IDENTIFYING ROOT CAUSES OF CONSTRUCTION INJURIES

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ABSTRACT: Accident prevention begins with having a clear understanding of those factors that play key roles in their causation. One source of information on the causes associated with many serious injuries and fatalities is maintained by the Occupational Safety and Health Administration (OSHA). This essential information is contained in abstracts that are brief descriptions of the conditions and circumstances that were existent at the time of the accidents. Unfortunately, the information cannot be retrieved readily. This paper presents recommendations on how the OSHA reports could be made more meaningful. First, injuries should be coded into one of the 20 possible cause categories, rather than the traditional five groups of falls, struck-by, electric shock, caught in/between, and other. Additional or secondary cause codes also were developed. If these cause codes were adopted and used to describe all accidents recorded by OSHA, relevant data retrieval may be more effective. This information could then be utilized to focus greater attention on those areas for which modifications in the regulations are warranted and it would be more helpful to the construction industry by emphasizing the major causes of serious accidents.

INTRODUCTION

In the past decade, many parties in the construction industry have become very interested in finding ways of curbing construction-related injuries and fatalities. Much of this interest is rooted in the escalating costs of injuries, largely attributed to the rising costs of medical treatment and convalescent care. The strong interest in safety is perhaps most acute among larger firms, those with sizable labor budgets, and consequently those with considerable sums at stake. Although small firms could similarly benefit from reduced injuries among their workers, generally they have not been as enthusiastic about expending efforts to reduce the injury rates.

Most recent research efforts in construction safety have been focused on safety management, means by which management practices and policies can effectively improve safety performance. These efforts have identified a variety of ways that supervisors and managers of construction can be instrumental in favorably impacting the safety performance in a company or on a construction project. Although these efforts have contributed noticeably to the body of knowledge by which construction injuries can be reduced, they have nonetheless failed to examine the actual field circumstances under which injuries have occurred. Instead, they have focused on the climate or environment established by the managerial and supervisory personnel.

Despite the knowledge that has been gained about means of improving safety performance on construction sites, the specifics about physical conditions related to the injuries that have occurred have been lacking. Much information is available about the causes of injuries, but it is often too generic in nature to provide any meaningful guidance by which accident prevention programs can be made more effective. Detailed information about the root causes of construction injuries and fatalities is needed for this to occur. Such a mechanism of data retrieval does not currently exist. This paper will describe a research study that resulted in the development of a means by which construction injuries and fatalities might be coded accurately to provide valuable information about their root causes. Although some differences may exist between the causes of injuries and the causes of fatalities, it will be presumed that they are essentially the same.

EXISTING INFORMATION ON CAUSES OF CONSTRUCTION ACCIDENTS

Since 1971, the Occupational Safety and Health Administration (OSHA) has had as one of its directives the role of collecting data on the causes of construction fatalities. This information is collected by OSHA compliance officers when they visit construction sites on which fatalities or serious injuries have occurred and is recorded in OSHA's Integrated Management Information System (IMIS). The compliance officers write up a brief narrative description or abstract of the incident, with some information about the incident being recorded in a number of code categories. The most well-known code categories are the five basic cause codes, which are falls, struck-by, caught in/between, electric shock, and other. With the use of these codes, OSHA examined the construction fatalities occurring from 1985 to 1989 (OSHA 1990). Results showed that 33% of the fatalities in construction were caused by falls, 22% were struck-by incidents, 18% were caught in/between incidents, 17% were electrocutions, and 10% were caused by other conditions (toxic gases, drowning, fire, etc.).

The results of the OSHA study on the causes of construction fatalities (OSHA 1990) has received much publicity and attention. Perhaps, at least to some extent, the revised OSHA regulations on fall protection were an outgrowth of that study. Unfortunately, little has been done in the other causal areas, namely, the struck-by, caught in/between, electric shock, and other causes. The problem with these four cause categories is that they are not sufficiently descriptive of the root causes of the accidents.

