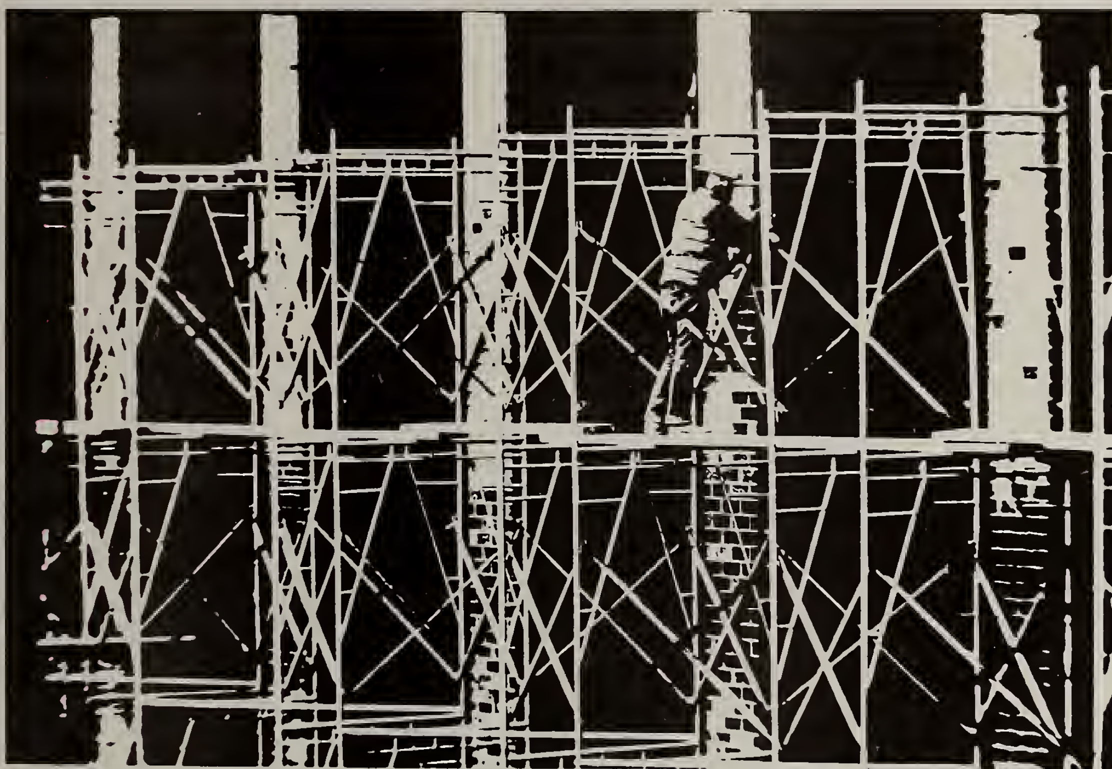
Reference

NBS Publications

NAT'L INST. OF STAND & TECH R.I.C.

A11105 037191

NBSIR 79-1955



Analysis of Scaffolding Accident Records and Related Employee Casualties

S. G. Fattal, C. L. Mullen, B. J. Hunt, H. S. Lew

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

January 1980

Prepared for

National Institute of Occupational Safety and Health
Department of Health, Education and Welfare
Washington, D.C.

QC
100
.U56
79-1955
1980

AUTHENTICATED U.S. GOVERNMENT INFORMATION GPO

NATIONAL BUREAU
OF STANDARDS
LIBRARY
NOV 24 1980

NBSIR 79-1955

ANALYSIS OF SCAFFOLDING ACCIDENT RECORDS AND RELATED EMPLOYEE CASUALTIES

S. G. Fattal
C. L. Mullen
B. J. Hunt
R. S. Lew

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

January 1980

Prepared for
National Institute of Occupational Safety and Health
Department of Health, Education and Welfare
Washington, D.C.

U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, ***Secretary***

Luther H. Hodges, Jr., ***Deputy Secretary***
Jordan J. Baruch, ***Assistant Secretary for Science and Technology***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

ACKNOWLEDGEMENT

This report was sponsored by the National Institute for Occupational Safety and Health (NIOSH), Department of Health, Education and Welfare. The authors wish to express their gratitude to the Bureau of Labor Statistics (BLS) and the Occupational Safety and Health Administration (OSHA) for their special assistance in providing the information used in compiling this paper.

In addition, to Ms. Ava I. Moore, University of Kansas School of Architecture, for capturing the special effects for the cover photograph and to Mr. Larry Hale, NBS Photographic Services, in making these effects part of this publication. A special thank you to Ms. Tracey Kistler, Ms. Ulesia B. Gray and Mrs. Mary Ramsburg for the typing of this paper.

TABLE OF CONTENTS

1. INTRODUCTION

This report presents an analysis into the causes of scaffolding accidents resulting in employee casualties based on statistical data of such incidents compiled by other sources. The study constitutes part of a multi-phase research effort consisting of a series of inter-related tasks to develop a technical basis for the improvement of the safety aspects of scaffolding practices.

In general terms, safety research may be defined as an effort to develop practices by which potential accidents and their consequences can be mitigated to achieve an acceptably low level of risk of human casualties. The word "practices" applies to a given segment of industry which, in this case, denotes the design, erection, operation and maintenance of scaffolding systems used in construction work or other work-related applications such as building renovation or maintenance. The subject of interest in this study is the protection of employees from occupational hazards during the conduct of their assigned tasks. Safety aspects of scaffolding uses in non-occupational or voluntary applications that may be different from those encountered within an employer-employee work environment are, therefore, not addressed directly in this study.

To bring critical research needs for scaffolding systems into focus, a number of avenues may be explored, such as an analysis of accident data, evaluation of applicable codes and standards, or field investigations of current practices. An analysis of accident statistics, if such statistics are available and sufficiently detailed to allow meaningful interpretation, should go a long way in providing the type of information sought. For example, it may point out the specific nature of structural, environmental and human factors that are the principal perpetrators of accidents; it may indicate which types of scaffolds are experiencing the most frequent problems and which are the ones most commonly used; it may indicate the rate and trend of scaffold accidents; and it may indirectly highlight specific deficiencies in existing code provisions for scaffolding systems.

The information used in this analysis provides answers on some of the above-noted trends and was derived primarily from two sources. The first source consists of survey records of scaffold accidents involving work-related injuries documented by the Bureau of Labor Statistics (BLS) for approximately a six-month period [1]*. The second source contains information on scaffold-related accidents involving worker fatalities for a four-year period compiled by the Occupational Safety and Health Administration (OSHA) [2]. Both these sources utilize backup data in the form of questionnaires or standard accident forms containing witness accounts of the individual accidents. By examining the narrative sections of this backup material, it was usually possible to identify

*The numbers in brackets indicate references listed at the end of the report.

the primary cause of the accident and the type of scaffold used. There were, however, a few cases that were not considered because of inadequate information. The scope and type of specific information contained in the source documents examined are discussed in Section 3.

2. APPROACH

Before reviewing the source documents from BLS and OSHA, a set of criteria was devised by which the contents of the accident data could be interpreted and classified (see Figure 2.1). Noting that an accident is usually characterized as a chain of events of discrete time duration rather than as a single instantaneous incident, it is possible that more than one factor may contribute to its occurrence and resulting consequences. Wherever possible, the factor responsible for the initiation of the accident was identified as the primary cause and the factor that could have mitigated the consequences of an accident in progress, but did not, was identified as a secondary cause. For any accident there may be several secondary causes but only one primary cause.

For the purpose of this study, accidents were classified as resulting from three major causes:

(a) system failures
(b) environmental factors
(c) human factors.

In the case of system failures, it was necessary to identify the cause of the accident more explicitly at the component level as follows:

(1) platform
(2) support elements
(3) connections
(4) anchorages
(5) foundation
(6) accessways
(7) safety devices.

