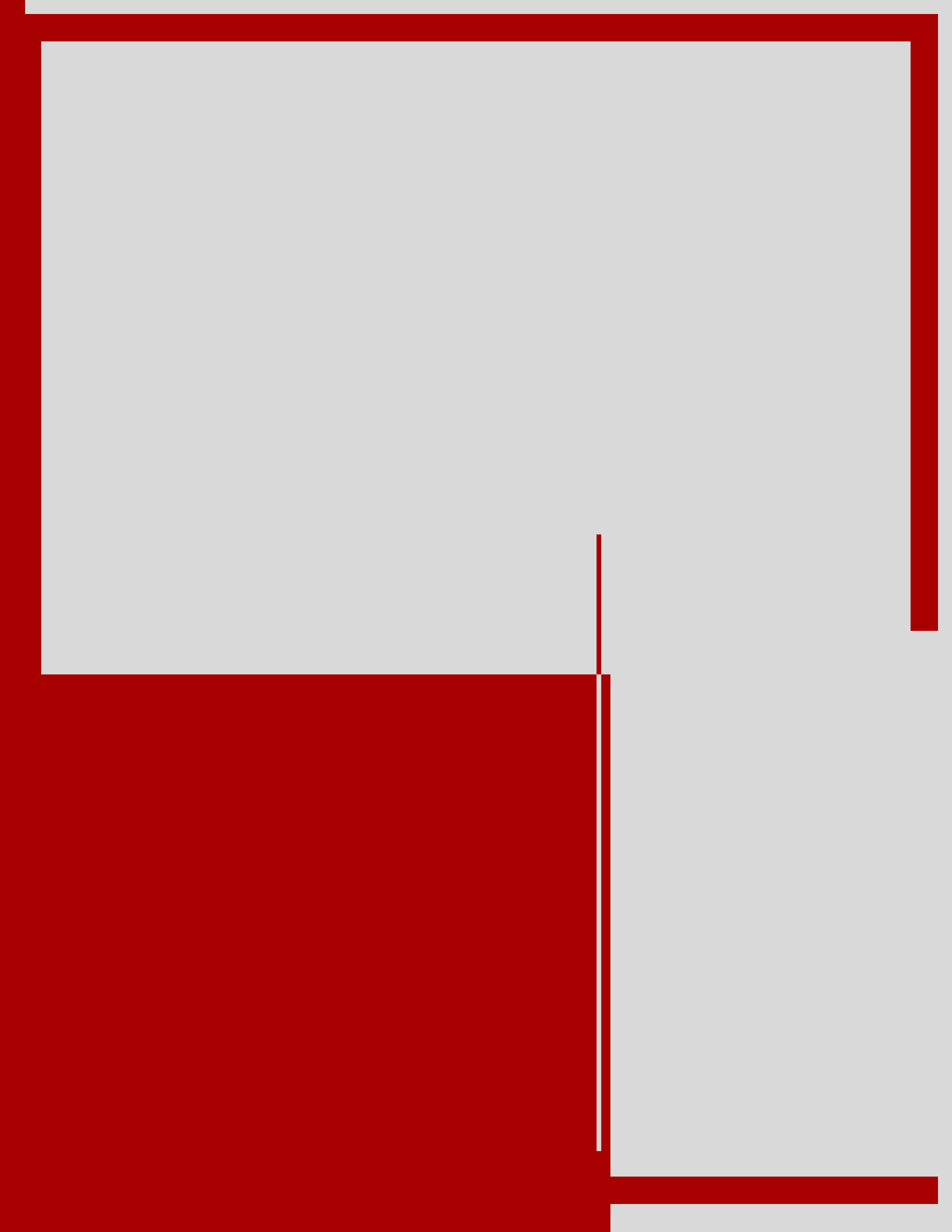

Contents

Summary

Compactors – also known as steamrollers – are mobile vehicles used to increase the density of soil and roadways and to seal and smooth asphalt surfaces. Compactors tend to overturn during some operations, thus putting their operators at risk. A rollover protective structure (ROPS) is a part of a compactor or other heavy equipment designed to protect an operator from a crushing injury in the event of a rollover. Particularly with seatbelt use, ROPSs have been shown to save lives.