The four cause categories of concern (struck-by, caught in/between, electric shock, and other) are not generally as descriptive of the causes of accidents as the category of falls. For example, suppose there are three separate incidents involving workers who are killed while laying pipe in unshored trenches. While worker 1 is making a pipe connection, the top portion of the trench wall suddenly breaks loose and falls onto the worker. While worker 2 is spreading ballast material in the bottom of the trench, one side of the trench wall moves laterally and pins the worker against the opposing trench wall, causing the worker to suffocate. While worker 3 is helping to set grades in the trench, a portion of the trench wall collapses, pinning the worker and preventing the worker from being able to move as the excavated area fills with water when a water main breaks.

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In each of these hypothetical (although typical of many cases) instances the workers were killed. In coding the information concerning the causes, the cause code for the incident involving worker 1 would be struck-by, the cause code for the incident involving worker 2 would be caught in/between, and the cause of death of worker 3 would be drowning, which is coded as other. Despite the seemingly different scenarios involved in these cases, the root cause for each death was the unshored trench. Does it matter if the worker was struck by the falling of earth materials, was asphyxiated by the confining trench walls, or drowned by the excess water entering the trench? Preventative actions would be implemented more readily if somehow the cause code reflected the fact that the trench walls were not shored. Instead, by relying on the codes of struck-by, caught in/between, and other, no indication is provided that either of the workers actually was killed in a trench at all. The coding system used to describe these three fatality cases highlights the limited assistance provided by the generic cause codes. These cases also indicate the need for more descriptive cause code categories.

RESEARCH STUDY

The objective of this research effort was to develop a coding system that would facilitate the categorization of injuries and fatalities in distinct groups of causation. Carefully developed categories of accident causation would provide a viable basis for implementing effective accident prevention programs. The five cause categories used by OSHA IMIS provide valuable information; however, they tend to be too broad in scope to delineate clearly many causes of accidents. Nonetheless, the OSHA cause codes were used as the initial basis to be considered for modification. For example, for fall accidents two codes were developed, namely, falls from elevation and falls from ground level. Struck-by accidents were coded into three specific cause codes, namely, struck by equipment, struck by falling material, and struck by material (other than falling material). Thus, the current OSHA codes were divided further into codes that provided greater detail. These detailed codes evolved as the various abstracts of accidents occurring in 1994 and 1995 were examined and analyzed. This process resulted in additional codes being developed when the initially revised code categories proved inadequate.

After 500 abstracts had been evaluated (most of the 1994 data), the accidents were examined in terms of their distribution among the various cause codes. In some cases, especially those with very low frequency counts, codes were further modified or merged with others. This process resulted in the development of 20 cause code categories.

Although the 20 cause codes were deemed to represent a considerable improvement over the five codes traditionally used, it was clear that these codes still did not fully describe accident causation. For example, it was noted that some accidents were caused by the failure to follow proper lockout/tag-out procedures. Also, it was noted that these accidents might result in an injury or fatality for which the primary cause codes would be related to electric shock (facility power), asphyxiation, struck-by, or caught in/between. It was determined that these accidents could not be described clearly with a single cause code so secondary codes were developed, this often being a numeric descriptor that provided additional detail for describing accident causation.

RESULTS

The OSHA cause codes were modified so as to create 20 cause codes. These resultant codes, describing accident causation with considerable detail, are shown in Table 1. From an examination of some of the cause categories, the relation of the codes to the standard OSHA cause codes is apparent, especially those related to falls, electric shock, struck-by, and caught in/between. The category of "other" was further divided to isolate incidents related to explosion, fire, asphyxiation, drowning, and natural causes. The category of "cave-in" is generally assumed to be related to caught in/between incidents, while some cave-in accidents were coded normally as struck-by incidents.

A total of 1,082 accidents were examined for 1994 and 1995. To make a comparison of the 1994–1995 injury fatality statistics with what was reported by OSHA for 1985–1989 (OSHA 1990), the revised coding scheme was collapsed into categories that reflected the categories traditionally used by OSHA. This resulted in the distribution of accidents as shown in Figs. 1 and 2.