The foregoing breakdown allows also the representation of all scaffolding systems in terms of basic components, or units used in the assembly of scaffolds. For clarity and consistency, the following definitions are introduced:

Accessway	-	system which provides access of personnel to and from scaffolds
Anchor	-	component used for securing scaffold to foundation
Anchorage	-	same as anchor, assembly of anchors
Connection	-	component used for the attachment of scaffolding elements
Element	-	component or structural unit other than connection or anchor
Foundation	-	means providing support to the scaffold system
Platform	-	component(s) comprising the work surface of the scaffold

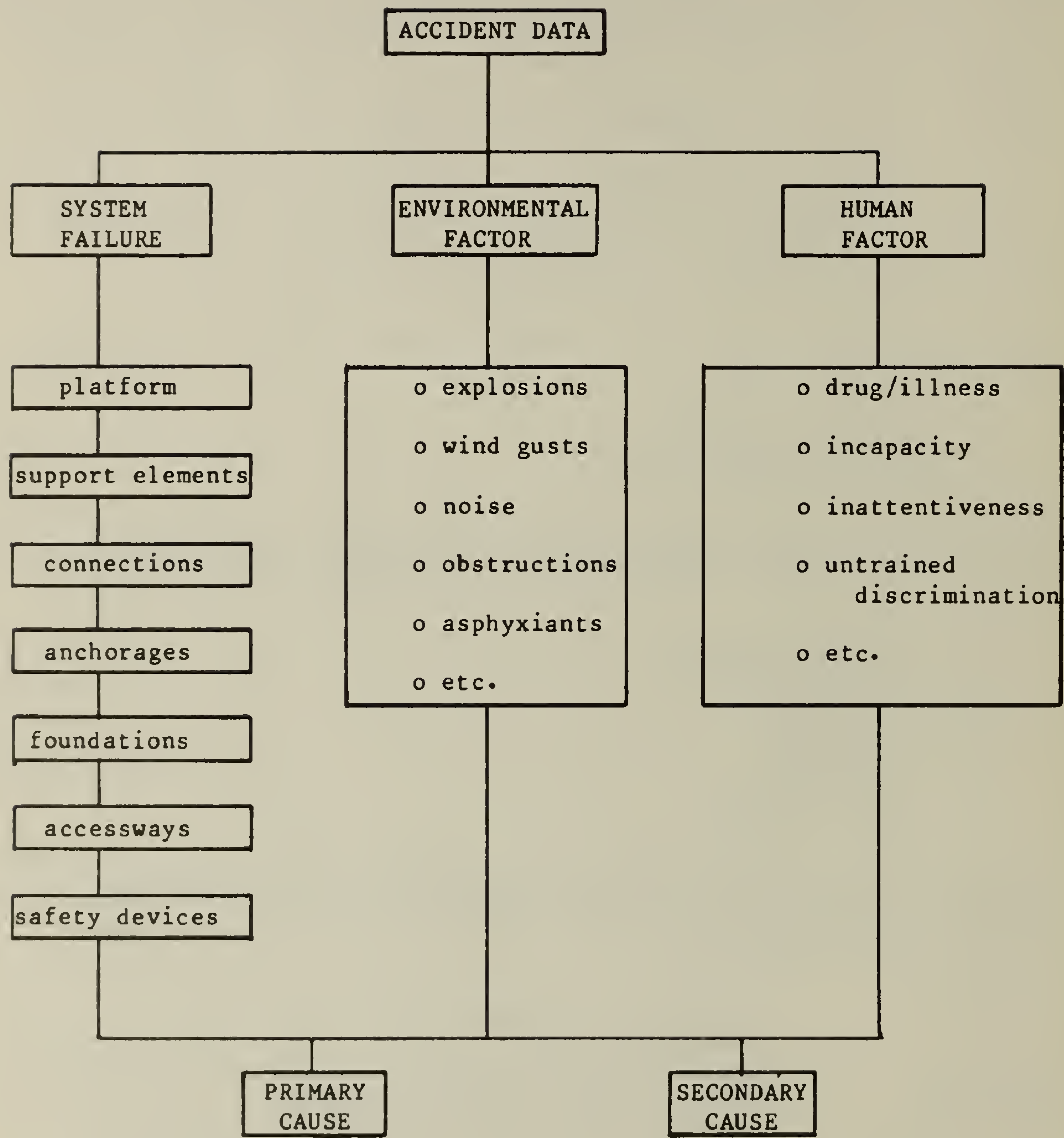


Figure 2.1. Systematic approach used in interpreting and classifying the accident data.

Safety devices	-	physical devices installed for the protection of employees, such as guardrails, nets, belts, lanyards and lifelines, screens, etc.
Structural system	-	assembly of components serving a structural function
Subsystem	-	assembly of part of a system consisting of more than one element and one or more connections and/or anchors
Support element	-	element of scaffold subsystem which supports the platform and transmits applied loads to the foundation.
System	-	assembly of components serving a specified function.

System failures occur as a result of inadequate strength or lack of stability. The failure of any component, foundation, accessway or safety device due to a lack of strength is considered as a system failure. Similarly, any system instability such as rolling, sliding, tilting, settlement or overturning of the scaffold, as well as buckling, sliding, tilting or loss of support of an unsecured platform or any other component is considered as a system failure. If a system failure initiates the set of events resulting in an employee casualty, it is classified as the primary cause of the accident. If, however, a system failure affects only the potential consequences of an accident already in progress, it is classified as a secondary cause.

Unsafe environmental conditions inherent to the work space could produce accidents or fail to mitigate their potential consequences. Environmental failures are often characterized by unexpected occurrences that can throw employees off balance during the conduct of work, such as sudden release of heat, noise, or wind gust. Environmental failures may also be attributed to exposure of employees to toxic fumes; the presence of ice, debris and other obstructions on the work platform that create slippery or unsafe walking and working conditions; or insufficient cues to other physical hazards which the worker fails to perceive, such as openings and precipitous edges without appropriate warning signs. It should be noted that as a matter of choice, the absence of protective devices, where responsible for the initiation or progress of the accident, is treated as a system rather than environmental failure. Furthermore, depending on the situation, wind or ice may be classified in one of two categories. Structural failures precipitated by wind or ice loads are treated as system failures. On the other hand, in cases where ice creates slippery conditions on the work surface or where a wind gust throws a worker off balance (which happens often when carrying a sheet of construction material with large surface area), the resulting accident is attributed to environmental factors.

Human factors contributing to accidents are somewhat more difficult to identify from the available information than those noted above. Human-created hazards in the work environment may be attributed to perceptual or behavioral failures. In other words, an individual may fail to perceive a danger or fail to act. Perceptual and behavioral failures are often due to the absence of environmental characteristics which indicate danger (as in a dark surrounding), or due to unreliable physical characteristics of the system (such as a guardrail which is weak but looks sturdy). In such cases, the factors contributing to the accident are not treated as human failures. On the other hand, perceptual and behavioral failures may occur even when environmental and system characteristics are present and reliable. For instance, perceptual failures may occur because of: (a) defects in the sensory apparatus, (b) immaturity in the sensory apparatus, (c) temporary incapacity due to drugs or illness, (d) untrained discrimination, or (e) inattention. Likewise, behavioral failure, or failure to react to a perceived danger, may occur because of defective, inadequately trained, or temporily incapacitated behavior. The solutions to these performance failures often involve training, education and proper safety orientation for the job. However, even with adequate preparation for the job, it is not entirely possible to eliminate human failures which may occur as a result of inadvertent unsafe acts or voluntary and deliberate abuse. In reviewing the accident records, whenever a clear indication was given that the accident occurred as a result of a voluntary unsafe act, such as an employee extending over or through the railing to reach the work area, human failure was classified as the primary cause of the accident. If the worker inadvertently misused the scaffold, or was compelled by a supervisor to do so, human failure was classified as a secondary cause of the accident.

In order to determine whether certain types of scaffolds may be susceptible to specific kinds of failures, it is also desirable to classify accidents according to the types of scaffold used. Twenty one major types of scaffolds were identified for the purpose of this study. Most of these are addressed by the OSHA regulations [3]. In addition, a twenty second category titled "improvised scaffolds" was created to classify all those scaffolds which could not be identified with any one of the major types. The types of scaffolds and the numbering system used for identification are illustrated in appendix A.

