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Evaluation of excavation cave-in accidents before and after the 1990 revisions to the OSHA excavation regulations/

Owen W. Hale
University of Tennessee

To the Graduate Council:

I am submitting herewith a thesis written by Owen W. Hale entitled "Evaluation of excavation cave-in accidents before and after the 1990 revisions to the OSHA excavation regulations/." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

James H. Deatherage, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Owen W. Hale entitled "Evaluation of Excavation Cave-in Accidents Before and After the 1990 Revisions to the OSHA Excavation Regulations." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

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Dr. James H. Deatherage, Major Professor

We have read this thesis and recommend its acceptance:

Kaun C. Chou

Wayne T. Davis

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

EVALUATION OF EXCAVATION CAVE-IN ACCIDENTS BEFORE AND AFTER THE 1990 REVISIONS TO THE OSHA EXCAVATION REGULATIONS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Owen W. Hale
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ABSTRACT

Excavation cave-ins in the construction industry have historically injured and killed workers throughout the nation. In 1990 the Occupational Safety and Health Administration (OSHA) excavation standards were completely revised in response to years of controversy over the ambiguities in the earlier standards.

The primary purpose for this study was to evaluate the historical data for excavation cave-in accidents over the period from 1985 through 1994 and determine if there is evidence that the 1990 revisions to the regulations have had a positive impact on reducing accidents. OSHA data from the Integrated Management Information System (IMIS) were utilized to obtain 540 reports on excavation cave-ins for a ten-year period from 1985 through 1994. These data were evaluated against various criteria to identify factors that influenced any trends in the data. A review of various other resources on cave-in accidents, training, and inspections were consulted to obtain a broader perspective on the causes and prevention of cave-ins.

Most cave-in accidents continued to occur in small companies, usually in relatively shallow trenches while installing pipelines. The primary cause of cave-in accidents continued to be the lack of employing any type of protective system. The incident rate of excavation cave-ins decreased over the ten-year period. The five-year period since the revisions to the regulations in 1990 showed a notable decrease in accident rates compared to the previous five years. Penalties for citations during the latter five years were significantly higher than for the prior five years.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Once or twice each year we hear of another accident in the community in which an excavation cave-in injures or kills one or more construction workers, such as a recent one in the author's community a few days ago that trapped and injured two workers in a pipeline trench (Garland 3). These excavations are often trenches being excavated for water or sewer lines or electrical utilities. The reaction of survivors and witnesses usually sounds familiar: "We had done this plenty of times in the past" or "It was a freak accident" (Towns 12). Cave-ins are actually too common, and predictable, to be described as freak accidents. The costs of lost job time, investigations, and litigation are significant, but the really tragic loss is the emotional, and often financial, suffering experienced by family members, friends, and fellow workers of the victim. Excavation accidents are not unique to recent times; they have been occurring for centuries. However, the increase in excavation work in this century from expanding industry and use of efficient powered equipment has resulted in more workers being exposed to excavation hazards.

Increased knowledge of soils mechanics, testing, and analyses have led to better understanding of how excavation walls fail and improved methods of protecting workers. Proven systems have been developed to prevent cave-ins. The equipment needed to protect workers from trench cave-ins is readily available. Sloping the walls of excavations, restraining them with wood or metal shoring, or use of shields, commonly called "trench boxes" are available and could essentially eliminate cave-in accidents if properly implemented.

Training is another primary defense against excavation cave-in accidents and is relatively new in that it has only been emphasized within the last few years.

Training courses typically strive to educate workers and supervisors to recognize trench hazards and understand how to monitor and control them.

There was a time when there were no regulations for controlling excavation safety. Prior to the existence of the Occupational Safety and Health Administration (OSHA), some states enacted legislation for construction safety, including excavation work. With the passage of the OSHA Act of 1970, new regulations were promulgated and renewed attention was directed at the enforcement of all areas of industrial and construction safety, including excavations. The original excavation regulations were promulgated in 1971. They became controversial as they were difficult to understand and were subject to varying interpretations. This resulted in a completely revised excavation regulation that became effective in 1990.

Knowledge, training, protective methods and equipment, laws, and penalties exist to protect excavation workers. Still, in all areas of the country, excavations continue to cave-in and workers continue to be injured or killed by them. This raises the question of how effective the regulations have been in reducing cave-ins.

The purpose of this thesis was to investigate the regulations affecting excavation safety, review training methods and protective systems for the prevention of cave-ins, and evaluate the impacts of the 1990 revisions to the OSHA excavation regulations. Accident investigation data and other sources were studied to detect any trends related to occurrences of cave-ins, and identify significant factors that influenced cave-in accident rates. Particular emphasis was given to the review of OSHA excavation accident reports for cave-ins for the ten-year period from 1985 through 1994. The data for the five-year periods immediately before and after the 1990 revisions to the regulations were evaluated to determine if the 1990 revisions were effective in reducing the incident rate of excavation cave-ins.

CHAPTER 2

LITERATURE REVIEW

The primary source of information utilized in this study was the OSHA IMIS data base from 1985 through 1994, but other literature concerning excavation cave-ins was also researched. Several OSHA publications were reviewed to obtain information related to excavation regulations, safety, and training.

An OSHA report by Culver, et al (2), that analyzed OSHA data for construction fatalities from 1985 through 1989 contained valuable statistical information on cave-in accidents. An Engineering News Record article by W. Krizan and H. Bradford (6) provided information on union vs. nonunion fatality rates.

Trench safety and training programs were reviewed including Georgia Tech Research Institute (4), M. F. Hein at Auburn University (5), J. L. Mickle at Iowa State University (7), and the Department of Energy's Pacific Northwest Laboratory (15). These provided insight into the structure, methods, and quality of available training.

A report by Thompson and Tanenbaum (11), that surveyed accident data on cave-ins in the mid-1970s, was found in the September 1977 issue of the ASCE Proceedings, Journal of the Construction Division. This report provided excellent information on the causes and frequency rates of cave-in accidents in that time period that was useful for comparative purposes. Another similar report by Suruda, et al (9), provided analysis of cave-in accidents from 1974 to 1986 that was also very beneficial for comparison to the data evaluated in this study.

CHAPTER 3

EXCAVATION REGULATIONS

Prior to OSHA

Excavation accidents no doubt have been occurring for centuries as past civilizations manually excavated for building foundations, canals, and raw materials. Photographs of construction work in the late 1800's and early 1900's document the absence of basic safety equipment and procedures in excavation work of that period. Such practices surely resulted in numerous accidents and fatalities, but about the only information one can obtain must be gleaned from newspaper articles of the time.

Concerns about excavation accidents received official government attention at least as far back as the early 1900's. Anthony Suruda, et al, (9) identified a study that was commissioned by Prime Minister Winston Churchill resulting in the Report of the Committee on Deep Excavations in London in 1912. The committee's report recommended shoring excavation walls with timber, providing egress ladders, and evaluation of soil stability, all elements in current OSHA regulations.

Prior to OSHA, some state governments enacted laws to require safer excavation methods. An example is the Tennessee Code Annotated, Title 53, Chapter 39, that created a Construction Safety Board within the State Department of Labor in 1965 (10). Part 9, Excavations and Shoring, contained elements similar to current OSHA standards. Any excavation over five feet in depth required cave-in protection measures of shoring, shields, or sloping to the angle of repose unless the work was being performed in solid rock. There were precautions about impacts of vibrations from vehicles and the increased risks of excavating in backfilled soils. Ladders were required at least every fifty feet of lateral travel. However, design criteria were somewhat vague, and there were no requirements for design calculations or approvals by a professional engineer.

OSHA Regulations Prior to 1990

The OSHA excavation regulations, 29 CFR 1926, Subpart P - Excavation, Trenching and Shoring (14), were first issued in 1971 to define and enforce national safety standards for excavation work. The regulation included four sections. Section 1926.650 provided general protection requirements. Among other requirements, it called for daily inspections of excavations by a "competent person" and work in the excavation was to cease if there was any evidence of potential cave-ins or slides. However, there was no definition or training mandated to qualify one as a competent person, and it was unclear who was to stop the work if dangerous conditions were observed.

Section 1926.651 provided specific *excavation* requirements, 1926.652 covered specific *trenching* requirements, and 1926.653 gave definitions of terms. Excavations were defined as "any manmade cavity or depression in the earth's surface ...producing unsupported earth conditions by reasons of the excavation." Trenches were defined as "a narrow excavation made below the surface of the ground" and "in general, the depth is greater than the width." These definitions generated arguments due to varying interpretations among contractors and OSHA inspectors. An article by Robert Polumbo (8) in Occupational Health and Safety explained, "Since all trenches are excavations, OSHA held that both sets of specific requirements were enforceable during trenching operations. However, if an excavation was not a trench, the agency held that only the excavation requirements applied. Some contractors had a different opinion. They argued that the trenching requirements applied to trenches and the excavation requirements applied to all other excavations."

Both sections on excavation and trenches contained ambiguous requirements. Excavations were required to be guarded by some protective method if workers would be exposed "to danger from moving ground." How to evaluate the potential for the danger of moving ground was unclear.