An examination of the information in Figs. 1 and 2 shows that the distribution of accident causes is generally consistent for the two different time periods. There seems to be relative consistency from the 5-yr period in the 1980s and the period from 1994–1995. This similarity not only shows that the causes of accidents have remained somewhat the same, but it

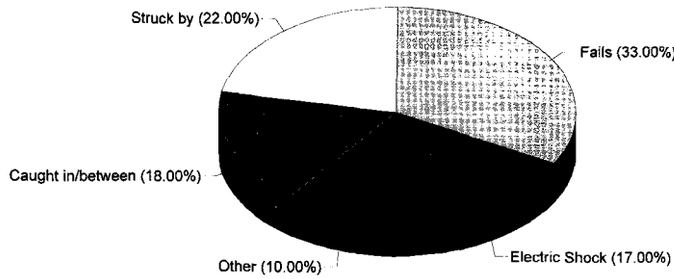

FIG. 1. Distribution of Fatalities by Causes, 1985–1989

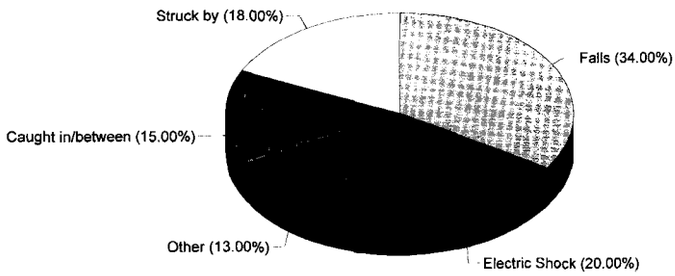

FIG. 2. Distribution of Accidents by Causes, 1994–1995

TABLE 1. Revised Codes of Accident Causation

Accident cause codes (1)
Falls from elevation
Falls from ground level
Electrocution (power lines)
Electrocution (building power)
Electrocution (faulty facility wiring)
Electrocution (faulty construction tool/wiring)
Electrocution (other)
Struck by equipment
Struck by falling material
Struck by material (other than falling material)
Caught in/between equipment
Caught in/between material
Cave-in
Explosion
Fire
Explosion/fire
Asphyxiation
Drowning
Natural causes
Other

also tends to indicate that the coding categories for this research effort are comparable with the prior OSHA effort. To that end, further examination of the details of the accident distribution of the revised codes was considered warranted.

Falls were categorized as being either falls from elevation or falls from ground level. The falls from ground level essentially were falls in which a worker or workers fell into a hole or excavated area. Of the 363 falls that were analyzed, only two involved falls from the ground elevation. Thus over 99% of the falls are falls from elevation.

The electrical shock incidents consisted of five subcategories. The distribution of these incidents is shown in Fig. 3. It is apparent that a large majority of the electric shock accidents are the result of contact being made with overhead electric power lines. Contact with the building power, generally the result of human error, represents the second most common (13%) source of electrical shock. These were followed by shocks resulting from faulty facility wiring and faulty construction tools or wiring. The category of other was utilized to describe incidents that were not described accurately by the first four categories.

The causes of struck-by accidents are summarized in Fig. 4. Struck-by accidents generally involve either materials or equipment, especially heavy equipment. Equipment-related accidents generally were categorized as struck-by or caught in/between incidents. Most material-related accidents involved falling material, generally material that is dropped or in some manner falls to a lower level. Only 7% of the struck-by accidents involved material that was not falling. These incidents included cases in which material was moving laterally at the time of making worker contact, whether caused by material that was being handled or transported. One incident coded as a material struck-by accident (other than falling material) consisted of a plug inserted into a pressurized pipe that failed and struck a worker.

The caught in/between incidents were grouped in three distinct categories, namely equipment, cave-in, and material. These three types of incidents are distinctly different and warrant being isolated (see Fig. 5). Accidents involving equipment, primarily heavy equipment, were the most frequently occurring (59%) of the caught in/between incidents. A third of the incidents involved cave-ins, a very specific type of accident that is lost under the traditional OSHA cause codes. Only a few (8%) of the incidents involve material, primarily accidents resulting from the shifting of materials or movement of materials that pin workers against other objects or the ground.