In 1971, the Employment Standards Administration, part of the U.S. Department of Labor, drafted the following language under the Construction Safety Act: “The promulgation of specific standards for rollover protective structures for compactors...is reserved pending consideration of standards currently being developed.” The newly established U.S. Occupational Safety and Health Administration (OSHA) adopted the language in its rules the following year. Although consensus standards were developed soon thereafter (by the Society of Automotive Engineers), the OSHA rules were never changed to require ROPS on compactors.

This study examined government investigation reports of work-related deaths and injuries in 1986-2002 to learn the public health implications of a widespread lack of ROPS and seatbelts on compactors. Among the findings:

Interior. In addition, several state highway departments specified ROPSs in purchase orders for construction and highway maintenance equipment.

The Society of Automotive Engineers Recommended Practice

In 1966, the Society of Automotive Engineers (SAE) began developing recommended practices for protective devices for mobile construction and earthmoving equipment. The SAE developed a standard to allow an ROPS to yield through deformation and absorb some of the energy of a rollover so as to lessen the violence of the overturn. The structure was designed to deform through a plastic range that would neither break nor intrude into the operator’s protective zone (National Safety Council 1976). It was not until 1975, however, that the SAE issued a recommended practice for ROPSs on compactors, classifying them as earth

In 1972, however, OSHA notified the public that if a standard was reserved with a delayed effective date, the working conditions would be subject to the General Duty Clause, Section 5(a)(1) of the

Starting in June 1973, Woodward Associates (1974) conducted a study for OSHA on the feasibility of retrofitting ROPSs on construction equipment, excluding compactors. Nonetheless, fatality data analyzed from California and the Corps of Engineers included compactors. The study concluded that ROPSs clearly reduced injuries and deaths related to vehicle rollovers. Moreover, the study found that ROPS designs were available for most heavy-construction equipment manufactured after 1960 and that rollovers occurred in all types of terrain and to all types of vehicles.

In Sweden, the use of ROPSs on agricultural tractors has proven to be effective in reducing death rates from 17 per 100,000 tractors in 1960 to 0.3

On compactors, an ROPS can be designed with two posts or four posts (fig. 4) and can have a canopy overhead to provide shade; these canopies may be designed as part of the ROPS system. Some modern compactors use a single-post ROPS with a canopy extending to the sides to absorb the impact of an overturn. A principle in ROPS design is to restrict an overturn to no more than 90°.

Research Methods

The collection of cases to be analyzed followed a two-step process. First, the researcher identified OSHA inspection reports and Fatality Assessment and Control Evaluation (FACE) investigations of compactor overturns and runovers by the National Institute for Occupational Safety and Health (NIOSH). Four of OSHA reports were also included in the NIOSH investigations. Most of the cases were found on the internet at the OSHA and NIOSH websites. Others were identified from newspaper articles, litigation files, and through assistance from the Portland, Oregon, Area OSHA Office. A total of 123 cases was identified.

The next step was to request the complete investigation report from OSHA under the Freedom-of-Information Act (although, to protect privacy, all names were expunged from the reports, except for decedents and officials representing the employers). The NIOSH reports were accessible through the internet.

Case files were compiled for 58 injury events involving compactor overturns (table 2). The cases ranged from the year 1985 to 2002.

Some OSHA reports related to the same incident; some addressed falls and collisions, as well as overturns. Eight others dealt with scheduled inspections in which the OSHA General Duty Clause was used to cite the lack of an ROPS or of a functioning seatbelt. OSHA data were not comprehensive and omitted many nonfatal events and all pre-1985 overturns, as well as incidents involving public employees where OSHA lacked jurisdiction.

Data from the reports were placed into a Haddon matrix to analyze the role of machine, environmental, and human factors and the temporal dimension (before, during, and after) of each incident (Runyan 1998; Hadden 1970, 1980). In addition, flowcharts were used to understand the factors that comprised the causal chain leading to and the characteristics of each overturn (Feyer and Williamson 1998; Myers 1992).

The Haddon matrix provided a way to categorize risk factors against three stages of an incident (*see* table 3). The first stage is pre-event (for example, compacting along an embankment edge); the second stage is the event (such as, an overturn); and the third stage is post-event (for instance, extrication). The risk factors were classified as related to the energy agent (such as, the compactor); the environment (for instance, a steep slope); and operator/driver (for instance, wearing a seatbelt).