TABLE 3.1

Profile of Scaffolding Accidents Involving Worker Injuries
(Based on Survey by the Bureau of Labor Statistics)

			No.	%
A. Organization			No. (out of 803)	%
	General:	Craftsmen and kindred workmen	479	60
		Laborers, except forman	190	24
		Operatives, except transport	90	11
				95*
	Specific:	Carpenters	216	27
		Construction laborers, except carpenters' helpers	130	16
		Brickmasons, stonemasons	53	7
		Painters, construction, maintenance	41	5
		Drywall installers, lathers	30	4
				59*
B. Type of Scaffold			No. (out of 779)	%
	General:	Self-supporting	476	61
		Improvised	131	17
		Supported by structure or other methods	95	12
		Suspended	15	2
				92*
	Specific:	Welded tubular	241	31
		Ladder scaffold	142	18
		Tube and coupler	60	8
		Bracket	41	5
		Pump jack	23	3
		Ladder jack	23	3
		Double pole	17	2
		Bricklayer's square	16	2
		Two-point suspension	10	1
		Single-pole	5	1
				74*
C. Description of work activity			No. (out of 800)	%
		Working directly from scaffold	476	60
		Climbing up to or down from scaffold	120	15
		Stepping on to or off of scaffold	78	10
		Building or tearing down the scaffold	77	10
		Moving the scaffold	42	5
				100
D. Description of the accident			No. (out of 801)	%
	H or I**	Fell off - nothing happened to scaffold	222	27
	C	Plank slipped	126	16
	A	Plank broke	62	8
	D	Support poles tilted or tipped over	57	7
	C	Wheels on bottom of scaffold rolled	45	6
	B	Cross-bracing gave way	45	6
	D	Anchoring into structure gave way	43	5
	H	Slipped on work materials	42	5
	B	Wood or metal support pole(s) broke	41	5
	E	Scaffold tilted on unlevel ground	35	4
	E	Scaffold base slipped on slick surface	31	4
	H	Struck by falling object while on scaffold	21	3
	E	Support poles sank in soft ground	16	2
	D	High winds moved scaffold	8	1
	B	Cable or suspension line broke	6	1
	G	Scaffold guardrail broke	1	-
				100

* Specific items that could be identified were less than total number of cases.
** Alphabetic coding corresponds to categories specified in Tables 4.1 and 4.2.

TABLE 3.1 (Continued)

E. Number of workers on the scaffold

	No. (out of 754)	%
1	429	57
2	200	27
3	67	9
4	22	3
0	20	3
≥10	2	-
		99

F. Description of work platform

(1) Composition	No. (out of 795)	%
wood plank	659	83
solid metal	74	9
metal grate	35	4
		96

(2) Height above ground (ft)	No. (out of 793)	%
<10	402	51
>10	377	48
		99

(3) Width (ft)	No. (out of 780)	%
2-4	354	45
<2	266	34
>4	134	17
		96

(4) Length (ft)	No. (out of 730)	%
8-12	365	47
>12	213	27
<8	174	22
		96

G. Description of platform support system

	No. (out of 782)	%
metal tube frame	511	65
wheels	218	28
guyed or anchored to structure	168	21
wood frame	93	12
screw jacks	37	5
suspended by wire cable	13	2

If scaffold had metal tube frame, was frame cross-braced?	No. (out of 428)	%
yes	362	85
no	47	11
		96

If wood frame, was frame cross-braced?	No. (out of 88)	%
yes	56	64
no	28	32
		96

3. BASIS OF STUDY

This section describes the scope and type of information found in the BLS and OSHA scaffolding accident records involving work-related injuries and fatalities, respectively. As noted earlier, these were the two major sources of information utilized in this study.

The BLS study [1] compiles scaffolding accident and injury statistics from May through mid-November, 1978. The study derives accident information from accounts given by the Employers' First Report of Injury required by State laws on worker's compensation, and from special survey questionnaires sent to injured employees whose reported accidents were judged to be within the scope of the survey. The information was collected from seventeen States named in the survey and described as providing a rough balance of geographic and industrial characteristics.

A total of 2237 cases of scaffolding accidents resulting in work-related injuries were reported within the specified period of the survey. Out of this total, 1007 cases were eliminated from the survey because they were: (a) out-of-scope accidents, (b) accidents involving fatalities, (c) cases more than ninety days old or (d) non-mailable. Of the remaining 1230 cases for which BLS issued survey questionnaires, there were 803 responses which were subsequently examined and used in the preparation of the accident statistics report issued by BLS.

The BLS survey provides a profile of scaffold accident characteristics based on injured workers' reports. The questionnaire was designed to provide information on (a) occupation; (b) type of scaffold; (c) description of work activity; (d) description of the accident; (e) number of workers on the scaffold; (f) type of work platform including composition, length, width and height above ground; (g) description of support system for the platform; (h) presence or absence of crossbracing; and (i) personnel data (such as nature of injury, age, sex and training of the workers) which are not directly related to the scope of this study.

Table 3.1 summarizes the responses received by BLS for the type of information sought in this study, shown in the order of decreasing frequency for each of the categories specified above. By examining the given data some useful inferences can be drawn. For instance, an interesting aspect of the BLS survey, and one that is of primary concern to this study, is the type of failures triggering the accident or the factor failing to mitigate its consequences (item D in table 3.1). Heading the list (27 percent) are falls without apparent damage to the scaffold. The preponderance of planks either breaking or slipping off supports, which accounts for the next highest rate of incidents (24 percent), points to definite targets for improvement in scaffolding applications.

The illustration of the types of scaffolds (16 in all) appended to the BLS survey questionnaire is shown in appendix B. The percentages of the scaffold types given in item B of table 3.1 are percentages of reported accident-related scaffolds. If an attempt were made to correlate frequency of accidents with type of scaffold, these values would have to be weighted by percentages of the types of scaffolds in use. At this writing, information is not at hand to determine frequency of use according to type of scaffold. The BLS data is, nonetheless, relevant in pointing out the trend of scaffold use and the need for further corroboration through a comprehensive field study. It is encouraging to note, with regard to coverage of various scaffold designs, that the sixteen scaffold descriptions offered with the BLS questionnaires apparently cover more than 90 percent of the reported scaffold accident cases.

The BLS document notes that 800,000 cases of Employers First Reports of Injuries were reviewed during the survey period. Of these, approximately 2200 cases involved scaffold accidents, which represent a seemingly low value of about 0.3 percent of the workers' compensation cases reviewed. This figure alone does not lend itself to meaningful interpretation without having comparable figures for the number of employees involved in scaffold-related work versus the total number of employees. More precisely, for a representative base period, total employee-hours of scaffold use should be compared to total employee-hours in other occupations.

In an attempt to gather any available information on the above subject, inquiries to BLS indicated that total wage and salary workers in the construction industries were about 5.7 percent of the total wage and salary workers in the U.S. Thus, for a given base period, if total scaffold work constitutes 5% of the total employee-hours in construction industries, then it would represent 0.3% of total wage and salary employee-hours (viz. $5\% \times 5.7\% \doteq 0.3\%$). Since this figure is the same as the percent rate of scaffold accidents reported, it may be concluded that the frequency of scaffold injuries is comparable to the average for all other industries taken collectively. If the scaffolding use is less than 5% of the total construction employee-hours, it would indicate potential safety problems for scaffold users. This still leaves the question on the rate of scaffold use unanswered but points out survey possibilities as a means of estimating the severity of safety problems of one segment of industry relative to other industries.

The other major source of information for this study was acquired from OSHA. The OSHA document [2] is based on scaffolding accident data involving worker fatalities covering a period from May, 1974 through April, 1978. Among 386 working surface accident reports, 82, or 21 percent, were identified as fatal incidents relating to scaffolds. Four of the incidents involved more than one death bringing the total to 86 deaths. The study excludes cases that occurred on permanent platforms, catwalks, oil derrick platforms, window washer belts or cases where scaffolds should have been used but were not. It should also be noted that the OSHA study excludes the 51 worker fatalities resulting from the Willow Island cooling tower collapse in West Virginia on April 27, 1978, which was the worst construction disaster in U.S. history [4].

The OSHA study identifies types of scaffold used as belonging to one of three general categories (suspended, self-supporting and other) which encompass the types of scaffolds specified in the OSHA regulations. It also provides a description of the types of incidents, employee activities at the time of the incident (but not necessarily those causing the incident), and a breakdown of causes into four categories: equipment failure, operating procedure, environmental and other. The OSHA study shows that equipment failure and failure to follow operating procedures accounted for 48 percent and 37 percent of the total incidents, respectively, while environmental and "other" conditions together accounted for 15 percent. It also shows that: 70 percent (17 out of 25) of suspended scaffold incidents and 31 percent (11 out of 35) of the self-supporting scaffold incidents involved equipment failures; 49 percent (17 out of 35) of self-supporting scaffold incidents were attributed to operating procedure; and, equipment failure accounted for 50 percent (11 out of 22) of the incidents in the "other" category of scaffolds. One-half of the total (11 out of 22) in this category were improvised scaffolds.

Although the definitions of the various classifications of accident causes in the OSHA report are somewhat different from those used in this study, the term "equipment failure" approximately corresponds to the term "system failure" referred to herein. The OSHA report indicates that connection failures or the absence of same account for the maximum number of incidents, followed in decreasing order of incident frequency by support element failures (referred to as scaffold component failures), failures due to faulty or improvised construction, insufficient strength, insufficient anchors, and failure of safety devices. As will be noted in section 4.2, this study categorizes all system type failures at the component level and therefore, has no direct counterpart to failures attributed to improvised construction or insufficient strength in the OSHA report.