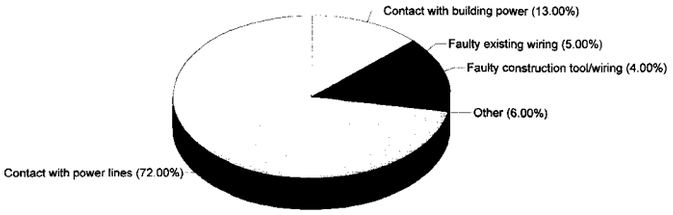

FIG. 3. Distribution of Electrical Shock Accidents

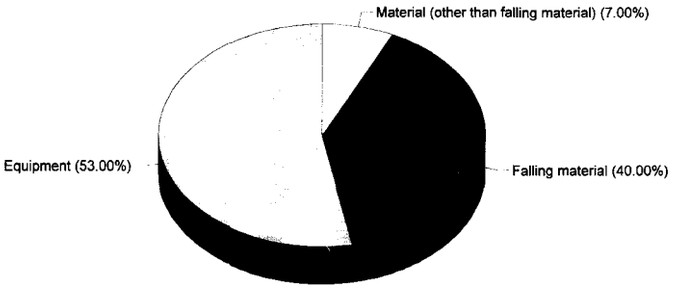

FIG. 4. Distribution of Struck-by Accidents

Further examination of the cave-in incidents showed that these consisted primarily of trench cave-ins (88%) and the collapse of excavations or tunnels (12%). In almost all trench cave-in cases, the workers in trenches were not protected properly by either sloped sides, trench boxes, or shoring. In some fatality cases, trench boxes were being used but workers would step out of the area protected by the trench box and would be caught by a cave-in.

The remaining types of accidents, generally coded as other, did not fit well with the description used for the previously noted incidents. Nonetheless, distinct groupings of accidents were identified. These are summarized in Fig. 6. Explosions and/or fire-related accidents made up 37% of the accidents. This was followed by natural causes, which may or may not have been job related. Note that 9% of these were still coded as other, but it must be recognized that this accounts for only about 1% of all accidents that were analyzed.

When compared with the five cause codes traditionally used by OSHA, the additional detail provided by the revised cause codes is readily apparent. These revised cause codes were examined as they relate to worker trades. Although the full extent of the details are not provided here, some indication of the primary sources of injuries for specific trades is given in Table 2. The table also shows the extent to which the different noted trades are involved in construction injuries/fatality accidents.

Some of the causes of accidents for some specific trades may be predicted, whereas others generally are not anticipated. Note that of 46 incidents involving carpenters over 67% related to falls from elevation. All seven of the crane maintenance incidents and 82% of the incidents involving equipment mechanics were coded as caught in/between equipment. Of the 35 incidents involving equipment spotters, 48% related to contact with overhead power lines. Ten of the 13 incidents involving drywall installers were caused by falls from elevation. Other interesting statistics can be identified from these data. It is clear that falls are a primary cause of injuries for such crafts as carpenters, welders/cutters, drywall installers, elevator repair workers, masons, sheet metal workers, painters, roofers, and steel workers. Crafts associated with the use and/or operation of heavy equipment are involved more frequently in accidents in which they are struck by equipment or caught in/