If plans at a work site were for the excavation walls to be sloped or shored to provide protection, then listed factors that must be considered were depth of cut, weather conditions, vibration from nearby equipment or traffic, stored materials, blasting, and various other factors. Assuming one considered all the factors, then the only guidance for sloping the excavation was a figure that indicated using a forty-five degree slope for "average soils." No definition or guidance was given for determining if one was working in an "average soil."

A note with the figure directed that "clays, silts, loams, or non-homogenous soils require shoring and bracing." The guidance for shoring was a trench shoring table showing increasing sizes of timbers at closer spacing with increasing trench depths and worsening soil conditions. Soil classifications were described "hard" and "likely to crack" which were subject to different judgments by construction personnel and inspectors. A footnote to the table provided for the alternative of using trench jacks "in lieu of, or in combination with, cross braces." Another footnote stated, "Where desirable, steel sheet piling and bracing of equal strength may be substituted for wood." In attempting to ensure the integrity of shoring systems, the regulations required that they be designed "by a qualified person and meet accepted engineering requirements." "Accepted engineering requirements" were defined as standards required by registered architects or engineers or "other duly licensed or recognized authority." Some contractors argued that due to their years of experience, they were recognized authorities and could design a shoring system. Excavations greater than twenty feet in depth were required to have support systems designed by a "qualified person," but again, without offering a definition or means of determining if a person was qualified.

The note with the figure on sloping further stated that "the presence of ground water requires special treatment." The special treatment for ground water and other conditions such as loose boulders, slide planes, etc., was to flatten the angle of repose. No guidance was provided to determine how much to flatten. Other vague terms describing soil types such as "unstable," "soft," and "hard or compact" were used, but without any guidance on how to determine which soil category was the correct characterization for a given excavation.

All of these ambiguities and differing interpretations of the regulations created controversies and were frustrating to both contractors and OSHA personnel. Eventually OSHA commissioned a study by the National Institute for Standards and Technology (NIST) to evaluate the regulations. The NIST study was conducted from 1976 through 1980, and with input from other studies and data, resulted in revised Subpart P regulations (13) that became effective in 1990. Originally, they were to become effective on January 2, 1990, but were later extended to March 5, 1990, to give contractors more time to educate their employees about the new standards.

OSHA Revisions of 1990

The 1990 revisions updated the entire regulation for excavation, and in the words of one of OSHA's Public Affairs Specialists, Deborah Crawford (1), the revisions were to "simplify many of the existing provisions, add and clarify definitions, eliminate duplicate provisions and ambiguous language, and give employers added flexibility in providing protection for employees." According to Ms. Crawford, OSHA estimated that the revised standards would prevent up to seventy-five fatalities and 3,000 injuries annually.

The revised standards redefined various terms to add clarity, rearranged the structure of the standards, and added new appendices to provide directions for soil classification, sloping, and benching requirements. Pictorial examples of shoring and shielding methods were provided along with tabulated data to assist in selecting shoring timbers and hydraulic shoring.

The disagreements over the original regulations as to whether earth removal at a given job was an excavation or a trench were addressed by not having separate sections for excavations and trenches. The standard now addressed only open excavations, with excavations being defined to include trenches.

"Competent person" was now defined as "one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees." As in the previous standard, there were no specific training requirements for the competent person, but the definition has been interpreted to imply that training in addition to on-the-job experience is necessary to meet the intent of the definition. This remained a debatable issue, but at least some guidance was now provided in selecting the competent person. The OSHA Technical Manual (20) provides some insight into OSHA's intent as it states that the competent person should have "training, experience, and knowledge of soil analysis, use of protective systems, and requirements of 29 CFR Part 1926, Subpart P."

To resolve the previous uncertainty about who was responsible for responding to hazardous situations, the competent person was further defined as one "who has authorization to take prompt corrective measures to eliminate" hazardous conditions. The competent person was still required to make daily inspections, but now the daily inspection requirements were more specific. Inspections were now required prior to the start of work, at any other time the competent person deemed necessary, and they were mandatory after every rainstorm.

The previous ambiguity in soil classification was addressed in the revised standard by the inclusion of Appendix A which classified soils into three types. Soil types were designated as type A, B, or C, in descending order of stability. There were specific characteristics defining each type to assist the competent person in classifying the soil. The revised standard required "at least one visual and at least one manual analysis."

Visual observations of the excavation walls, the excavated material, and the surface adjacent to the excavation were required. Suspicious conditions were identified as moisture content, general soil grain size, tension cracks, layered soils, seeping water, and vibrations from adjacent traffic or construction equipment.

Several simple manual tests that could easily be performed in the field were provided. Plasticity could be evaluated by rolling a thread of soil about one-eight inch diameter by two inches long between one's hands and suspending from one end. Dry strength could be evaluated by observing how easily the soil crumbled under pressure. Compressive strength of soil could be evaluated by the "thumb penetration test" adopted from the American Society for Testing and Materials. This test is self descriptive in that one observes how easily the thumb can penetrate the soil and correlates that to ranges of compressive strength. Pocket penetrometers or handoperated shear-vane instruments were also identified as acceptable methods of making compressive strength evaluations in the field. To assist in classifying cohesive, fissured, or granular material, a practical drying test was described using a one-inch thick by six-inch diameter sample of soil. Instructions were provided on how to characterize the sample, after drying, based on observations for evidence of cracking, and then hand breaking of the sample to gauge its strength.

Obviously, all of these manual tests were subject to interpretation of the person performing the tests. However, considering the absence of any guidance for soil classification in the previous standard, the ease and practicality of these simple field tests in the revised standard represented a significant improvement.

As in earlier versions, the revised standard required that any excavation five feet or more in depth, unless it was entirely in stable rock, had to have a protective system before it could be entered by workers. The protective system could be sloping, shoring, or shields. Alternatively, a system could be designed by a professional engineer. Unique, job specific designed systems by professional engineers appear to be rare, probably because the range of viable designs is already covered in the regulations. Also, the concern with liability is a deterrent to an engineer designing a unique system rather than deferring to the standard OSHA systems. There are some specialty systems such as ground freezing systems that freeze a wall around the excavation area. Such systems are very expensive, and are designed more for protection of structures than personnel, and are not practical or cost effective for the majority of excavations.

Guidance for sloping or benching ("stair stepping") the face of excavations was included in Appendix B. Pictorial examples were provided to show correct methods to slope or bench excavations in each of the three soil types, including layered soils, for varying excavation depths. This provided a “menu” of sketches from which a given excavation could be compared and thus made it much easier to select a safe configuration that could be implemented in the field.

Appendix C was added to provide guidance in building timber shoring. Tabled data were provided that clearly indicated the sizes of all members of shoring systems that should be employed in for each of the three types of soil. Similarly, Appendix D offered an easily understandable method of selecting proper aluminum shoring from a series of sketches and tabled information.

Appendix E provided other approved methods of shoring such as vertical rail shoring with hydraulic, pneumatic, or screw type jacks. Trench shields, commonly called trench boxes, were another available option if they were designed by a professional engineer.

Finally, Appendix F provided simple flow charts to guide one through the entire process of evaluation of the physical conditions of an excavation to the final selection of the proper method of shoring, sloping, or shielding.

State OSHA Programs

OSHA offers encouragement and financial assistance to states for the operation of their own health and safety programs. OSHA will finance up to one-half of a state's budget to operate an approved plan. To be approved, OSHA requires that the state plan must be "at least as effective as" the federal program and provide site inspections, training, and education programs (21). Currently, twenty-three states operate complete state plans, meaning they have jurisdiction over private, and state and local government employees. Two other states have partial programs covering public employees only. After a state has sufficiently proved its ability to independently enforce standards, OSHA will grant "final approval" at which time it relinquishes its authority over the state's program. Among the twenty-five states or territories with their own programs, fourteen have obtained final approval including Alaska, Arizona, Hawaii, Indiana, Iowa, Kentucky, Maryland, Minnesota, South Carolina, Tennessee, Utah, Virgin Islands, Virginia, and Wyoming.

State programs can impose standards beyond those required by the federal program. For example, California requires contractors to obtain a permit before starting any excavation that will exceed five feet in depth. Most states also require contractors to be licensed to assist in monitoring the industry.

CHAPTER 4

EXCAVATION TRAINING

Notable in the regulations, both before and after the 1990 revisions, was the absence of any explicit training requirements for competent persons, workers, or supervisors. However, in OSHA's publication Training Requirements in OSHA Standards and Training Guidelines (22), certain standards are listed as ones that require training. Among those listed as having required training for competent persons are the design of structural ramps used for access or egress from excavations, protection of hazards associated with water accumulation, and the daily inspections. There are no training requirements mentioned for workers or supervisors. Even in the absence of explicitly required training, companies and government entities recognized the need for training and created a market for training on how to avoid cave-ins and in understanding the OSHA standards.

Materials for training courses from private providers, government contractors, Auburn University's Building Science Department, the Georgia Tech Research Institute, and the training materials in the OSHA Technical Manual were reviewed to obtain an overview of the methods and quality of typical training courses. A variety of formats are available, including conventional seminar texts for instructor-led courses, videos, and self-taught courses via the internet.