	CAUSE OF ACCIDENT / SCAFFOLD TYPE	WOOD POLE	TUBE & COUPLER	FABRICATED TUBULAR FRAME	MANUALLY-PROPELLED MOBILE	VEHICLE-MOUNTED ELEVATING	TELESCOPING	SELF-PROPELLED ELEVATING	OUTRIGGER	MULTIPLE-POINT SUSPENSION	TWO-POINT SUSPENSION	SINGLE-POINT SUSPENSION	BOATSWAINS' CHAIR	NEEDLE BEAM	FLOAT OR SHIP	CATENARY	BRACKET	SQUARE	HORSE	LADDER JACK	WINDOW JACK	PUMP JACK	IMPROVISED	TOTAL	PERCENT
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
SCAFFOLD SYSTEM COMPONENTS	A PLATFORM			1 (1)																			3	4 (1)	7
	B SUPPORT ELEMENTS	3		3			1										1 (1)							8 (1)	14
	C CONNECTIONS			3	3						1						2					1		10	17
	D ANCHORS	2															6						2	10	17
	E FOUNDATION	1		2 (1)	3		1																1	8 (1)	14
	F ACCESSWAYS	(1)		(4)	(1)																			(6)	-
	G SAFETY DEVICES	1 (1)		(2)	(3)												(1)						1 (1)	2 (8)	3
H WORK ENVIRONMENT		1 (1)		3	4 (3)		1 (1)				(1)												1 (2)	10 (8)	17
I HUMAN FACTORS		(3)	1	(3)	5 (3)												(1)					(1)	(3)	6 (14)	10
TOTALS	PRIMARY	8	1	12	15		3				1						9					1	8	58	
	(SECONDARY)	(6)		(11)	(10)		(1)				(1)						(3)					(1)	(6)	(39)	
	% PRIMARY	14	2	21	26		5				2						16					2	14		100

Table 4.1 Injury Statistics of Scaffold Accidents

CAUSE OF ACCIDENT \ SCAFFOLD TYPE		WOOD POLE	TUBE & COUPLER	FABRICATED TUBULAR FRAME	MANUALLY-PROPELLED MOBILE	VEHICLE-MOUNTED ELEVATING	TELESCOPING	SELF-PROPELLED ELEVATING	OUTRIGGER	MULTIPLE-POINT SUSPENSION	TWO-POINT SUSPENSION	SINGLE-POINT SUSPENSION	BOATSWAINS' CHAIR	NEEDLE BEAM	FLOAT OR SHIP	CATENARY	BRACKET	SQUARE	HORSE	LADDER JACK	WINDOW JACK	PUMP JACK	IMPROVISED	TOTAL	PERCENT
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
SCAFFOLD SYSTEM COMPONENTS	A PLATFORM	1		2 (4)	(3)						1						(1)						3 (3)	7 (11)	8
	B SUPPORT ELEMENTS			(1)							3 (1)												1 (1)	4 (3)	5
	C CONNECTIONS			4 (1)	4					1	1						1						6 (1)	17 (2)	20
	D ANCHORS			1	1						8 (1)						3							13 (1)	15
	E FOUNDATION				1						2				1									4	5
	F ACCESSWAYS	(1)		(1)							1													1 (2)	1
	G SAFETY DEVICES	(1)	2	4 (5)	3 (6)					(1)	1 (20)		1 (1)		(1)		1 (3)						6 (10)	18 (48)	21
H WORK ENVIRONMENT		1		1	2 (1)						1 (1)		2				1						6 (1)	14 (3)	17
I HUMAN FACTORS			(2)	1 (3)	3 (3)						3 (7)		(2)										(3)	7 (20)	8
TOTALS	PRIMARY	2	2	13	14					1	21		3		1		6						22	85	
	(SECONDARY)	(2)	(2)	(15)	(13)					(1)	(30)		(3)		(1)		(4)						(19)	(90)	
	% PRIMARY	2	2	15	17					1	25		4		1		7						26		100

Table 4.2. Fatality Statistics of Scaffolding Accidents

4. ANALYSIS OF ACCIDENT RECORDS

The following sections present an analysis of the causes of the accidents examined. Section 4.1 describes the method used to present these causes according to the breakdown discussed in section 2. Section 4.2 notes the general trends observed in the accident data. Section 4.3 and its subdivisions present itemized descriptions of accident causes attributed to system component failures, and sections 4.4 and 4.5 describe respectively, accident causes attributed to environmental and human factors.

4.1 PRESENTATION OF THE DATA

In order to identify the types of failures associated with the reported accidents according to the breakdown noted in section 2, it was necessary to examine, in addition to the BLS and OSHA reports, the individual accident records upon which these documents are based.

In the case of the OSHA study, all of the 82 accident files were reviewed, of which 3 were dropped because of insufficient information. Typically, an accident file contained the following: (a) a standard Safety and Health or Accident Inspection Report which provided accident data in numerical code format corresponding to a specified legend, (b) a standard Citation and Notification of Penalty form which specified any violations of OSHA employee safety regulations, and (c) various witness accounts of the accident in narrative form, where available. Some of the records showed sketches and photographs of the accident site as well.

As noted earlier, the BLS study of scaffold injuries was backed up by more that 800 individual accident accounts. They were reported by the respondents (parties injured in the accident) using standard questionnaires which also provided spaces for narrating the incident and sketching the type of scaffold involved, when different from the 16 types illustrated in the questionnaire (see appendix B).

An initial examination of the BLS questionnaires indicated that in most instances the narrative section and the space for sketching non-typical scaffolds were left blank, and as a result, were of limited use as backup material for the purpose of this study. Consequently it was decided to select 10 percent of the available reports on the basis of the amount of information supplied by the respondents. Furthermore, at least one but not more than 10 percent of the reports from any given state was included in the sample to maintain approximately the geographic distribution of the original source data. Ultimately, 58 cases or slightly over 7 percent of those reported satisfied these requirements and were retained for further evaluation.

Tables 4.1 and 4.2 compile accidents involving injuries and fatalities based on the respective source data from BLS and OSHA. In order to present the selected data from both sources in a consistent fashion, the matrix format indicated in these tables was adopted.

The rows of the matrix represent the primary (and secondary) cause of each accident while the columns represent the corresponding type of scaffold used. The three major categories of factors leading to the accidents are identified as follows: system failures, rows A through G; work environment, row H; and human factors, row I. The system failure subdivisions A through G correspond to those already defined in section 2. Columns labeled 1 to 21 correspond to the types of scaffolds illustrated in Appendix A. Improvised scaffolds are indicated in column 22.

Each matrix is supplemented with additional rows and columns that sum up the results. The last two rows represent the number of incidents involving each scaffold type and the corresponding percentage of the total number of cases considered. The last two columns show the number of incidents associated with each category of failure and the corresponding percentage of the total.

In both tables, a distinction is made with regard to whether any particular factor was the primary or secondary cause of the accident in accordance with the concept introduced in section 2. The numbers representing secondary causes are shown in parentheses to distinguish them from primary causes. However, the percentage figures in the last row and column represent only the primary causes and should add up to 100 percent (lower right-hand number) because only one primary cause is identified for each accident investigated.

4.2 INTERPRETATION OF GENERAL TRENDS

The interpretation of injury statistics compiled in table 4.1 is subject to possible errors that may have been introduced in the sampling process. To estimate any differences between the 7 percent sample used in this study and the BLS data source, the percentage values of the various causes of accidents shown in table 4.1 were compared with the corresponding values from the BLS report after identifying the latter (item D, table 3.1) according to the categories used in table 4.1. This leads to the following results:

Type of Failure	Percent of 801 cases (table 3.1)	Percent of 58 cases (table 4.1)
A - Platform	8	7
B - Support elements	12	14
C - Connections	21	17
D - Anchorages	13	17
E - Foundation	10	14
F - Accessways	< 1	0
G - Safety devices	< 1	3
H - Environmental and I - Human factors	36	27

It is seen from the above that differences between sample and source data are not major for the purpose of examining the trend of accident causes on the basis of the figures in table 4.1. The difference between the values for environmental and human failures taken collectively may be due to different interpretations of the source data, because the definition of causal factors used in this study are not coincident with those used by BLS. For example, a "fall with no apparent damage to the scaffold" may be interpreted here as a fall precipitated by movement or instability of the scaffold if the data examined gave any indication that this may have been the case.

