragnet system, developing a maintenance schedule, PID (photoionization detector) unit and grid soil sampling, and adding a spill kit at the end of EER.

Dragnet system

A dragnet system includes energy absorbers, steel barrier nets, and concrete median barriers that provide mounting and restraining of the nets and absorbers requires less distance and less time to stop the runaway vehicle. The final construction cost of the dragnet system can vary between $3.2 million to $4.6 million with an additional cost of $0.4 million for sub-surface heating system. The system helps to decrease the possibility of saddle tank rupture, jackknifing, and overturning.

In addition to these recommendations, an investigation is warranted to analysis the spill clean-up materials/products after trucks enter EERs, spill clean-up practices of Dragnet System including the fuel spill containment techniques as well as the costs of spill clean-up on Dragnet System. Also, the comparison of the results of grid soil sampling method and sampling aggregate at three locations, near the entrance, midway and near the end of higher used ramps may have the potential of revealing possible correlations regarding contamination levels and their locations.

Develop a maintenance schedule for arrester beds

The fines intrusion increases the deceleration rate, which may lead the trucks stop less smoothly. Therefore, the effect of increase on the deceleration rate theoretically increases the chance of uncontrolled positioning of the truck and resulting potential contamination of the aggregates. The time required for EER aggregate to become contaminated with fine aggregate, soil and dust and consequently, consolidated and compact, will vary by location. Therefore, if a regular maintenance schedule is developed based on time, some EERs will need maintenance and some may not. However, because development of a specific custom schedule for maintenance would require sampling and testing the aggregates in each EER, one recommendation is to use a time-based schedule where each EER is scarified and, during the scarification process, the character of the aggregate in the EER is evaluated to determine efficacy as an arresting medium.

Based on the research conducted by Outcalt (2008), the aggregate gradations in many of the EERs are unacceptable with respect to reducing vehicle velocity. Therefore, for those EERs suspected of not meeting the current specifications, aggregate should be sampled at three locations, near the entrance, midway and near the end. The thickness of the aggregate in the EER should be measured. Samples should be taken at third points within the thickness at each location. Other sieve and particle shape analyses should be completed and compared with the state DOTs specification. If the material meets the specification requirements, nothing more is needed. However, if the material does not meet the specification, the location of the material violating the specification should be determined and that material should be removed and replaced with materials that meet the specification. Mill the fines from the arrester beds using track mounted, mobile screening equipment such as a Powerscreen Chieftain or Warrior Series mobile screening application or similar applications.

PID (photoionization detector) unit and grid soil sampling

Most of the western state DOTs reported that any amount of the spill should be reported by truckers. It was found that lower amount of fuel spills was not reported as much as the high volume spills. Subsequently, smaller spills such as those caused by fuel tank rupture may result the aggregate accumulating fuel over time. A photoionization detector (PID) unit measuring and grid soil sampling are two effective methods of detecting hazmat contamination. A PID unit measures the volatile organic compounds (VOC) and other gases during manufacturing processes, waste handling, and hazmat contamination control. It uses ultraviolet (UV) rays to detect a wide range of VOCs providing a reading that indicates the presence of compounds in the site. Wireless, portable, and transportable versions are available that have common usage among the first responders.

Grid soil sampling is a technique used for determining the hazmat contamination of a defined site involving a sampling grid of the site and collection of soil samples from the center of each grid. The first step of the grid soil sampling is to have the knowledge of the nature and the magnitude of the hazmat that contaminates the site. Sample depths depend on the characteristics of site and the contaminant type. According to Environmental Protection Agency (EPA) Supplemental Guidance to Risk Assessment Guidance for Superfund (RAGS) (1992) the minimum number of samples is ten, regardless of site size. The maximum grid size should not exceed a residential lot, specified to be 1/5 acre (about 8700 square feet). Grid sizes vary depending the characteristics of the site. (Wyoming Department of Environmental Quality [DEQ], 2000)

For the data analysis of the sampling, direct comparison and statistical analysis methods are used. The direct comparison method is the comparison of the soil sample result to the soil clean-up level at each grid. Statistical analysis is the comparison of the 95 percent upper confidence limit (UCL) of mean to cleanup levels. The 95 percent UCL is EPA's concentration term in the calculation of risk assessments under Superfund (EPA, 1992). Statistical analysis requires more than 10 sample locations in the data collection. Laboratory analyses of the grid soil sampling should include volatile organic compounds, semi-volatile organic compounds, total petroleum hydrocarbons - gasoline range organics (TPH GRO), total petroleum hydrocarbons - diesel range organics (TPH DRO), and priority pollutant metals (DEQ, 2000). Additionally, in states where EERs account for higher usage (above 60%), grid sampling could be restricted to those areas with high likelihood of contamination.

Add a spill kit at the end of EER

Spill kits are prompt response and clean-up instruments containing absorbent material, containment devices and personal protective wear used to prevent the contamination of fuel/hazardous materials spills into the environment. The capacity of the spills kit varies from an indoor workplace to a general environmental spills. According to the type of material and volume of the spill the content changes. The key products the spill kits contain are booms, pads and socks, plugs and dikes, waste disposal bags, and personal protective equipment.

In conclusion, according to the responses received from the interviewees, the recommendations can be ranked from higher to lower as follows: considering a dragnet system, developing a maintenance schedule, PID (photoionization detector) unit, and grid soil sampling, and adding a spill kit at the end of EER. The dragnet system had the highest recommendation with the advantages of having little damage to the vehicle itself and the prevention of roll over and jackknife. Also, developing a maintenance schedule to scarify the aggregates in the EERs was another top recommendation of the interviewees. Finally, future studies are recommended to evaluate aggregate contamination as well as evaluating the design and operation of EERs that have heavy usage. The authors acknowledge the time and support from all the participants in this study. Also, the material presented in this paper is based on work supported by the Colorado Department of Transportation, Grant No. SAP PO 411012339.

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