All of the courses impressed upon the student how quickly a cave-in can occur. They nearly always occur without warning. There is very little probability of outrunning them. Numerous victims have died from asphyxiation from being completely engulfed by cave-ins. Others have died or lost limbs from the crushing pressure of being buried in soil covering only part of their bodies. All of the training courses noted that soil weighs approximately one hundred pounds per cubic foot and thus it takes only a few cubic feet of it from a cave-in to trap and immobilize a worker. The tragic statistics and some news coverage of actual accidents were usually presented to further gain the student's attention. Convincing the average worker of the seriousness of cave-in risks appeared to be the most important element in effective training. If all excavation workers understood how quickly a cave-in could kill, and how often they have, certainly they would have more incentive for learning how to recognize and avoid excavation hazards.

Each of the courses also covered the mechanics of how a cave-in occurs, a review of the OSHA standards, training on how to detect dangerous conditions, and the types of acceptable sloping, shoring, and shields available to protect workers. All of the courses appeared to be very adequate in providing all of the pertinent information necessary for a worker to become aware of excavation dangers and the methods available to avoid injury or death from a cave-in.

A detriment to widespread training being obtained throughout the industry may be the direct cost for the training and cost of time away from the job. Fees for training sessions typically cost from $100 to $200 per student for courses led by an instructor, and about $500 for a video taped course that can be presented to groups. Eight hours of training was typical for most courses. Also, the location of available courses often requires additional time for workers to travel to a metropolitan area to receive training. These obstacles are easier for large companies to overcome, but as will be discussed in more detail later, the majority of accidents occur on the jobs of very small companies. The greatest potential for reducing the frequency rates of cave-ins exists in convincing the owners and workers of small companies to learn about cave-in hazards and to implement methods of preventing them.

CHAPTER 5

THE OSHA ACCIDENT REPORTING SYSTEM

OSHA's Integrated Management Information System

The OSHA Integrated Management Information System (IMIS) was implemented in 1984 to establish a national data base for accident investigations. This data base receives information from both federal and state OSHA investigations and compiles comprehensive information on each accident. An example of a typical IMIS report is provided in Figure 5-1.

The company's name is provided, and is followed by the address, city, and state where the accident occurred. The standard industrial classification (SIC), and union affiliation of the company are also listed. The dates of the accident and the investigation starting and closing dates are provided.

A list of OSHA standards cited for violations is given with a classification for each violation as either "willful", "serious", "repeat", "unclassified", or "other." Each violation is also assigned a gravity rating from 1 to 10, representing respectively from lowest to highest the severity of the violation. The classification and gravity rating are used as some of the determinants in setting the amount of penalties. Initial penalties, and if reduced, the current penalties are listed for each violation.

Each report includes a narrative of the accident with details of the activities underway at the time of the accident and the physical conditions of the site. For excavation accidents, the narrative typically provides information on the dimensions and geometry of the excavation, the type of protective systems being used, other conditions contributing to the cave-in, a discussion of what caused the failure, and how the victim was injured or killed.

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                         OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
               ACCIDENT INSPECTIONS WITH 1926.650, 1926.651 OR 1926.652 VIOLATIONS CITED        PAGE: 536
                                   01/01/85 THROUGH 09/08/95

ESTABLISHMENT INSPECTED        REPORT ID ACTIVITY# CSHO      SIC1/SIC2  SUMMRS
ADDRESS                        OPEN DATE INSP TYPE CATEGORY  #REMITIED  EMPESTAB
CITY                STATE ZIP  CLOSECONF OPT REPT# SCOPE     OWNERSHIP  EMPINSP    LWDI
COUNTY (NAME/CODE)             CASE CLSD PREV ACT  UNION     CLASS      EMPCNTRL
                                         RELTD ACT
                                            OR                  ABT                                 INITIAL   CURRENT    C SETTLM-T HZ/D
                                 CITATION   RE ISSUANCE  ABATE  CMP  INITIAL   CURRENT    F-T-A     F-T-A      N DISPOS-N SUBS
            STANDARD             TYP IDENT  VC   DATE     DATE  CDE  PENALTY   PENALTY    PENALTY   PENALTY    T /FINORDT CODE

###############################
HURST PLUMBING                 0728900   100888411 B1629-C  1711        37.0
5120 SHERMAN STREET             8/31/89  UN-FATCAT SAFETY     2300         2
Lincoln              NE 68506   9/01/89  991/89    COMPREH  PRIV SEC       2
Lancaster            109       11/07/89   (NONE)   NONUNION SPG-CONST      3  (PENALTIES PAID)
                                         A360383400         N.TRENCH
      OPT-INFO. N-20 CORR ACTION

            1926.021 B02         S 01001  09  9/28/89 10/03/89 X   1000      1000       0         0
            1926.059 E01         S 01002A 03  9/28/89 10/30/89 X    300       300       0         0
            1926.059 G01         S 01002B     9/28/89 10/30/89 X      0         0       0         0
            1926.059 H           S 01002C     9/28/89 10/30/89 X      0         0       0         0
            1926.652 E           S 01003A 10A 9/28/89 10/03/89 X   1000      1000       0         0
            1926.651 I01         S 01003B  A  9/28/89 10/01/89 X      0         0       0         0
            1903.002 A01         O 02001      9/28/89 10/03/89 X      0         0       0         0
                                               TOTAL PENALTIES     2300      2300       0         0

                                      ####    ACCIDENT DATA    ####

  SUMMARY #  14421580 DATE, 8-31-89 KEYWDS,                 DESCRIP,CAUGHT IN
  ABSTRACT, EMPLOYEES WERE OPERATING A BORING MACHINE UNDER THE STREET ABOUT 8 FEET DEEP WHEN THE WEST BANK OF THE TRENCH CAVE IN EM
            PLOYEE #1 WAS COVERED UP WITH DIRT AND EMPLOYEE #2 WAS STRUCK BY THE MOVING DIRT HE MANAGED TO CLIMBE OUT OF THE TRENCH
            AND SUMMONS HELP. HE SUFFERED A BROKEN RIGHT COLLAR BONE.                                  ---(ABSTRACT NOT REVIEWED)

               VICTIM, 001  ROGER BLACHA          AGE, 38     SEX, M  OCCUP, Not reported
                       DISPOSITION , FATALITY                  EVENT-TYPE  , STRUCK BY
                       INJ NATURE  , ASPHYXIA                  ENVIR FACTOR, SQUEEZE POINT ACTION
                       INJ SOURCE  , DIRT/SAND/STONE           HUMAN FACTOR, MISJUDGMENT, HAZ. SITUATION
                       PART-OF-BODY, MULTIPLE                  HAZ SUBSTNCE, NO SUBSTANCE IMPLICATED

               VICTIM, 002                        AGE, 33     SEX, M  OCCUP, Not reported
                       DISPOSITION , NONHOSPITALIZED INJURY    EVENT-TYPE  , STRUCK BY
                       INJ NATURE  , FRACTURE                  ENVIR FACTOR, SQUEEZE POINT ACTION
                       INJ SOURCE  , DIRT/SAND/STONE           HUMAN FACTOR, MISJUDGMENT, HAZ. SITUATION
                       PART-OF-BODY, SHOULDER                  HAZ SUBSTNCE, NO SUBSTANCE IMPLICATED


QY50943A     95/09/13- 8.39 PM     MLS         OWEN H. HALE                     OFFICE OF MANAGEMENT DATA SYSTEMS
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Figure 5-1. Typical IMIS Report

Finally, details are given for the victim(s) including their age, sex, nature of their injuries, and whether the accident resulted in fatal or nonfatal injuries. Notations of other human or environmental factors that contributed to the accident are also listed.

IMIS Data Base

A primary source for this study was the IMIS computerized data base (16) obtained from OSHA's Office of Management Data Systems. The data base represents a compilation of all accident reports from January 1, 1985, through December 31, 1994, that contained citations for any of the three excavation standards 1926.650, 1926.651, or 1926.652. Some reports covered accidents other than cave-ins, but appeared in the data base because the company received one or more excavation citations in addition to those directly related to the accident being investigated. Those reports were excluded from the data utilized in this study which concentrated on excavation cave-ins. There were also some incomplete reports in the data base that were excluded from this study as it could not be determined if those reports were for cave-in accidents.

It should be noted that the IMIS data base does not cover every cave-in as it is known that many accidents are not reported, with some estimates projecting as high as fifty percent unreported. Also, sometimes reports are improperly coded under categories such as "caught in, under, or between" and thus are not included in the excavation accident data base. Also, OSHA does not attempt to investigate all cave-in accidents. There are approximately 2100 inspectors covering the U. S. and its territories which is not enough to inspect every accident, so guidelines are set on whether an investigation is mandatory or optional for a given accident. For example, Tennessee requires an accident investigation if there is a fatality or at least three victims requiring hospitalization.