Possible differences between sample and source data may also be investigated by comparing the percentage values of the scaffold types shown in table 4.1 with the corresponding values for the specific types shown under item B of table 3.1. Sampling distortions were generally more apparent in this case, the sample being most heavily biased toward bracket and pole types (30 percent) relative to the source (8 percent). On the other hand, the highest rate of accidents involved (collectively) frame type and manually propelled mobile (or ladder type) scaffolds, and was about the same for both sample and source data (approximately 50 percent of the cases).

The accident statistics involving fatalities compiled in table 4.2 do not present any sampling problems because they represent almost all of the cases on record. The data in tables 4.1 and 4.2 exhibit certain similarities and differences worthy of note. For instance, they agree remarkably well by pointing out that in about 3 out of 4 cases the primary cause of the accident is attributable to a system failure. Within that category, they both show that about 30 percent of all accidents are triggered by connection and anchorage failures, and 7 or 8 percent are triggered by work platform failures. On the other hand, the rate of incidents attributed to foundation or support element failures resulting in injuries is about three times the corresponding rate of incidents resulting in fatalities.

A comparison of accident rates for the various types of scaffolds is not very meaningful because no information is available on the frequency of scaffold use according to type. If, for example, a particular type of scaffold is used 90 percent of the time but accounts only for 50 percent of all accidents, its accident rate per unit time of use will be much less than indicated by the 50 percent figure. This points out the need for compilation of statistical data of frequency of scaffold use according to type through field studies or other means.

It should be emphasized that extreme care must be exercised in comparing the injury and death statistics compiled in tables 4.1 and 4.2. The data in tables 4.2 constitutes nearly all of the scaffold-related work fatalities in the U.S. over a period of four years. On the other hand, the injury data in table 4.1 represents a 2.6-percent sampling of all scaffold-related injuries (58 out of 2200 cases) occurring within a period of 6-1/2 months in states representing about 47 percent of the U.S. population. If the injury statistics are adjusted to the same time span and population bases as those for the death statistics, the number of cases involving injuries will be about 35,000, or about 410 injuries per fatality. Therefore, the individual figures shown in these tables (the matrix elements) cannot be compared directly for the purpose of estimating incident rates according to the various categories listed. Rather, they should be viewed in relation to each other by comparing the given percentage values and the relative figures of injury and fatality rates for a common base period. It should also be kept in mind that the information in table 4.1 is subject to sampling distortions and the possible effect of seasonal factors on the BLS data which was assembled during a period of peak construction activity.

In way of illustrating a possible pitfall in the interpretation of the data catalogued in tables 4.1 and 4.2, the following example may be cited. According to table 4.2, the second highest rate of death incidents is associated with two-point suspension scaffolds, while the corresponding rate of injuries is among the lowest of the group (table 4.1). At first glance, this may suggest erroneously that two-point scaffold accidents involving casualties almost always result in death. However, a comparison drawn on a common time span and population basis will show that two-point suspension scaffold injuries occur about 20 times more frequently than fatalities. This ratio is probably on the high side because of the seasonal factors mentioned above. Note that for the limiting (unlikely) case of no scaffolding activity occurring outside the 6-1/2 month (BLS survey) period in a year, the ratio would still be 10 to 1.

For the reasons stated above, there appears to be no expedient way of combining the data in tables 4.1 and 4.2 for the purpose of developing total casualty statistics of scaffolding accidents. Where the corresponding percentage figures from the two sets of data are in close agreement, they will indicate a definite trend. If, however, differences in the corresponding percentages are appreciable, the rate of the injury data in table 4.1 will, in general, indicate the dominant trend (exceptions are noted below), because the frequency of scaffold-related injuries is at least two orders of magnitudes higher than the frequency of fatalities. Keeping these factors in mind, the following observations of general trends in scaffold-related work casualties can be made.

System failures are by far the major causes of casualties accounting for almost 3 out of 4 cases reviewed. At the component level, the most common primary cause of casualties was the failure of connections and anchorages (17 percent each), followed by foundation and support element failures (14 percent each), failure of work platforms (7 percent), failure of safety devices (between 3 and 21 percent), and accessway failures (1 percent).

The major difference between the data in the two tables is in the percentage figures identifying a safety device failure as the cause of the accident both in the primary sense (3 percent injuries vs. 21 percent fatalities) and secondary sense (8 out of 39 injuries versus 48 out of 90 fatalities). In an attempt to find a logical explanation for these large discrepancies, the following were observed. The BLS source data (the questionnaires) do not specify explicit violations of the OSHA regulations on safety devices as do the citations which are part of the fatality statistics. Consequently, it was simpler to identify any evidence relating the fatality incidents to deficiencies (primary cause) or the absence (secondary cause) of safety and fall protection devices than in the case of injury data. However, the BLS report does indicate that only 33 percent of the scaffolds (out of 803 cases) were equipped with guardrails and of these, only 54 percent (or 18 percent of the total) provided protection on all exposed sides. The BLS report also states that 80 percent of the accidents were falls from scaffolds. Based on these observations, it is estimated that failure of safety devices is a leading cause of scaffolding casualties both in the primary sense and secondary sense, and therefore, the percentage figures in table 4.2 are more indicative of this trend than those shown in table 4.1.

Only in about one out of four cases was the primary cause of an accident attributed to an environmental and human factor (17 and 10 percent, respectively). Note that in the secondary sense, human factors contributed to the accidents in about twice as many instances as environmental factors.

The highest number of incidents involved manually propelled mobile, fabricated frame, bracket, wood pole and improvised scaffolds, which collectively represent about 90 percent of the cases considered. Two-point suspension scaffolds are not among this group because their casualty rate is low (the 2 percent figure in table 4.1 prevails for reasons noted above). However, because the severity of the consequences of an accident is a primary safety concern, the high rate of accident fatalities attributed to two-point suspension scaffold failures (25 percent, table 4.2) takes on more significance as a critical safety problem than the above-observed trend of the total casualty statistics would indicate.

4.3 SYSTEM FAILURES

In the preceding section, the breakdown of accident causes into specific categories was helpful in developing an overall grasp of major safety problem areas with regard to scaffolding practices. It was observed that about three-quarters of the accidents were a result of failure of the scaffolding systems and that connection and anchorage failures were the most common. In this section, failure of the various components of scaffolding systems will be discussed in detail in order to establish the nature of these component failures, such as stability or strength.

4.3.1 Work Platforms

The work platform is the component of the scaffolding system in direct contact with the loads which include workers, materials, and equipment. The work platform also transmit other loads such as ice or wind to the scaffolding structure. Furthermore, the platform can be the location of many environmental hazards due to the presence of work materials and slippery surfaces. Such hazards of the work environment are discussed in Section 4.4.

Approximately 7 percent of all scaffolding accidents reviewed were caused by structural failure of the platform which usually consists of wooden planks. Failure occurred as the result of defective pieces of lumber, inadequate number of planks, planks of insufficient size and strength, or excessive loads. The majority of such failures occurred on improvised scaffolds where less care was probably given to provide adequate support to anticipated loads.

Accident descriptions reveal that some planks were split and splintered; however, even after inspection these planks were used for the platform surface, sometimes repeatedly. One injured worker stated that after having fallen when a plank broke, he returned to the site and discovered that the same piece of wood had been put back. The ends had simply been squared and 2 x 4-in cleats had been nailed to the bottom. Furthermore, only a short time thereafter, he fell again when another plank split diagonally.

Examination of some of the schemes for constructing platforms (derived from sketches in the reports) reveals that in some cases planks were not placed in sufficient numbers on the scaffold or did not have sufficient cross-sectional area to support the imposed loads. For example, due to limited space, improvised scaffolds consisted of one plank with nominal dimensions of 50 x 250 mm (2 x 10 in). This may or may not be sufficient to support one person depending on the span and the condition of the plank. Such a condition is also hazardous as well from the viewpoint of protection against falls. Loading conditions can be critical where such improvised scaffolds exist. In one instance, a worker fell to his death when another worker stepped down from a platform two feet above causing the plank to fail. Dangers are not limited to improvised platforms consisting of wood. One platform where aluminum planks were used failed when a third worker stepped on carrying two buckets of fresh cement.

In some of the accidents which involved platforms, it was found that the platform elements themselves were not the primary cause of the accident. Rather, the cause was attributed to lack of adequate connections to the supporting elements, gaps between planks, or slippery surfaces.

When planks are not secured to the supporting elements they become laterally unstable. In some cases, when workers were getting the platform the planks moved as a result of the applied horizontal thrust. The consequences of such movements varied from a jammed finger to death of the worker. This problem is also related to openings between adjacent planks. When planks are secured against lateral movement, openings remain fixed. If the gap becomes large and the worker begins to fall through, he may still have an opportunity to grab onto the planks and impede the fall.