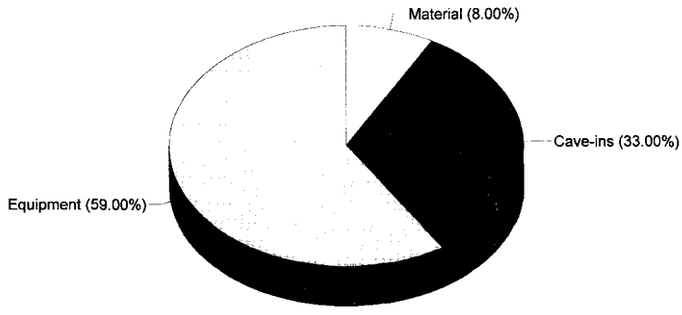

FIG. 5. Distribution of Caught in/between Accidents

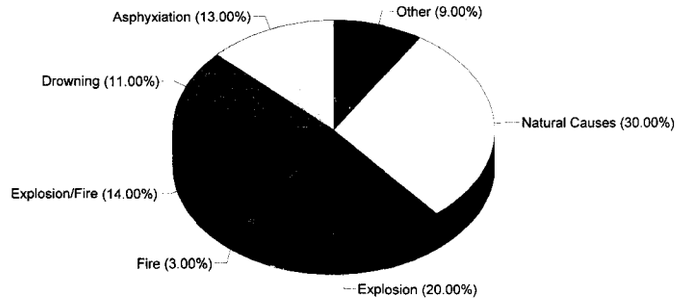

FIG. 6. Distribution of Accidents Generally Classified as Other

TABLE 2. Analysis of Major Event Types by Occupation Types

Work type (1)	Event type (2)	Percent of total (3)	Total number of incidents (4)
Carpenter	Fall from elevation	67.4	46
	Struck by falling material	17.4	
Concrete worker	Struck by equipment	27.3	11
	Struck by falling material	18.2	
	Fall from elevation	18.2	
Crane maintenance	Caught in/between equipment	100	7
Welder/cutter	Fall from elevation	32.1	28
	Explosion/fire	25	
	Natural causes	10.7	
Spotter	Electrocution (power lines)	48.6	35
	Struck by falling material	17.1	
	Struck by equipment	11.4	
Drywall installer	Fall from elevation	76.9	13
	Natural causes	15.4	
Electrician	Electrocution	63	106
	Power lines	40	
	Building power	13	
	Other	7	
	Fall from elevation	26.4	
Elevator repairer	Fall from elevation	33	12
	Struck by falling material	33	
Equipment mechanic	Caught in/between equipment	82	17
	Struck by equipment	11.7	
Equipment operator	Caught in/between equipment	50.5	101
	Electrocution (power lines)	9.9	
	Struck by equipment	8.9	
Flagger	Struck by equipment	100	14
HVAC mechanic	Electrocution (building power)	33	12
	Fall from elevation	33	
Mason	Fall from elevation	76.5	17
Sheet metal worker	Fall from elevation	58.3	12
	Electrocution (power lines)	16.7	
Painter	Fall from elevation	50	20
	Electrocution (power lines)	25	
Plumber/pipe fitter	Cave-in (trench)	50	52
	Electrocution (faulty exist wiring)	9.6	
	Fall from elevation	7.7	
Roofer	Fall from elevation	82.4	74
	Electrocution (power lines)	10.8	
Steel worker	Fall from elevation	74.4	39
	Struck by falling material	12.8	

between equipment. Work performed near power lines, as evidenced by electric shocks caused by such contacts, was most often performed by equipment spotters and electricians. Plumbers and pipe fitters are most often involved in accidents resulting from trench cave-ins. Regardless of the craft, any successful accident prevention efforts must be directed to the causes generally associated with that craft.

It should be noted that in order for the cause codes to be applied accurately and consistently, clear guidelines should be established that provide direction to the individual developing the cause code categories. This also was done in this research effort even though all of the coding was done by one of the researchers. The guidelines for determining appropriate cause codes are particularly useful when an incident is of a nature in which the code might appear applicable to more than one cause code. This ambiguity was noted frequently when categorizing accidents with the currently used cause codes, especially the coding of struck-by and caught in/between incidents. To clarify the distinction, struck by equipment accidents were defined as those in which the equipment was traveling at least 8 k/h (5 mph). However, if the equipment rolled over a worker, the accident type was determined to be caught in/between equipment, regardless of the speed.