CHAPTER 6

EVALUATION OF CAVE-IN ACCIDENT DATA

A total of 540 complete reports were found in the IMIS which provided the data base for this study. These reports provided information on 414 fatalities and 273 injuries over the ten-year period from 1985 through 1994. This data base made it feasible to detect trends on cave-in accidents based on various selected criteria for the ten-year period, which included the five years before, and five after, the 1990 revisions to the excavation regulations. Foremost, the data indicated a positive change since 1990 with fatalities down from the prior five years as indicated in Figure 6-1. There was an annual average of fifty-four fatalities during 1985-1989, and the annual average decreased to twenty-eight during the 1990-1994 period. In comparison, a review of the OSHA database for 1984 through 1986 by Suruda, et al, (9) reported 192 fatalities, or an annual average of sixty-four. A similar review of the OSHA data base for a three-year period in the mid-70's by Thompson and Tanenbaum (11) reported an annual average of ninety-nine fatalities. The 1985-1994 IMIS data base was also reviewed relative to various selected criteria to identify factors that may have influenced cave-in incidence rates. These criteria are identified and discussed in the following sections.

Trench Depth

Trench depths were provided in 84% of the accident reports in the IMIS data base for the ten year period from 1985 through 1994. The reported depths ranged from forty feet to a minimum of 2.5 feet. The mean depth was 10.7 feet for the ten-year period with very little variation from year to year. This was fairly consistent with mean depth of 11.4 feet as reported by Suruda, et al, (9) in a study of OSHA cave-in

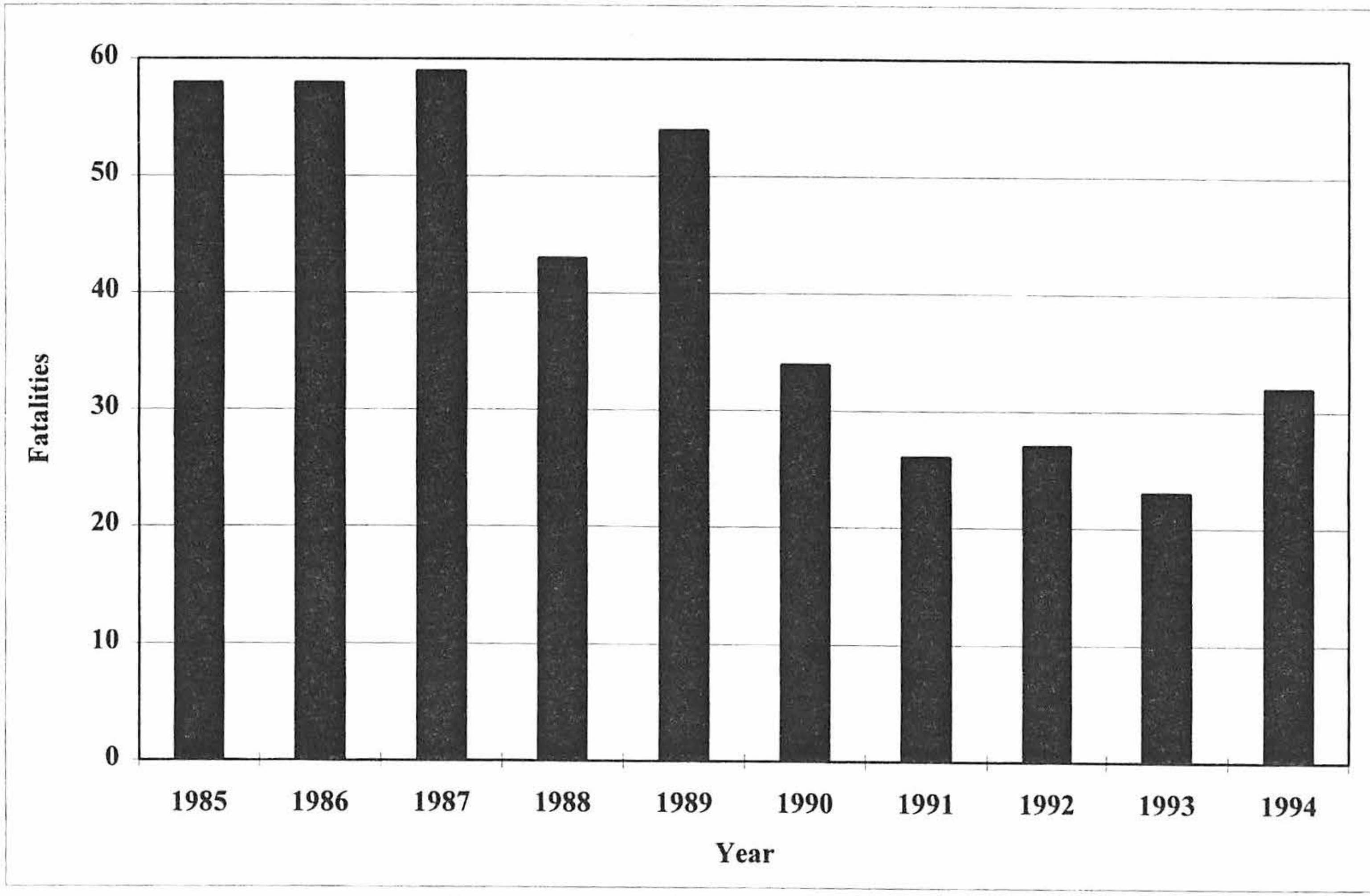

Figure 6-1. Summary of Cave-In Fatalities

fatalities from 1974 to 1986. Thompson and Tanenbaum reported that 87% of cave-ins were in trenches less than twenty feet deep, the depth at which an engineered protection system is required. The 1985-1994 data contained 96% in that depth range.

It was notable in the 1985-1994 data that relatively shallow trenches can be fatal. There were twenty-one fatalities in trenches that were five feet or less in depth, representing 5% of the total 414 fatalities. Fourteen of these fatalities were in trenches of two and one-half to five feet deep and were a result of the excavation wall failing under the load of an adjacent masonry wall or foundation that fell into the trench. The other seven of the twenty-one fatalities were in trenches five feet deep that failed under their own weight and then buried or crushed the worker. The Suruda study found that 2% of deaths occurred in excavations under five feet deep. This percentage change in the later data is possibly because the hazards in the deeper excavations are more readily recognized due to publicity and training. Also, under the penalty structure, penalties may be less severe in shallow excavations. This could be a reason for some contractors to take chances in shallow, but still dangerous, excavations which would account for the increased percentage of accidents in them. Cave-ins in trenches deeper than five feet were nearly always a result of the excavation wall or slope failing under its own weight because it was not properly shored or sloped.

Protective Systems

Most of the accident reports in the 1985-1994 data base identified the causes for the cave-ins. Essentially all of the accidents were caused by failure due to the lack of, or improper use of, a protective system. Only thirty-eight of the accident reports indicated some method of sloping was employed, and they were almost always noted as being too steep, or the description of the physical dimensions of the excavation made it clear that they were out of compliance. Shoring was noted as being used in only eight of the reports and usually it was stated that it was improperly built or the workers were injured while attempting to install or remove it. There were no cases where the investigation indicated that a slope or shoring which had been constructed in apparent compliance with the regulations had failed. As one would expect, the Suruda study and the Thompson and Tanenbaum study also found lack of adequate protective systems as being the predominant cause of cave-ins.

Trench boxes were noted as having been used in twenty-four of the reports in the 1985-1994 period. However, there was almost always evidence noted of the misuse of the box. Most often, workers were injured or killed by working outside the trench box and placing themselves in the path of a cave-in. A couple of cases resulted from an excavation wall or slope falling in over the top of a trench box that was not of adequate height. One case resulted from the end wall of a trench caving in and engulfing workers through the open end of the trench box. Two other cave-in reports noted that a trench box was at the site, but was not being used in the trench.

Standards Most Frequently Cited

All of the violations cited in each accident were listed in the investigative report by subsection and paragraph corresponding to the specific standard violated. An evaluation of all citations for each standard was performed for this study and then reviewed to determine which standards were most frequently violated and if there were differences in the frequencies or types of violations before and after the 1990 revisions to the regulations. The 1990 revisions completely changed the organization of the excavation standards so that the subsection and paragraph numbers no longer corresponded. Thus, to review and compare the types of violations occurring in the five year periods before and after 1990, one must look at the description of the violation and not compare the identification numbers. Table 6-1 summarizes the most frequent violations for each of the five year periods studied.

The analysis showed that the most cited violation consistently throughout the ten year period was for lack of protective systems in excavations greater than five feet deep, representing 24% of the violations for 1985-1989, and 26% for 1990-1994. The regulations permit sloping, shoring, or trench boxes, but they all have disadvantages that discourage contractors from using them. Sloping requires substantially more excavation time, and often restrictions such as adjacent roads or property lines make sloping impractical. Shoring is very labor intensive to install and remove and greatly impedes accessibility to work in the excavation due to the horizontal braces passing through the work area. Trench boxes are usually the fastest means to provide protection, but they also impede work due to the horizontal braces or jacks spanning the work area. Boxes are also either expensive to maintain enough of them to simultaneously protect a length of trench or else too laborious to move one box, often back and forth, to follow the various stages of work. Some contractors continued to risk their lives and those of their workers by trying to save the time and expense required for adequate cave-in protection.

The next most cited violation in the 1990-1994 period was the requirement for daily inspections by a competent person. It accounted for 21% of the violations for the period, but only for 6% of the citations in the 1985-1989 period. The increase in citings for lack of daily inspections likely reflected enforcement of the emphasis in the revised standard on the responsibilities of the competent person and the importance of his (her) control over the excavation activities.