If the planks are not secured against lateral movement, it is less likely that a woker will be able to impede his fall by such countermeasures. Incidents caused by movement of unsecured planks are identified with connection failures (sec. 4.3.3).

4.3.2 Support Elements

By reference to appendices A and B, it is apparent that there are a variety of ways to support a work platform. In all cases, however, the supporting elements act to transfer the loads acting on the work platform to the foundation. Various work environments necessitate different foundations and thus different support systems. When the foundation is the ground below, a framework or some type of mechanical elevating system is required. If height, space, or access are restraints, particularly during a construction process, it may be necessary to anchor the scaffold onto the structure itself. In such cases the platform must cantilever outward from the structure and an outrigger or bracket may be utilized. When a secure foundation exists above the level of the work platform, the platform may be suspended by ropes or cables.

When an accident can be related to the supporting elements, consideration of the type of support system is necessary in order to understand the nature of the consequences. The modes of failure of a framework are different from those of a suspension cable or bracket. Furthermore, if one element of a framework fails, the system may not collapse; whereas, if one of the two cables from which a platform is suspended snaps, it will precipitate collapse. About 14 percent of the total number of accidents were attributed to support system failures. The distribution of such failusres according to type of scaffold shows no definite trend.

Support system failures were responsible for a larger share of accidents leading to injury than accidents leading to death. Collapse depends on whether each supporting element involved in the failure is vital to the transfer of loads to the foundation. When redundancies or alternate load paths are present, failure of one element may only result in local instability, such as in a fabricated tubular frame scaffold. Two of the three accidents reviewed which led to injuries were attributed to the use of a diagonal brace as a means of access; not designed for this purpose, the brace broke or yielded. The primary function of this brace is to resist loads applied laterally to the structure. Consequently, failure of the brace did not cause collapse of the structure nor death to the worker. Rather, the worker probably lost his balance and either struck the hard metal or fell (some distance less than the height of the platform level which he was accessing). It is also interesting to note that no accidents involving fabricated tubular frame scaffolds were reviewed where death occurred primarily as a result of support system failure. However, two-point suspension scaffolds, in which failure of the support system occurred, were involved in three accidents resulting in death and none resulting in injuries. The failures were attributed to breakage of the suspension rope or, in one case, the safety line which was secured to the suspension cable.

4.3.3 Connections

According to the definition in section 2, a connection is a component used for the attachment of scaffolding elements. Any physical device used for the purpose of interconnecting scaffold support elements or braces, or securing work platforms, accessways, and safety devices to the scaffold, fall within the scope of this definition. Examples of commonly encountered mechanical connecting devices used in scaffolding applications are nails, bolt, wires, clamps, locks, clips, sleeves, inserts, clevices, couplers, hooks, splices and turnbuckles.

As noted in section 4.2, connection and anchorage failures top the list of all accident causes, accounting for 17 percent each of all the cases reviewed. Examination of the individual accident descriptions revealed that absence of proper connections as well as failure of connections in place were about equally responsible for the initiation of the accidents. Connection failures in frame and manually propelled mobile scaffolds were by far the most common. In manually propelled mobile scaffolds, connection failures were often characterized by such incidents as the collapse or detachment of a wheel, or the malfunctioning of a worn locking device, causing the scaffold to tilt, roll or tip over.

In one case, the detachment of a brace secured to an improvised scaffold by one nail precipitated its collapse. Other instances where the failure of a single connection brought about the collapse of the entire scaffold or work platform were: the rupture of a clip causing the slippage of a cable clamp and consequent collapse of the suspended scaffold; and detachment of a platform support bar causing the work platform to collapse. Descriptions indicating such occurrences as the detachment of a bolt, the slippage of a loose frame connection, the snapping of a locknut not securely fastened, or the dislodging of a notched angle bar from its support (not a positive connection against pull) were instances of improper use and maintenance of connections in place.

In nearly all of the cases reviewed where the absence of adequate connection was judged to be the primary factor causing the accident, the work platform was either not secured or partially secured to the scaffold. It thus appears that lack of proper connection between platform and scaffold is a major cause of instability of working surfaces. In view of the nature of construction work activities, this hazard cannot be eliminated by training and safe conduct of work alone, as indicated by the following accounts: The platform overturned when a worker stepped over a 0.9 m (3 ft) overhang section. The overhang had been supported earlier by a frame which had been removed before the incident; a worker fell when attempting to step down on a board which slid backwards causing him to lose his balance; another worker fell through an opening between planks which were not tightly placed or secured.

The absence of platform connections create the kind of environmental hazard that is difficult to perceive or anticipate. An unsecured overhanging platform, for instance, may not provide an adequate visual cue to the construction worker as to the exact location of its support point which it conceals. Workers in the act of carrying materials or equipment often have their field of vision temporarily narrowed or impeded and may well fail to perceive and stay clear of openings between unsecured planks. A worker descending on the platform may assume erroneously that the platform is secured or has sufficient friction to take a horizontal thrust without movement. A horizontal thrust will also occur in many other work situations such as when an employee is pushing a screw gun to fasten facade elements on a building.

Based on the foregoing arguments it would be reasonable to expect that work platforms, especially in construction work, will be subjected frequently to horizontal thrusts, overturning forces, or wind-induced uplift. To resist such forces, the platforms must be adequately secured to the scaffold frame. Considering the available accident casualty evidence, there exists strong justification for banning the use of unsecured platforms on scaffolds where the platform is to serve the function of a working or walking surface. Accident statistics also indicate the need to develop a technical basis for improvement of the structural performance of scaffold connections.

4.3.4 Anchors

According to the definition in section 2, anchors are used to connect and secure the scaffold to its foundation. The scope of this definition includes any device that connects the scaffold to its supports at the support points. In the case of a guy wire, its point of attachment to the scaffold is treated as a connection point and its point of attachment to the support or foundation is treated as an anchorage point. The guy wire itself braces the scaffold and, therefore, is treated as an element of the system.

Anchorage failures were one of the two leading causes of scaffold accidents within the system component group. Unlike failure associated with connections, in most cases anchorage failures were actual failures of anchors which were in place. Bracket and two-point suspension scaffolds experienced the most frequent anchorage problems resulting in injury and death, respectively.

Incidents of anchorage failures in two-point suspension systems included the following accounts: the cable at one end of the work platform slipped through the U-clamp at the anchorage point causing loss of support; a hook of a cable broke at the support point. The hook was reported to have been cracked before the accident; the wire tie securing the platform to the building broke and the platform swayed out causing the worker to fall. This happened when the screw gun, which the worker was pushing against the building, suddenly yielded; the inside support of one of the outriggers failed causing the scaffold to collapse. Where the collapse of the scaffold was attributed to lack of anchorage, one incident was described as having occurred because there were no safety clips at anchorage points. Another accident occurred when rollers supporting the suspended platform slipped off the end of an I-beam flange where no roller stops were provided.

Anchorage failures involving bracket scaffolds were of two types: failure due to lack of strength or failure due to insufficient embedment.

Embedment failures were described as triggered by nails or walls ties pulling out at points where the bracket was attached to the building; while failures due to lack of strength were identified in cases where there was evidence that an anchor had ruptured. In two cases of anchorage failures involving other types of scaffolds, the inadequacy of anchors to resist wind was cited as a cause that precipitated a collapse or overturning of the scaffold. Other instances cited included a weld failure of an angle attaching a work platform to a steel tank, rupture of cleats anchoring a board to the wall (improvised scaffold), and a bracket which became disengaged from the wall.

Many of the examples cited above are indicative of a major problem area in structural design, namely, the paucity of research information for formulating an adequate design basis for anchorage systems. Of particular concern is the load capacity of nails, inserts and similar mechanical devices driven into concrete, masonry or mortar for the purpose of anchoring scaffolds. The use of such anchorage devices is encountered quite frequently in scaffolding and shoring operations and the decision as to what constitutes a proper anchorage for a given support system is often left to the contractor or field supervisor. Technical information is needed to aid in the development of a rational design approach for anchorages to such support systems, in order to minimize the occurrence of anchorage failures which have been shown to produce major collapses rather than localized failures. Such information should address not only the design strength of anchorage devices but also identify the magnitude of construction loads.

4.3.5 Foundation

A foundation may be conveniently defined as the means that lends support to the scaffold system (section 2). This broad definition allows a structure or any other object to which the scaffold is attached for support, as well as the ground upon which it bears, to be classified as foundation.