TABLE 3. Secondary Factors of Construction Worker Fatalities

Factor (1)	Comments (2)
Lockout/tag-out	Used properly: 3 cases (1.5% of lockout/tag-out cases)
	Used improperly: 3 cases (1.5% of lockout/tag-out cases)
	Not used: 193 cases (97% of lockout/tag-out cases)
Confined space	21 cases involved confined space
Fall height	Average: greater than 1.8 m
Trench depth	Average: 3.5 m (42 incidents)
Age	Average: 33.4 yr (954 incidents)
Sex	Male: 947 cases (99%)
Time	a.m.: 145 cases (50%)
	p.m.: 144 cases (50%)
Others involved	325 cases (34%)
Subject caused	541 cases (57%)
Equipment type	Project: 354 cases (37%)
	Private: 21 cases (2%)
	None: 579 cases (61%)
Material handling	Lateral: 256 cases (27%)
	Altering: 93 cases (10%)
	Hoisting: 93 cases (10%)
	None: 512 cases (54%)
Type of project	New construction: 250 cases (26%)
	Repair: 138 cases (14%)
	Demolition: 44 cases (5%)
	Renovation: 9 cases (.9%)
	Remodel: 2 cases (.2%)
	Unknown: 523 cases (55%)

The secondary or additional information was examined to further describe the types of incidents. For example, for the 1994–1995 data, the average age of the victims was 33.4 yr; 99% of the injured workers were male; the timing of accident occurrence was most frequently between 11:00 a.m. and noon, with a significant number of accidents occurring between 9:00 and 11:00 a.m. and between 1:00 and 4:00 p.m. Of the accidents, 34% involved two or more workers and 57% of the accidents were caused by some contribution by the injured worker. Some additional information is summarized in Table 3.

CONCLUSIONS

The results of this research have demonstrated that the causes of construction accidents can be characterized in greater detail with a minimum amount of effort. The level of detail that can be attained provides much more valuable information by which accident prevention programs can be made more effective. The generic cause codes currently in use provide only a limited amount of information, often at a level for which no specific prevention actions can be initiated.

The revised cause codes that were developed in this study provide valuable information in that the specific nature of the causes of accidents is captured to a greater degree. For example, the focus of efforts to reduce electric shock accidents should be directed logically to work performed near overhead power lines. Most efforts to reduce struck-by accidents should be focused on practices related to the use of equipment, whereas in some situations the effort should be directed to the prevention of falling materials. Caught in/between accidents are categorized more accurately as being associated primarily with equipment, with a separate category having been created for cave-in accidents. For those categorized as other under the current cause codes, greater specificity has significantly reduced the ambiguity associated with these accident causes. Also, the use of the secondary codes that were developed

J. Constr. Eng. Manage., 1998, 124(1): 67-71

would provide additional information that would be quite valuable in efforts to curb construction accidents.

RECOMMENDATIONS

The improvement of the quality of information associated with the causes of construction accidents can be a considerable asset in the enhancement of efforts to reduce construction accidents. The current cause codes used by OSHA, while helpful, do not provide the specific type of information by which the root causes of accidents are described clearly. The codes developed in this study constitute an improvement to the existing cause codes being utilized. It is recommended that OSHA give serious consideration to the adoption of such a system. Even if the revised codes are not adopted verbatim, it is recommended that OSHA consider devising its own coding scheme, perhaps by using the revised cause codes as a possible model.

The effort required to generate these codes for every accident that is investigated would be minimal. A brief training session with OSHA compliance officers would be sufficient to ensure that the coding of all information is performed consistently. Greater details associated with accident causation will assist the regulatory bodies with enacting additional safety standards that are focused on clearly identified problem areas. The cost of achieving this level of detail in the information on accident causes will be small, but the benefits that might ultimately be reaped are considerable.

APPENDIX. REFERENCE

The Occupational Safety and Health Administration (OSHA) Data Base 1985–1989 (1990). "Analysis of construction fatalities." U.S. Department of Labor, Occupational Safety and Health Administration, Washington, D.C.

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