Table 6-1. CFR Sections Most Frequently Cited in Cave-in Accidents

Standard Violated	CFR Sect. Cited 1985-1989	% of Citations 1985-1989	CFR Sect. Cited 1990-1994	% of Citations 1990-1994
Provide protective system for excavations >5' deep	652(b), 652(c)	34	652(a),(b),(c)	29
Provide egress within 25' if excavation > 4' deep	652(h)	16	651(c)(2)	12
Place spoils at least 2' back from edge of excavation	651(i)(1)	12	651(j)(2)	11
Wear personal protective equipment (hard hats, etc.)	650(e)	7	NA*	NA*
Support previously disburbed soil or for vibrations	652(e)	7	Part of 652(b),(c)	3
Daily inspections by competent person	650(i)	6	651(k)(1)	21
Other violations (45 others cited)		18.		24

* Personal protective equipment (PPE) requirements not included in 1990 revisions. PPE covered in Subpart E of regulations.

Industry Type

Figure 6-2 summarizes the specific industries most often responsible for cave-in accidents, and the results were not surprising. By tabulating the Standard Industrial Classification (SIC) listings from the accident reports, the water, sewer, and pipeline contractors (SIC 1623) were identified as most often involved, representing 58% of all cave-ins during 1985-1989, and 43% during 1990-1994. This did not appear abnormally high considering that the majority of the linear feet of trenching work was probably done by small pipeline contractors. Similar results were reported by Suruda indicating that 60% of all trenching citations from 1973 to 1986 involved sewer and pipeline firms. Thompson and Tanenbaum also reported that a majority of the accidents reviewed in their study involved sewer firms.

Following in second place for the 1985-1989 and 1990-1994 periods were plumbing contractors (SIC 1711) at 11% and 16%, respectively. The excavation and foundation contractors group (SIC 1794) was third at 11% and 9%, respectively for the same periods.

Federal and local government work crews were responsible for only 3% and 4% of the accidents in the two periods, respectively. The balance of accidents were accountable to smaller numbers of occurrences among the twenty-three other SIC construction classifications.

Company Size

Small companies of less than ten employees were responsible for the majority of all cave-ins in the 1985-1989 period, when they accounted for 251 accidents, representing 72% of the total for the period. For 1990-1994, they were involved in 140 accidents, which was less in absolute terms, but still accounted for 73% of the total.

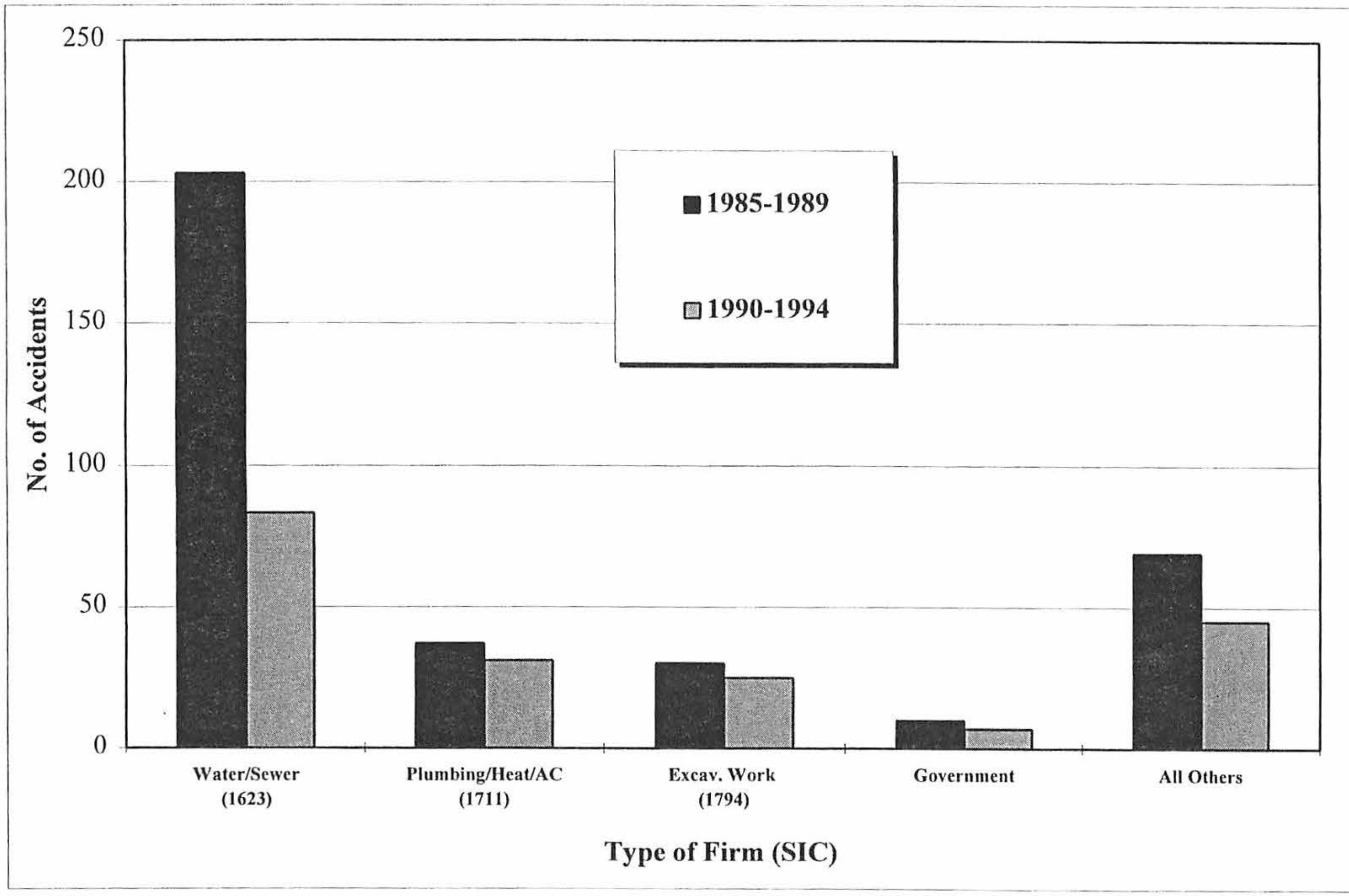

Figure 6-2. Firms Most Frequently Responsible for Cave-Ins

Suruda investigated this for the three years 1984 to 1986 and found 36% of deaths in excavations were attributable to firms of less than eleven employees. An explanation for the increase in recent years may simply be that a larger percentage of excavation work was now being done by the smaller firms. Also, it may be because these smaller firms were the least able financially to obtain training, and to buy and install protective systems. Figure 6-3 compares the frequency of accidents by various company sizes for the two time periods.

Union vs. Nonunion

This study found that for cave-in accidents, the jobs classified as union had a proportionately lower rate of accidents than nonunion. The national union work force accounted for an average of 21% of the total work force throughout 1985-1994, but accounted for an average of only 14% of cave-in accidents. Figure 6-4 shows the comparison of percentage of union and nonunion related cave-in accidents for each of the ten years. It is recognized that this proportionately lower union rate may be due to the fact that most cave-ins occurred on jobs run by very small companies, and a greater percentage of them were likely to be nonunion if compared to the national work force.

The performance of union versus nonunion contractors in excavation safety has been a controversial issue. A 1990 OSHA report by Culver, et al (2), on the data base of fatalities in all industries from 1985 through 1989 showed that the national union work force accounted for about 22% of the work force throughout the period but, on average, about 28% of the annual fatalities. Another report by Krizan and Bradford (6) for the period of 1985 through 1993, showed similar results with the national union work force representing about 21% of all workers, but accounting for 27% of all fatalities.