On the basis of the data compiled in section 4.2, the number of accidents attributed to foundation failures was the same as that attributed to support element or platform failures, each representing about 14 percent of the total accident cases reviewed. There were, however, some cases which were classified as foundation failures but could have been interpreted differently as the following examples will indicate. One accident was attributed to the movement of a mobile scaffold reportedly caused by debris on the floor upon which it was resting. Another accident occurred when a wheel of the mobile scaffold sank into a floor depression. In either case, the movement of the scaffold was assumed to have occurred without rolling. Had there been any indication of rolling, the cause of the accident would have been identified as a connection failure. In another instance, hooks and tiebacks pried loose from a brick veneer wall which was being restored (loose bricks and mortar were being replaced). A judgment was made that in view of the conditions of the wall, it did not have retention capacity for anchors and, therefore, the accident was attributed to a foundation rather than anchorage failure.

Like anchorage failures, foundation failures appear to affect the stability of the entire scaffold system rather than remain localized. Thus, foundation failures have the potential to precipitate major disasters, particularly in the construction of large structures using well-populated scaffolds. This point was dramatically illustrated by the Willow Island cooling tower collapse in West Virginia, on April 27, 1978, as a result of which 51 employees were killed[4]. At the time of the collpase, the employees were working from scaffolds suspended from the partially-cured portion of the concrete shell 52 m (170 ft) above ground. A 1.5 m (5 ft) top section of the shell collapsed causing the scaffold and workers to plunge to the ground. Even though this incident is not included in the OSHA death statistics records used in this study (it did not occur within the specified time period), it clearly falls within the definition of foundation failures adopted in this study. The scaffold was entirely supported by the concrete shell which functioned as its foundation, but was not capable of resisting the imposed construction loads.

It is extremely unlikely that in practice much engineering attention is given to ascertain that the foundation used will provide sound and stable support to the scaffold and the imposed loads. In view of the potential hazards noted above, it is important that foundation problems receive high priority in any investigative effort aimed at the improvement of safety aspects of scaffolding practices.

4.3.6 Accessways

Accessways should provide the means for safe access of workers, materials or equipment to and from the work area of the scaffold. Examination of the accident statements revealed that in most instances improper accessways, or more often the absence of accessways, caused unsafe employee acts which led to accidents as highlighted by the following accounts. Accidents typically occurred in the absence of accessways when employees used the scaffold rungs, braces, frame sections, etc., to ascend onto or descend from the work platform. In all these cases an accessway failure was classifed as the secondary cause of the accident. In another instance, the absence of a proper accessway tempted an employee to jump down on the work platform which ruptured under the impact. In this case the absence of an accessway was interpreted as the primary cause of the accident. The conclusion drawn from these examples is that the problem is one of proper implementation of accessway regulations to keep employees from being tempted to perform an improper or unsafe act to gain access to the work area.

4.3.7 Safety Devices

Safety devices protect employees from falls, air-borne objects and other environmental (natural or human-made) hazards. Examples of installed safety devices are: guardrails, to keep employees from accidentally entering into hazardous areas such as falling from heights; safety nets, to capture employees in the act of accidental falls; and screens, to protect employees from air-borne (mostly falling) objects. Examples of devices worn by the workers are hard hats, goggles, safety shoes, heat- toxic fume- or electric shock-resistant apparel, etc. Once in progress, accidental falls can also be checked by a "fall protection system" (a term herein used) consisting of a safety belt worn by the employees, an independently suspended lifeline, and a lanyard hooked to the lifeline at one end and to the safety belt at the other. The OSHA employee and construction safety regulations spell out requirements for the various safety devices to be used in the workplace.

In reviewing the individual records of accident fatalities, it was noted that a significant portion of the cases involved non-compliance with existing OSHA regulations for safety devices. The explicit citations found among these records allowed an assessment to be made of the nature of primary causes of accidents attributed to safety device failures, as indicated by the following accounts: the top rail broke where an employee leaned over it to reach his work; another employee fell over a top rail reportedly less than 1.07 m (42 in) in height; in one case an employee fell where a lanyard which was rubbing against a toeboard broke; two instances were cited where the lanyard had too much slack in it and broke under the impact of the fall.

Explicit citations also helped identify numerous instances where a safety device was judged to have been the contributing factor to the accident in a secondary sense. These were predominantly cases where a guardrail was not present to prevent a fall, or fall protection systems were not independently suspended.

Based on the evidence at hand, it may be concluded that better utilization and maintenance of safety devices will have a significant impact in reducing the severity of the consequences of scaffold accidents.

4.4 ENVIRONMENTAL FACTORS

While reviewing the accident accounts, it became apparent that the cause of some accidents could not be related to failure of the scaffold system. Rather, other factors contributed to the events leading up to the accident or to the consequences of the accident. Many of these factors were related to conditions of the work environment while others involved some human element. Human factors are discussed in Section 4.5.

Conditions of the work environment are highly variable and often unique. Each job where a scaffold is utilized has peculiar space requirements and exposure to the natural environment. Also, there are many scaffold types and various uses of the same scaffold.

Conditions of the work environment were considered to be responsible for 17 percent of all accidents reviewed. Over 40 percent of the fatalities (6 out of 14), caused by factors related to the work environment, occurred on improvised scaffolds. The remaining 60 percent were distributed among other types. However, of those accidents whose consequences included injury to the worker, 40 percent occurred on manually propelled mobile scaffolds and 30 percent occurred on fabricated tubular frame scaffolds. At first glance, it might seem that scaffold type should not necessarily correlate with the occurrence of accidents where the work environment was a factor. However, after reviewing the descriptions of accidents involving the improvised and metal scaffolds mentioned above, the cited statistics take on some meaning. Improvised scaffolds are generally erected because space or access conditions prohibit the use of manufactured scaffolds. Examples of locations described in the accident reports include elevator shafts and the interior of a boiler hopper. In some cases where the accidents occurred on fabricated tubular frame or manually propelled mobile scaffolds (both manufactured scaffolds) the scaffold itself presented environmental hazards. For example, after a rain the metal tubes became slippery and made access difficult, or bolts protruded which scraped one worker. During normal operations these items of the scaffold constitute part of the work environment with which the worker has to deal. Manually propelled mobile scaffolds present the same hazards, but in the accidents reviewed problems were associated mainly with the wheels falling into ruts or striking objects or clutter on the ground surface.

Most of the instances where the work environment contributed to the accident involved hazardous circumstances due to the nature of the work that was being carried out. Several accidents occurred as a result of hazardous conditions in the work environment where the danger was implicit in the work. The workers violated the prescribed modes of work, exposing themselves to the hazardous conditions. In a few instances, a sudden event occurred during the course of work to disrupt the equilibrium of the worker. The inadequacy of fall protection then allowed the accident to proceed. In other instances fall protection was present and adequate, but the worker took a voluntary risk in order to complete some aspect of his work which could not be done easily from the work platform provided.

Several accidents involved hazardous conditions in which the nature of the work and the type of scaffold had no part. These conditions were attributed to such factors as slippery surfaces, materials on the work platform, or the natural environment which somehow disrupted the equilibrium of the worker. Conditions of the natural environment such as ice or gusts of wind can be disruptive to the stability of the scaffolding system as well. When this was the case, the particular accident was attributed to a system failure.

4.5 HUMAN FACTORS

The human element pervades through all activities during which accidents occur. There is interaction between the workers, the supervisor, the safety officer, and possibly the contractor during erection, maintenance, and dismantling operations. Coordination and perception are involved during a worker's access to the platform level and the performance of his normal tasks while on the platform. Furthermore, during many of the operations performed on the platform, there is communication and interaction between the people on the platform and others on the ground or at some other level.

It is often a matter of judgment as to whether or not the human element is actually responsible for a particular accident. If the scaffold system does not fail in any respect and no factor of the work environment appears to be responsible, it may indicate that an unsafe act was the cause of the accident. Most of the accidents reviewed, however, did not appear to be caused in a primary sense by the action of a person. Rather, the human element was merely one factor contributing to the set of events leading to the accident or to its consequences.

Referring to table 4.1 it is noted that human factors were the primary cause of about 10 percent of all the accidents reviewed. Most of the the accidents where a human action was primarily responsible occurred on manually propelled mobile scaffolds. These scaffolds appear to be prone to misuse. In one case, six scaffolds were lined up in a row and the worker fell while moving from one to the other. In another case, a worker jumped from a roof to the platform. Other cases involved coordination and memory: one man simply missed a step, another forgot that he had raised the platform to a higher level and fell because he descended directly from the platform. Several accidents involved the collective misuse by several persons. For example, workers who were on the scaffold while it was being pushed from below, died from the subsequent falls; a coworker's neglect in locking the brakes on the wheels of a mobile scaffold was the source of injury to a man working on the platform.