Nonetheless, because of limitations in the data, this analysis can't show whether one type of compactor is more dangerous than the others; there is no way to know how much of the work was done using each type.

contrast, an ROPS in combination with a seatbelt offered a system of operator protection in the case of an overturn. However, two new compactors failed to have a seatbelt installed, and two other seatbelts were inoperable with a broken latch and a missing nut needed to secure the belt to the unit.

When a compactor was restricted to a 90° overturn, the severity of any injury was less. Two additional examples not investigated by OSHA indicated the value of ROPS (U.S. Department of Energy 2002). In one such overturn, the operator, who'd worn a seatbelt, walked away without serious injury (fig.6). This unit overturned because it was compacting a slope laterally rather than up and down the slope. In another case, a four-post ROPS is credited with saving the operator's life in another pad-foot single-drum overturn (Patterson 1987). The operator suffered no fractures and was released from the hospital.

Environmental Factors

The most significant environmental factor contributing to compactor overturns was found to be working near an edge of a road or embankment (*see* fig. 5). The slope at which an overturn was initiated ranged from 12° to 45°, and some overturns occurred with abrupt drop-offs such as over a pavement edge. A compactor may extend over an edge, an edge may give way and sink, or an edge may be sloped so that other factors may accumulate so as to reach the tip angle of the unit. There were two cases in which a compactor sank on a deep asphalt pour that was still warm and caused a tipping situation.

Next in significance in this category were steep slopes and roadway curves, where gear-shifting problems or poor brakes led to runaways (fig. 7). Indeed, steep slopes and curves at the bottom of a roadway have combined to present an overturn hazard; notably, no pad-footed compactor experienced a runaway, perhaps because that type of compactor does not operate on smooth surfaces. Other conditions contributing to runaways included hitting soft soil areas that depress on relatively level land, turning too fast, and kinetic issues such as striking rocks or other obstructions in a roadway.

In connection with the environment, the type of operation was also associated with compactor overturns. In compacting soil, pad-footed and smooth-drum compactors predominate, because rubber-tired compactors are rarely used for this task. Driving a compactor from one location to another as a method of transport was also related to overturns, principally through runaway excursions.

Compacting roadway shoulders presented a risk because a shoulder is an edge. When a compactor attempted to stay off asphalt while compacting a shoulder, some overturns occurred where a shoulder wasn't wide enough. Asphalt compacting presented a risk at the road edge where the deep, hot mix sank under the compactor's weight and on slopes when runaway excursions occurred on the smooth surface.

Hazards during gravel compacting may be similar to those associated with shoulder work Loading and unloading compactors from trailers posed hazards because of the lack of friction of a steel-drum on ramps, the sometime lack of adequate width to reach from one ramp to another, the occasional use of unstable boards as ramps, or unloading onto a slope where a runaway was possible after descending a ramp. Compacting stone may be hazardous because the stone can be slippery. Landfills present irregular and steep terrain.

Human Factors

The most serious human factor was a lack of seatbelt use, or an operator's unbuckling a seatbelt during an overturn and attempting to jump. However, using seatbelts without an ROPS is a recognized crushing hazard also, and one individual was belted in while there was no ROPS. In an overturn without an ROPS, the operator's chance of survival depends on jumping clear of the overturn path. One victim was unable to jump because of a disability.

Possible ROPS Design Defects

One argument against implementing an OSHA standard for ROPSs on compactors has been that ROPSs are a hazard, because Brickman and Barnett (1999) identified 11 cases in which an ROPS was the crushing agent in an overturn injury.

In this study of 58 cases, one ROPS design feature did emerge as a consistent safety issue. In five of the cases in which an ROPS was cited as the cause of a fatal injury, a canopy struck the operator. Canopies have typically been used for shade, but have been adopted in some cases as part of ROPS design. Other cases of individuals struck by ROPSs did not contain enough information to determine the part of the structure that struck the victim. The number of incidents may have been higher than the 5 incidents identified, because a falling or jumping operator would likely move in the direction of the canopy during a rollover.