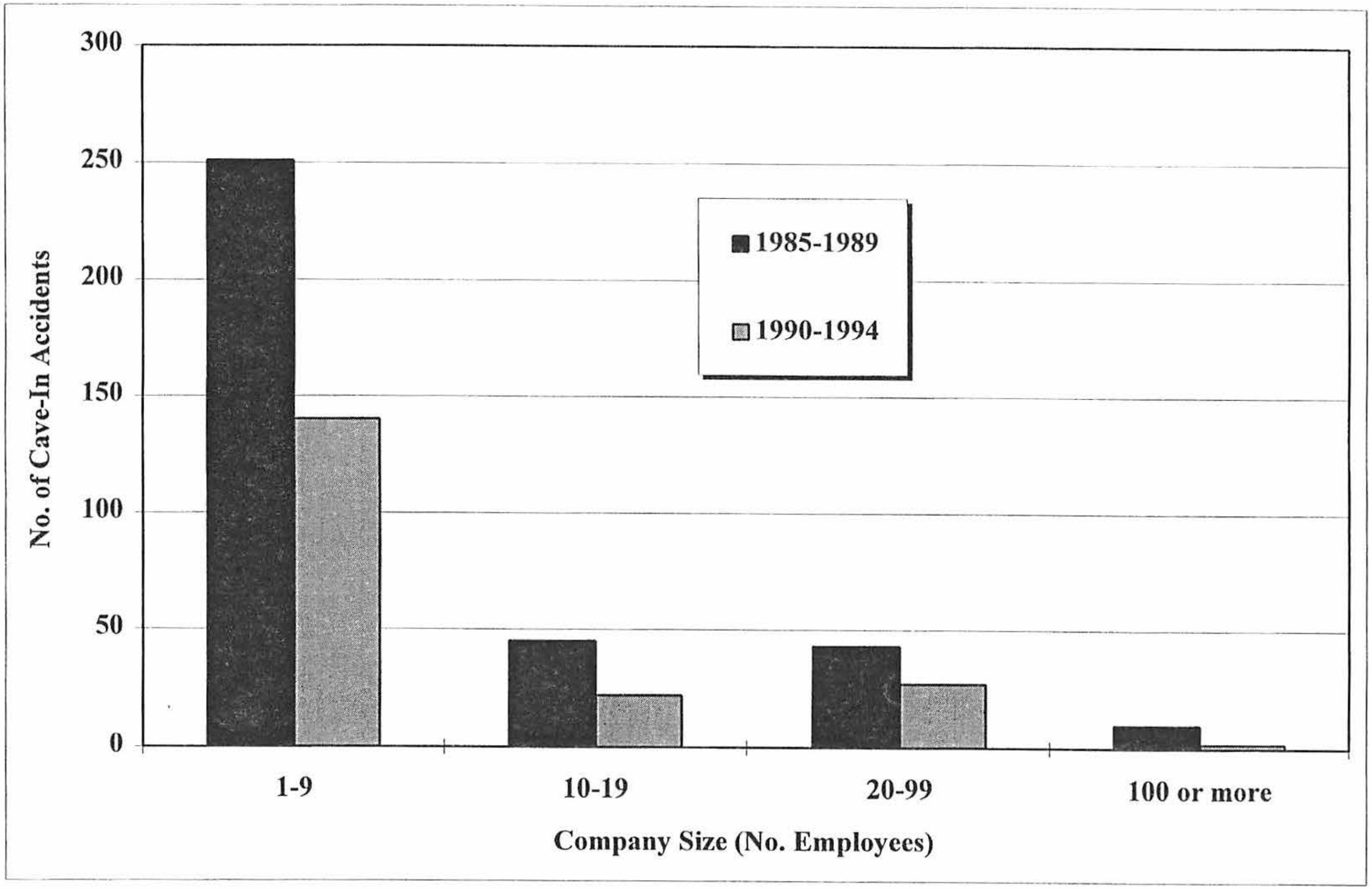

Figure 6-3. Comparison of Cave-In Accidents vs. Company Size

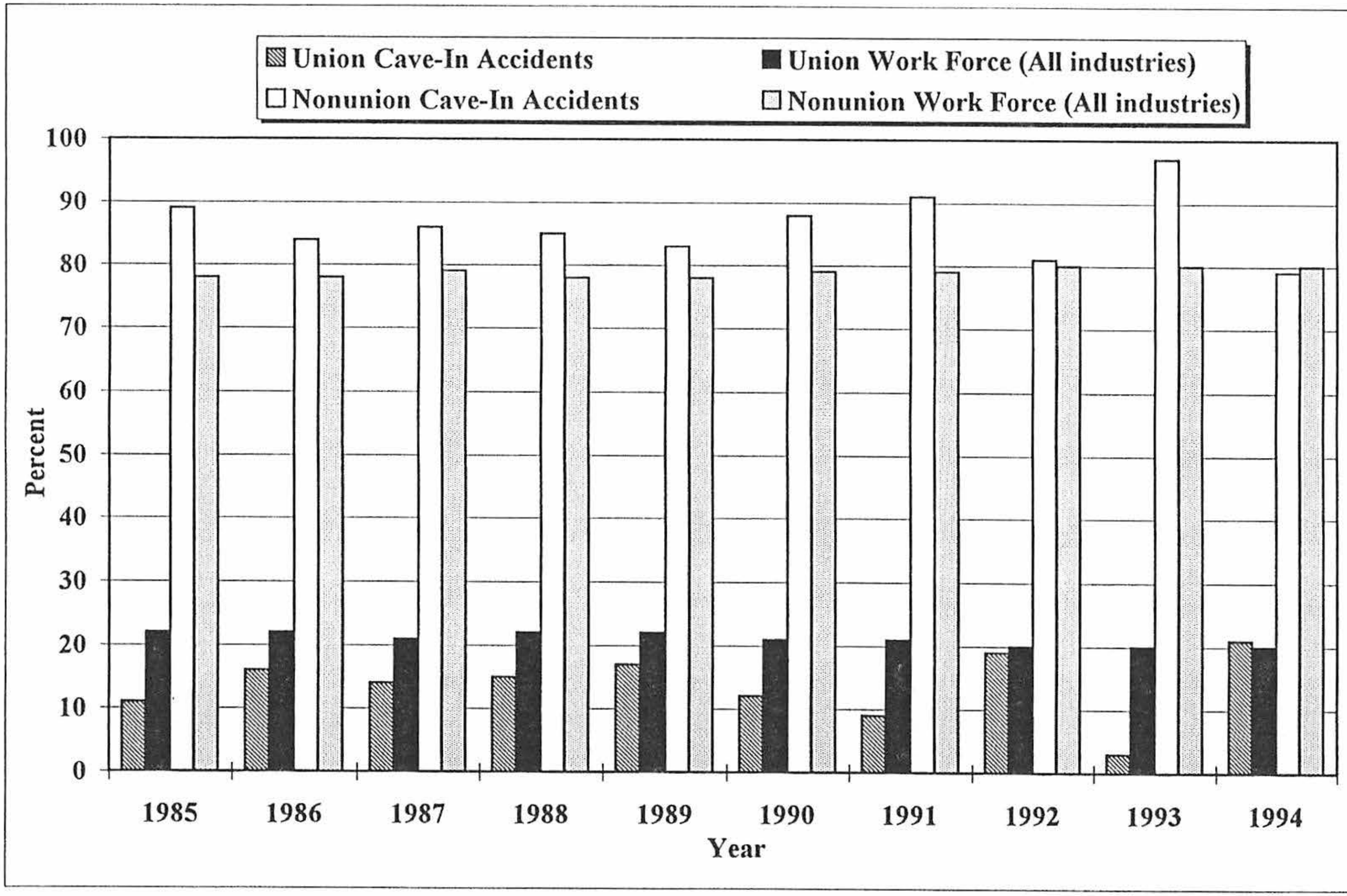

Figure 6-4. Comparison of Union and Nonunion Cave-Ins vs.Work Forces

In fairness to the unions, it should be noted that the OSHA system seemed to bias the accountability for accidents toward unions. If any one worker at an accident site was a union worker, then the accident was recorded in the investigative report as a union job. Also, the unions argued that independent contractors' accidents are less likely to show up on OSHA records and that it would be more accurate to compare fatality rates to man-hours worked rather than to size of work force.

Regardless of the controversies, it was encouraging to note that the total number of cave-in accidents had declined by about 50% for both union and nonunion jobs. The number of cave-in accidents on union-designated jobs dropped from an average of almost ten per year during 1985-1989 to less than five per year during 1990-1994. For nonunion jobs in the same periods, it dropped from sixty to thirty-three per year.

Region

OSHA, like other federal agencies, is organized into ten geographical regions designated by Roman numerals I through X. Table 6-2 provides a list of the states and territories comprising each OSHA region.

This study reviewed the accident data for each region, comparing the number of fatalities for the two time periods 1985-1989 and 1990-1994 as shown in Figure 6-5. Region IV, a large region that accounted for a large volume of construction work, led the regions in 1985-1989 with seventy fatalities, or 26% of the total 272 fatalities reported. Region IV also reported the most during 1990-1994 with thirty-nine fatalities, or 27% of the total 142 fatalities. As might be expected, Region X covering the less densely populated areas of Alaska, Idaho, Oregon, and Washington had the fewest fatalities.

Table 6-2. States and Territories in OSHA Regions

Region	States and Territories
I	CT*, MA, ME, NH, RI,VT*
II	NJ, NY*, PR, VI*
III	DC, DE, MD*, PA, VA*, WV
IV	AL, FL, GA, KY*, MS, NC*, SC*, TN*
V	IL, IN*, MI*, MN*, OH, WI
VI	AR, LA, NM*, OK, TX
VII	IA*, KS, MO, NE
VIII	CO, MT, ND, SD, UT*, WY*
IX	American Samoa, AZ*, CA*, Guam, HI*, NV*, Pacific Trust Territories
X	AK*, ID, OR*, WA*
	* Indicates states/territories operating approved plans; CT and NY cover public employees only.

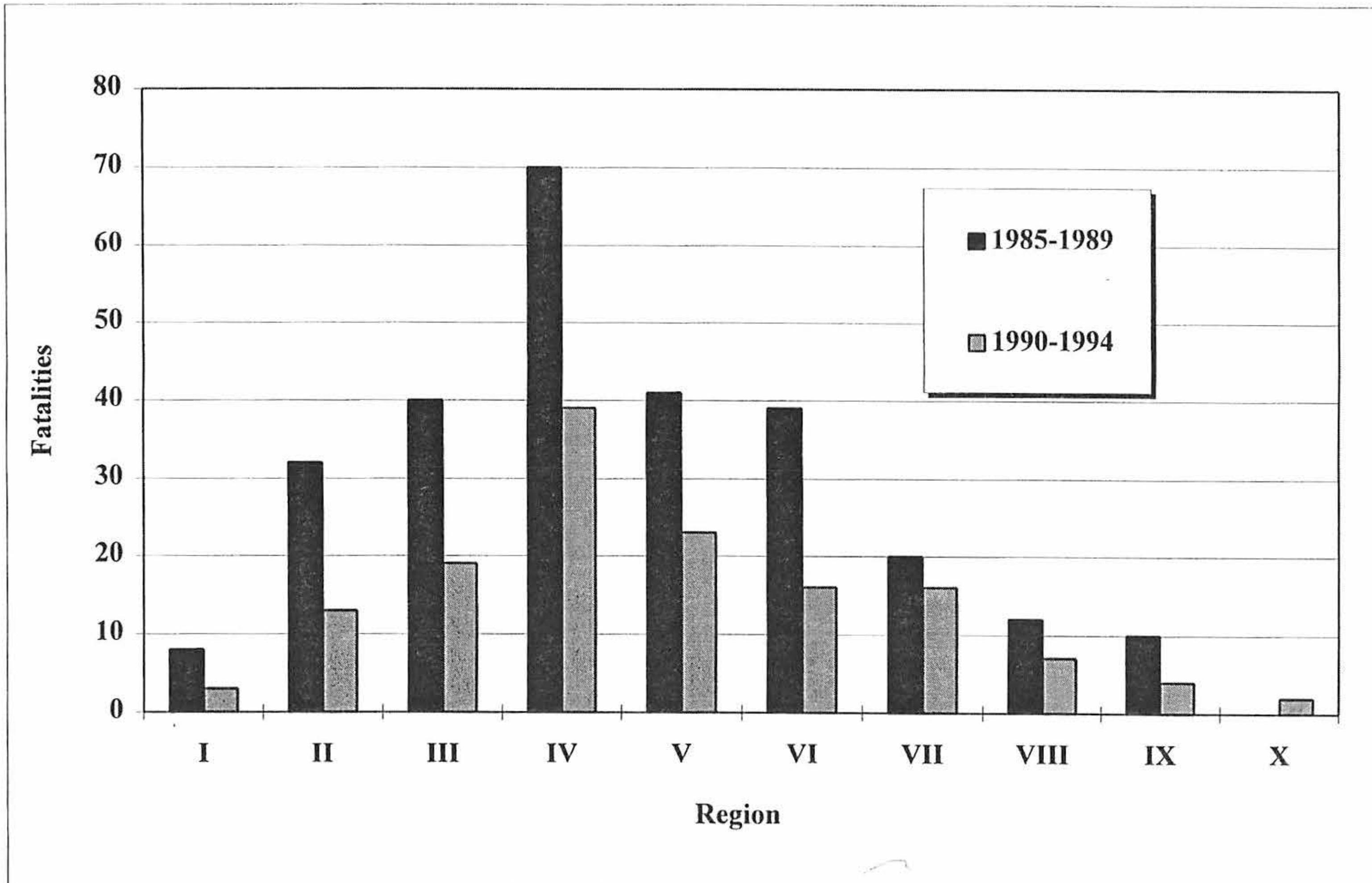

Figure 6-5. Summary of Cave-In Fatalities by Region

The amount of excavation work performed in each region will affect the number of fatalities incurred, and must be considered when comparing fatality rates of the regions. For example, Region IV reported the most fatalities, but it also accounted for a much larger volume of construction work than the other regions. To compensate for the variations, an assumption was made that the volume of excavation work in each region is proportional to the total construction work force employed in the region. Then to normalize the data, each region's number of fatalities was divided by the average work force employed in the region during the two time periods considered. Figure 6-6 depicts the normalized results for each region and shows that Regions VII and VIII incurred the highest rates of fatalities with approximately 9.9 and 8.4 cave-in fatalities, respectively, per 100,000 construction workers in 1985-1989 and 7.3 and 4.3, respectively, in 1990-1994. Region IV was in third place in the normalized evaluation, after accounting for it having the largest average annual construction work force among the regions (999,000 workers during 1985-1989, and 942,000 workers during 1990-1994). Region X results showed it to have the lowest fatality rate among the regions, and it also had the smallest average construction work force (156,000 workers during 1985-1989 and 207,000 workers during 1990-1994).

It is encouraging that Figures 6-5 and 6-6 both depict a positive trend in all areas, except Region X, with the fatality rates being consistently down, in most cases by approximately 50%. Region X increased from no fatalities during 1985-1989 to having two fatalities during 1990-1994, thus causing its rate to increase significantly, although the absolute number of fatalities was very small.

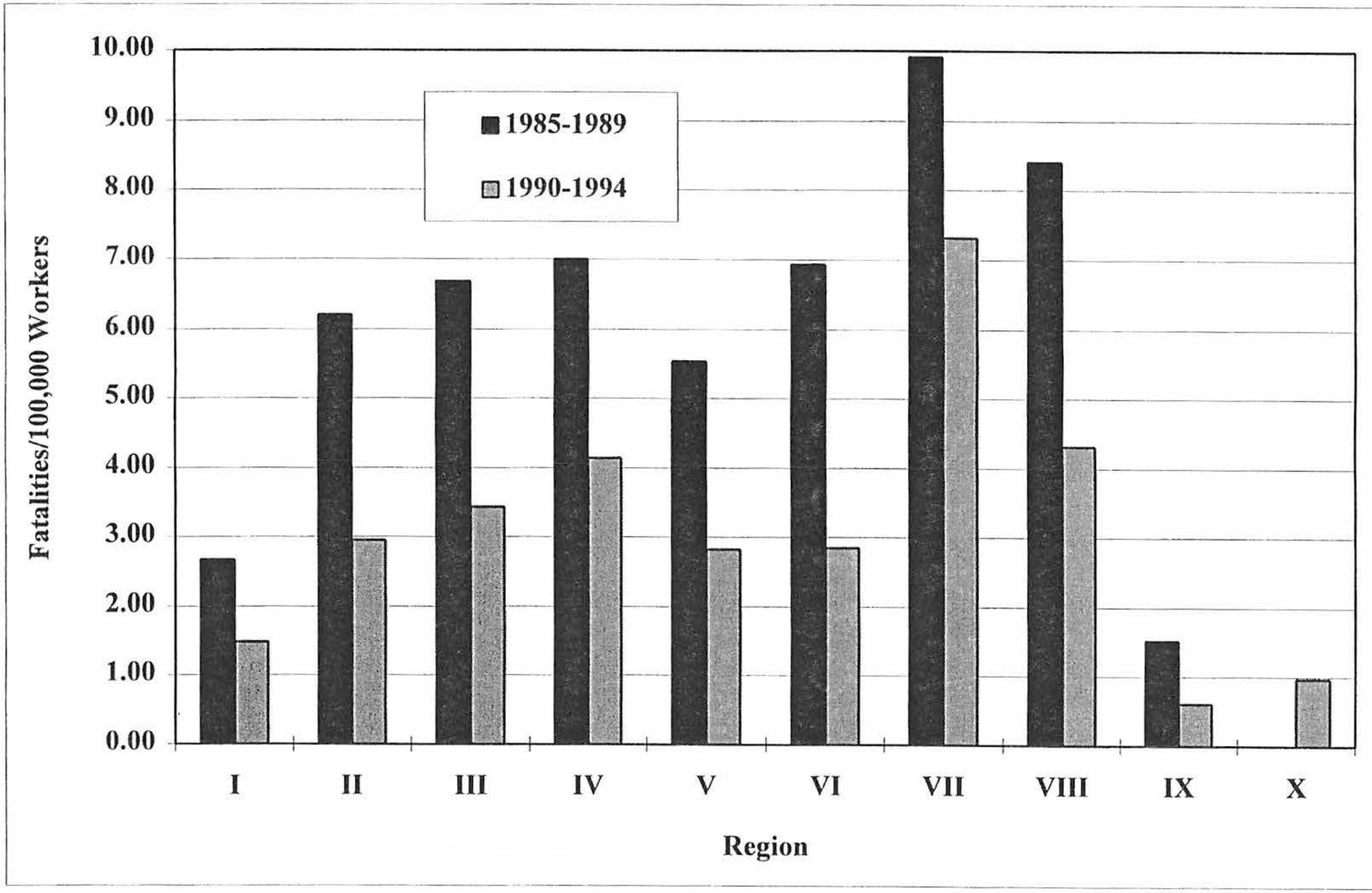

Figure 6-6. Cave-In Fatalities per Region (Normalized)

Penalties

One very notable trend in the data was the increase in penalties, particularly in comparing the 1990-1994 period to the prior five-year period. The average penalty in the 1985-1989 period was $2,723 but for the 1990-1994 period it jumped to $12,390. The range of penalties during 1985-1989 was from none up to $62,000 and for 1990-1994 the range was from none up to $497,000 (an initial penalty for a case that was still open and likely to be reduced as discussed below).