Every ROPS-equipped compactor considered in this study of 58 cases was restricted to a 90° overturn, except one. The exception was a 1972 model landfill pad-foot compactor with an atypical tricycle design that overturned, crushing the cab, and killing the operator. The compactor overturned twice (720°), with the cab offering little resistence to the overturn, thus making it ineffective as an ROPS.

In another case of a fatal overturn in an ROPS-equipped compactor, there was a design problem: the seat was situated to the side for improved edge viewing but rendered the unit more awkward to steer, especially in a runaway situation (fig. 8). (The compactor was not equipped with a seatbelt.)

Seatbelt Effectiveness

Seatbelts appear to prevent injuries as a result of collisions or potential falls from an ROPS-equipped compactor. Several cases included runaway units that did not overturn, but from which operators fell or jumped and were injured by the impact of the fall. An ROPS-seatbelt combination might have prevented injuries, if a seatbelt had been used. Other situations involved collisions with either off-highway or highway vehicles in which a seatbelt likely would have saved lives. The victims in the two collisions that did not involve overturns were thrown off a compactor by the force of a collision and killed by the impact of the crash.

Several factors led to the problem of seatbelt non-use. Among these were the failure of an operator to use a belt (possibly because of discomfort or seatbelt malfunction), unfastening a belt during a runaway excursion or overturn as a panic response, the lack of a seatbelt with an ROPS, the presence of a seatbelt when an ROPS was not present, and dependence upon a cab as a restraint system.

If cabs are used as restraints, instead of seatbelts, the doors must be closed. Three cases involved cabs. One was a case of a non-crush-resistant cab, which was discussed above. The other two cases involved operators who had a cab door open and, during an overturn, each operator was unrestrained, falling through the door and being crushed by the cab frame. The Scandinavians have adopted enclosed cabs as their restraint device (Myers 2000), but the door needs to be closed to restrain the operator in the event of an overturn.

OSHA Enforcement

Until the early 1990s, OSHA typically excluded overturns from ROPS-related citations, because a standard was not in force. However, some jurisdictions and states used OSHA's General Duty Clause to cite employers who failed to provide a workplace free of the overturn hazard. In addition, compliance officers used the clause to cite employers for not requiring the use of a seatbelt in the presence of an ROPS. The OSHA 1998 directive (Swanson) provides for consistency in citing the lack of an ROPS as a violation under the clause. Six compactor-overturn cases were cited as General Duty Clause violations between 1999 and 2002.

Discussion and Recommendations

Workers continue to die and suffer injury from overturns of compactors lacking ROPSs more than 30 years after the passage of the Occupational Safety and Health Act of 1970, which established OSHA. The problem has long been recognized.

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Annex A: Figures 1 - 8

Figure 1. A double smooth-drum compactor with an ROPS canopy and articulated steering.

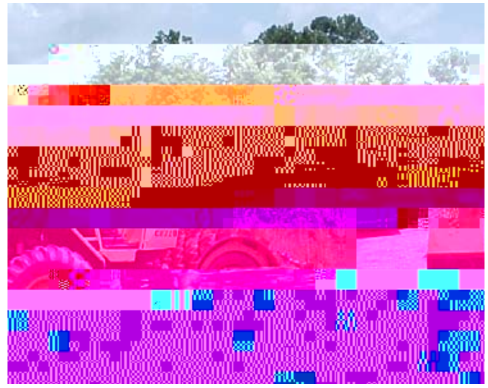

Figure 2. A pad-foot compactor with a single drum and articulated steering.

Figure 3. A rubber-tired compactor with a two-post ROPS.

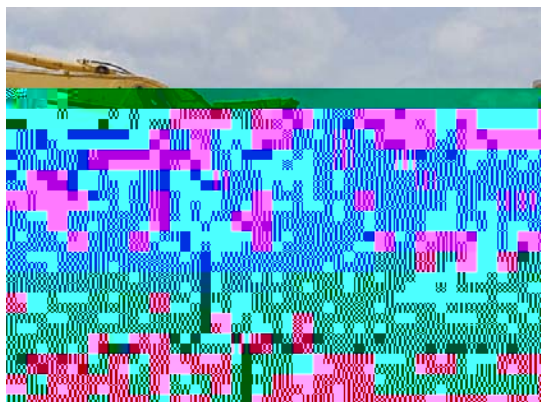

Figure 4. A double drum pad-foot compactor with articulated steering and a four-post ROPS with a canopy.

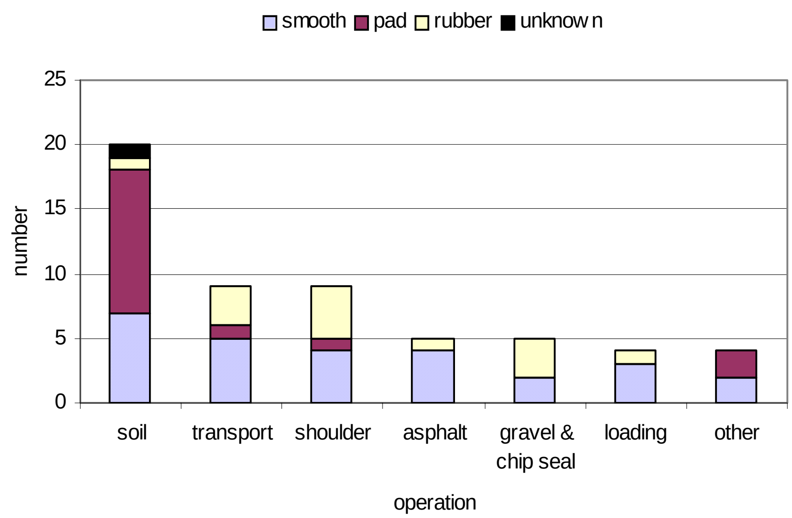

Figure 5. Number of compactor overturns resulting in operator injury, by conditions and type of compactor, 1985-2002

Note: 56 cases

Source: Based on OSHA and NIOSH reports

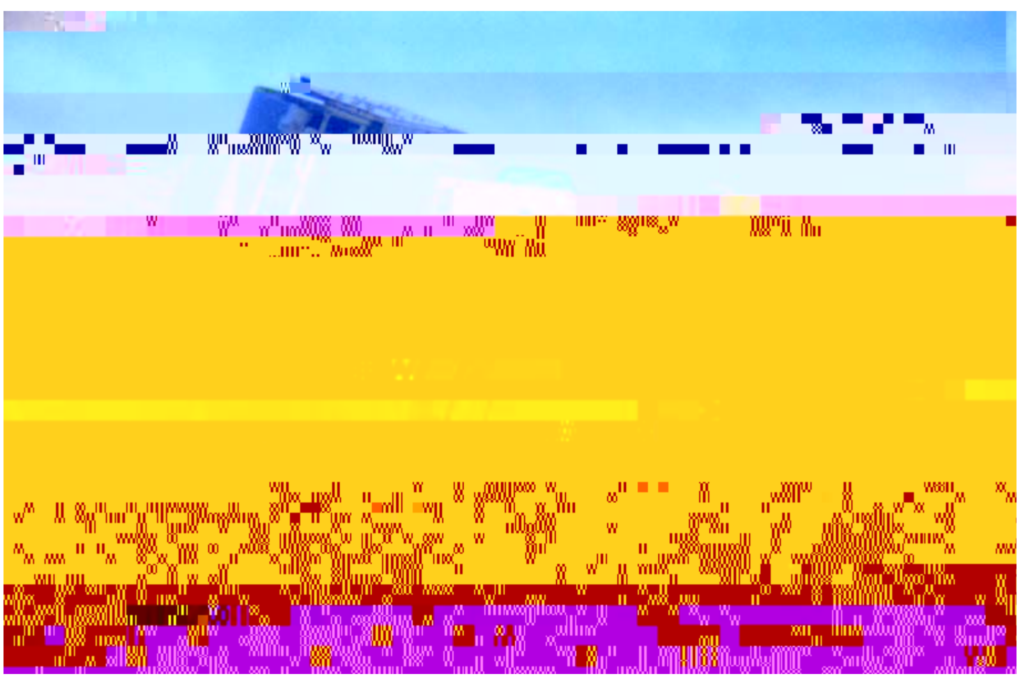

Figure 6. A compactor overturn that shows the anti-roll function of an ROPS

Source: U.S. Department of Energy