Congress passed a law effective in November, 1990, that set new minimum mandatory penalties for willful violations, and increased the maximum limits of fines seven-fold (17). The penalty assessment process remained as it had been, weighing factors such as the gravity, or seriousness, of an accident along with the size, good faith efforts, and history of the company to apply graded reductions to the maximum initial penalty for a given accident. Small companies with up to twenty-five employees qualified for 60% reductions, while companies larger than 250 employees received no reduction due to company size. Companies judged to have made good faith efforts to provide a safe workplace received up to an additional 25% reduction, and without any repeat violations in the past three years, an additional 10%. Thus it was possible for a small company to pay only 5% of the maximum penalties. The IMIS data base contained examples of cases where all penalties were waived, as were almost always the case for local, state, or federal government agency accidents.

This new law increased the maximum penalty for each willful or repeat violation to $70,000. The IMIS data base contained an average of six violations cited per accident during 1990-1994, so the new penalty system sometimes resulted in huge fines. There were eight accidents that were fined in excess of $100,000 each between 1991 and 1994. The largest one assessed, and not yet closed, was against an Oregon company for $497,600 for a fatal accident in December, 1994, with three serious and seven willful violations. The company was listed as having only two employees with no repeat violations indicated, so the fine was likely to be reduced at least 70% based on the graded penalty system. Still, 30% of the initial penalty is over $149,000 which is a huge fine for most two-person companies. Six of these eight cases were still open and under protest from the companies, so final penalties were likely to be reduced. The largest fine listed in the data base as having been paid was for $115,000 in 1992 against a Kansas company of thirty employees for a fatality and a nonfatal injury.

A chart showing the history of average penalties per accident for the ten-year period is shown in Figure 6-7. To prevent the huge penalties in the contested, and still open, cases mentioned above from skewing the data, this study reviewed each one and factored in the reductions from the initial penalty for company size and absence of repeat violations that are all but certain to be applied. It is believed that this approach resulted in a more accurate estimate of the most likely final penalties for comparison to previous years.

Several factors may have concurrently influenced the downward trend in cave-in fatalities, and certainly increasing penalties contributed. A curve showing the declining numbers of cave-in fatalities is also included in Figure 6.7. The fatality rate for this chart was normalized by determining the frequency of cave-in fatalities per million construction workers in the national work force for each year. The national construction work force was obtained from the National Bureau of Statistics. It fluctuated from approximately four and one-half to five million workers per year during the ten-year period studied. The comparison of the increasing penalties and the corresponding decrease in fatality rates indicated a correlation between the two.

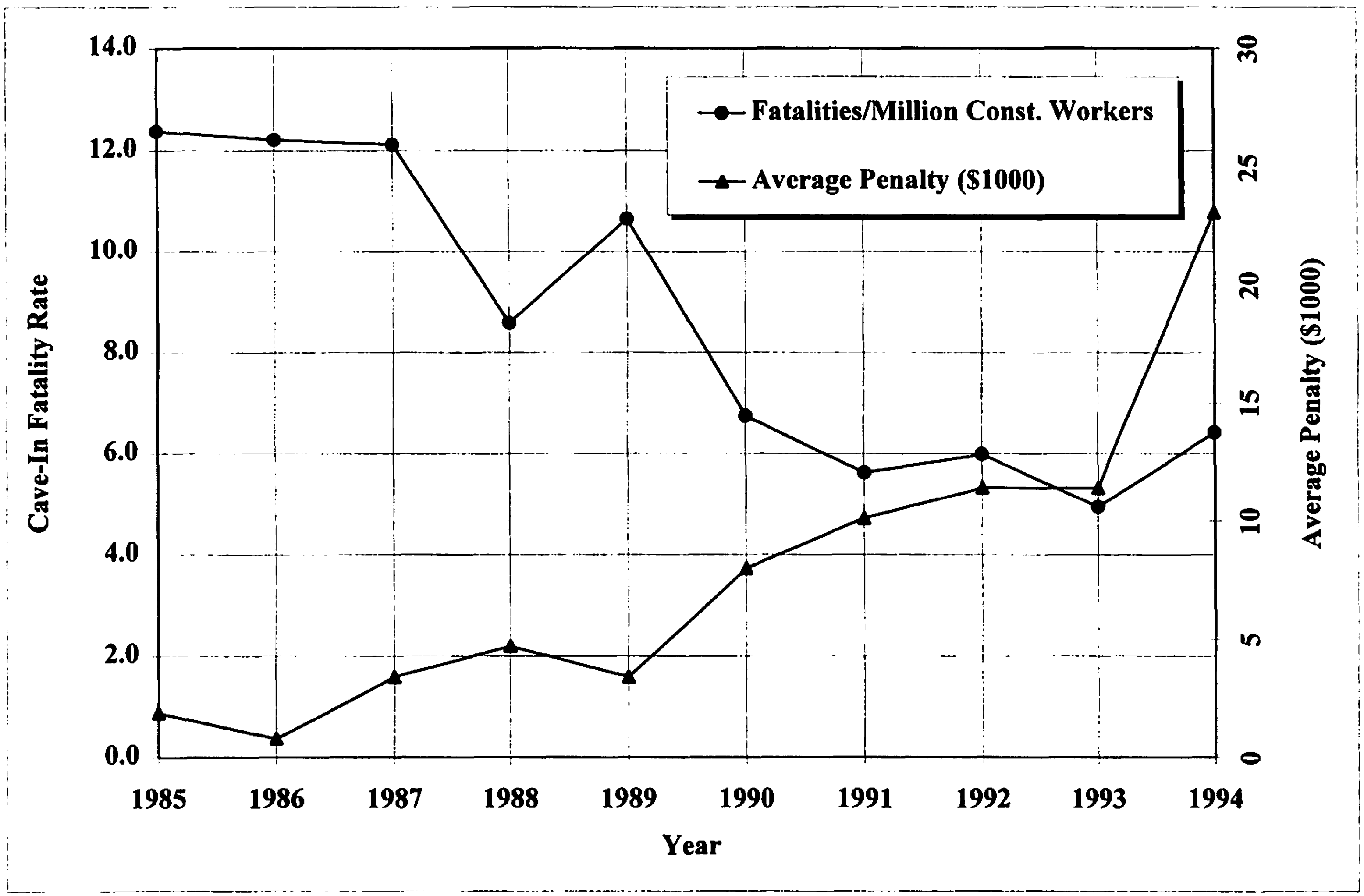

Figure 6-7. Comparison of Average Penalties vs. Fatalities

Other Factors

The sex of accident victims was noted in all of the 540 reports studied. All of the victims were male. The excavation industry historically has been comprised almost entirely of male workers, so this finding was not surprising.

Age was another factor noted in the data base. The average age for excavation workers was thirty-four years old, approximately the same as the construction industry in general. This was approximately the same as the Suruda report which found the average age to be thirty-five years old. The range of ages of victims was from fifteen to sixty-eight years.

One finding of concern was the number of accidents in which the victims were very young. There were five separate accidents in Arizona and Texas in 1985 whose victims were only sixteen years old, three of them were fatalities of young men with Hispanic names. Two more sixteen year olds were killed in Iowa in cave-ins in 1988 and 1991. Also in 1991, cave-ins injured a fifteen year old boy in Virginia and a sixteen year old in Utah. According to the accident reports, all of these young victims were hired workers, except the fifteen year old who went into a trench to talk to his older cousin who was employed by the trenching contractor. Hopefully, the absence of any young victims in the 1992-1994 data was an indication that contractors were refraining from working young people in excavations, or at least they were adequately training and protecting them.

CHAPTER 7

CONCLUSION

Evaluation of the IMIS data base for cave-in accidents from 1985 through 1994 indicated that there had been a notable decrease in cave-in accident and fatality rates subsequent to the 1990 revisions to the OSHA excavation regulations. The corresponding, and substantial, increase in penalties for citations assessed to contractors since 1990 appeared to have influenced this trend. The increased requirements for qualifying competent persons, and more emphasis on training of excavation workers, likely influenced the trend also. These results indicated the importance of two key people in excavation firms who are in positions to most influence reduction of cave-in accidents. The company owner or supervisor must ensure that resources are provided for protective systems, and the competent person must accept the responsibility, as required in the revised standards, to ensure that an excavation is safe.

Although the overall frequency rate of cave-ins decreased after the 1990 revisions, the firms most often responsible for accidents remained consistent with data from the prior five years. Very small firms, usually water and sewer pipeline companies of less than ten employees were most often responsible. Concentrating on training and enforcement of the excavation standards in this area of the construction industry offers the most potential for further reducing cave-in accident rates. A significant impediment to improvements among small companies is thought to be the expense of providing training and cave-in protection systems.

As found in past studies, the cave-ins that occurred were almost always a result of not using any protective system in the excavation. The majority of the accidents continued to be in relatively shallow trenches. Usually, the walls of the excavations were at, or near, vertical and often the earth spoil was piled at the edge of the excavation. There were almost always other contributing factors such as water saturated ground, or vibrations from adjacent traffic and equipment.

Evaluation of the data relative to union membership, geographical location of accidents, and age or sex of workers did not indicate any findings that were significantly inconsistent with the size of work forces associated with these factors.

In conclusion, this study indicated that the revisions to the 1990 excavation regulations resulted in decreased cave-in accident rates. Accidents still continue to occur, so continued emphasis on education and training, coupled with appropriate penalties for violations, will likely be the most effective means to further reduce the number of cave-ins.

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