The highest percentage of accidents where human factors were involved in a seconday sense, occurred on two-point suspension scaffolds. The consequence of the accidents was death to a worker in every case. The human element involved here was failure of the worker to be adequately safeguarded against falls. Several reasons were found to have permitted this situation to exist: (1) a safety belt and lifeline or lanyard were not provided by the contractor or company supervisor, or (2) the equipment was provided and not used or (3) the equipment was not attached or used properly.

The human element in many accidents involved inadequate training or an involuntary situation. One drywall installer who fell from an improvised scaffold stated that the contractor had failed to supply a proper scaffold which he could use. One worker who overextended himself and fell commented that he had not been advised on the proper use of the scaffold. Another worker who fell as a result of defective planking pointed out the lack of safety inspection of the scaffold. In one case, a worker reported a defective brace to the union job steward. The steward ignored the comment and required that the man return to his work. Upon return to the scaffold the brace failed and the worker fell.

Some accidents occurred as the result of improper construction or use of the scaffold. One man removed a support and inadvertently stepped onto the scaffold thereafter. An accident occurred when a man tried to do work at a height of 2.7 m (9 ft) on a scaffold designed for work done at 1.2 m (4 ft). One telescoping scaffold was put into free-wheeling position downward when a hammerhead flew off and struck a makeshift crank. A pump jack collapsed when the worker standing on it tried to raise the center jack higher than the end jacks in order to do work at the top of an A-frame building. Also, the use of supporting elements as means of access was a frequent abuse and a source of many casualties.

5. SUMMARY AND CONCLUSIONS

This study identifies and interprets the causes of scaffold accidents based on information acquired from two different sources. One source provided individual accounts of scaffold accidents involving work-related fatalities resulting from scaffold accidents and supplementary records describing the incidents. The other source provided information on work-related injuries resulting from scaffold accidents reported by the injured workers on standard questionnaires.

The causes of accidents have been identified in this report with one of the following categories: system failures, environmental factors or human factors. In cases where an accident is attributed to a system failure, it is further identified with one of the sub-categories at the component level. A concept is introduced that allows an accident to be identified with a primary or secondary cause. The factor triggering the incident is viewed as its primary cause while a factor that fails to impede an accident in progress is viewed as a secondary cause. The following summarizes the major findings of this study.

In three out of four cases reviewed, the primary cause of the accident was identified with a system failure. At the component level within the system failure category, nearly one-half of the accidents were interpreted as having been triggered by connection and anchorage failures, and about one-fourth by safety device failures. The rest of the accidents were attributed to support element, foundation or platform failures. In one case the primary cause of the accident was classified as an accessway failure.

Primary system failures were caused by inadequate strength or lack of stability. The rupture of an anchor, platform, connection or support element, or yielding of a foundation were treated as conditions of inadequate strength to support the imposed loads. Among these, anchorage and foundation failures frequently created conditions of overall system instability. Several other instances were noted where conditions of local instability due to the absence of positive connections precipitated the accident. This was particularly true in cases of work platforms sliding or overturning under human-induced loads because they were unsecured or inadequately secured to the support systems. In other cases, connections and locking devices were not tight enough to prevent slippage or rolling.

Within the system group, there were numerous instances where the absence, defectiveness or improper use of a safety device was judged to have failed to impede an accident in progress. This represented about 80 percent of all secondary causes attributed to component failures. The problem appears to be related to non-compliance with existing safety regulations which give comprehensive coverage to provisions for the installation and proper use of such devices in the work place.

In one out of four cases, the primary cause of the accident was attributed to a human or environmental factor. In such cases, environmental factors occurred about twice as frequently as human factors. On the other hand, two to three times as many human factors as environmental factors were considered to have been the secondary causes of the accidents. Environmental conditions triggering accidents were typified by sudden or unexpected occurrences such as an electric flash or ignition of gas, the presence of toxic fumes, excessive heat, slippery surfaces, debris and other obstructions in the work area, or impact by a crane or other moving equipment. The primary cause of an accident was attributed to a human factor in cases where such incidents were triggered by what were judged voluntary unsafe acts. Inadvertent misuse or involuntary acts were classified as human factors contributing to accidents in a secondary sense.

This report also classified the frequency of accidents according to the various types of scaffolds used. The trend of the accident data indicates that the highest rates of incidents, which collectively represent about 90 percent of all the casualties, occurred on manually-propelled mobile, tubular frame, bracket, wood pole and improvised scaffolds. Improvised scaffolds are less likely to comply with safety regulations than other types while manually-propelled mobile scaffolds appear to lend themselves to misuse. However, the incident rates indicated for the various types of scaffolds cannot be used for the purpose of assessing the proneness of a particular scaffold to accidents relative to other types without statistical information on the frequency of use of each type. At this time, information on the frequency of use of each type is not available. A particular trend was the number of cases involving two-point suspension scaffolds where the secondary cause of the accident was attributed to a safety device failure. Ten out of 22 types of scaffolds identified in this study were not associated with any of the accidents reviewed.

6. RECOMMENDATIONS

The analysis of scaffold accidents presented in this report brings into focus potential safety problems in the design, erection, operation and maintenance of scaffolding systems used in construction work and other applications. The following statements suggest an approach to trace the source of these problems and to develop an appropriate course of remedial action.

To understand the need for identifying the source of a particular safety problem, it must be recognized that an analysis of accident records alone will not suffice and further investigative efforts must be performed. Without identifying or having proper knowledge regarding the problem, it is not possible to prescribe the best course of remedial action for its resolution.

Limitations of the available accident data must be recognized as well. The records that were examined were post-facto witness statements usually made by laypersons in the technical sense. Therefore, the accounts generally lack the type of specifics by which a complete and technical evaluation of the problem can be performed. This limitation in itself warrants the need for an on-site study, performed by a technically oriented team. However, before such a program is implemented, a review of all applicable codes and standards must be performed. Such a review should identify any major deficiencies in existing scaffolding provisions such as inconsistencies, inadequacies, lack of clarity, noncomprehensiveness or unenforceability and their possible correlation with the problem areas encountered in this accident study. This assessment is further warranted in a review of a recent independent study which revealed major discrepancies in pertinent OSHA regulations regarding allowable design properties of wood used in scaffolding [5].

It is further recommended that a comprehensive literature search for technical and non-technical information regarding scaffolding systems be performed. This task would serve as a means to determine whether any code deficiencies which may exist are due to a lack of technical information or a lack of recognition of such existing information.

The foregoing tasks are viewed essential in corroborating the findings of this accident study and in identifying prime targets of needed research to develop the technical basis for the improvement of scaffolding practices. Once such tasks have been substantially performed, a field technical evaluation of scaffolding systems and practices with documentation is recommended.

Such an exploratory field investigation of selective scaffolding installations during operation will enable the identification of realistic and common scaffolding practices. The purpose of this effort would be to evaluate the intensity and distribution of construction loads (including dynamic effects), to identify the types and conditions of system components in prevalent use and to develop an understanding of safety problems due to those factors identified in this accident study and the other studies recommended above. Once the origin of the major safety problems have been identified in conjunction with the other information mentioned above, it would then be possible to develop a comprehensive research plan that would address and resolve these problems in the most effective manner.

A research plan formulated on the basis of this study alone, will have to place heavy emphasis on structural investigations of system components in recognition of the finding that indicates three out of four accidents are attributable directly to system failures. It should be noted that even without taking into consideration such casual factors as the absence or improper use of components (which fall within the broad definition of system failures adhered to in this study) the structural failures of system components accounted for more than 50 percent of all the accidents reviewed.

Anchorage and connection problems appear to be particularly critical in light of the high rate of incidents attributed to their failure. However, noting that significant problems exist with regard to platform, foundation and support element failures observed, they should also be given research recognition.

Based on all of the above mentioned efforts, a final recommendation would consist of formulating a comprehensive set of construction standards that will promote and facilitate safe scaffolding practices. The abovementioned research efforts would enhance and develop the scientific and technological base by which such a set of safety standards could be formulated.

7. REFERENCES

1. Study of Scaffolding Accidents Resulting in Injury, Conducted by the Bureau of Labor Statistics (BLS) under the auspices of the Occupational Safety and Health Administration (OSHA) for the period of May to November, 1978. No publication, for administrative use only.

2. OSHA Fatality/Catastrophe Investigations, Occupational Safety and Health Administration, U.S. Department of Labor, Washington, D.C., May, 1979.

3. Occupational Safety and Health Standards (Federal Register 1910 and 1926), Occupational Safety and Health Administration, U.S. Department of Labor, Washington, D.C., 1974.

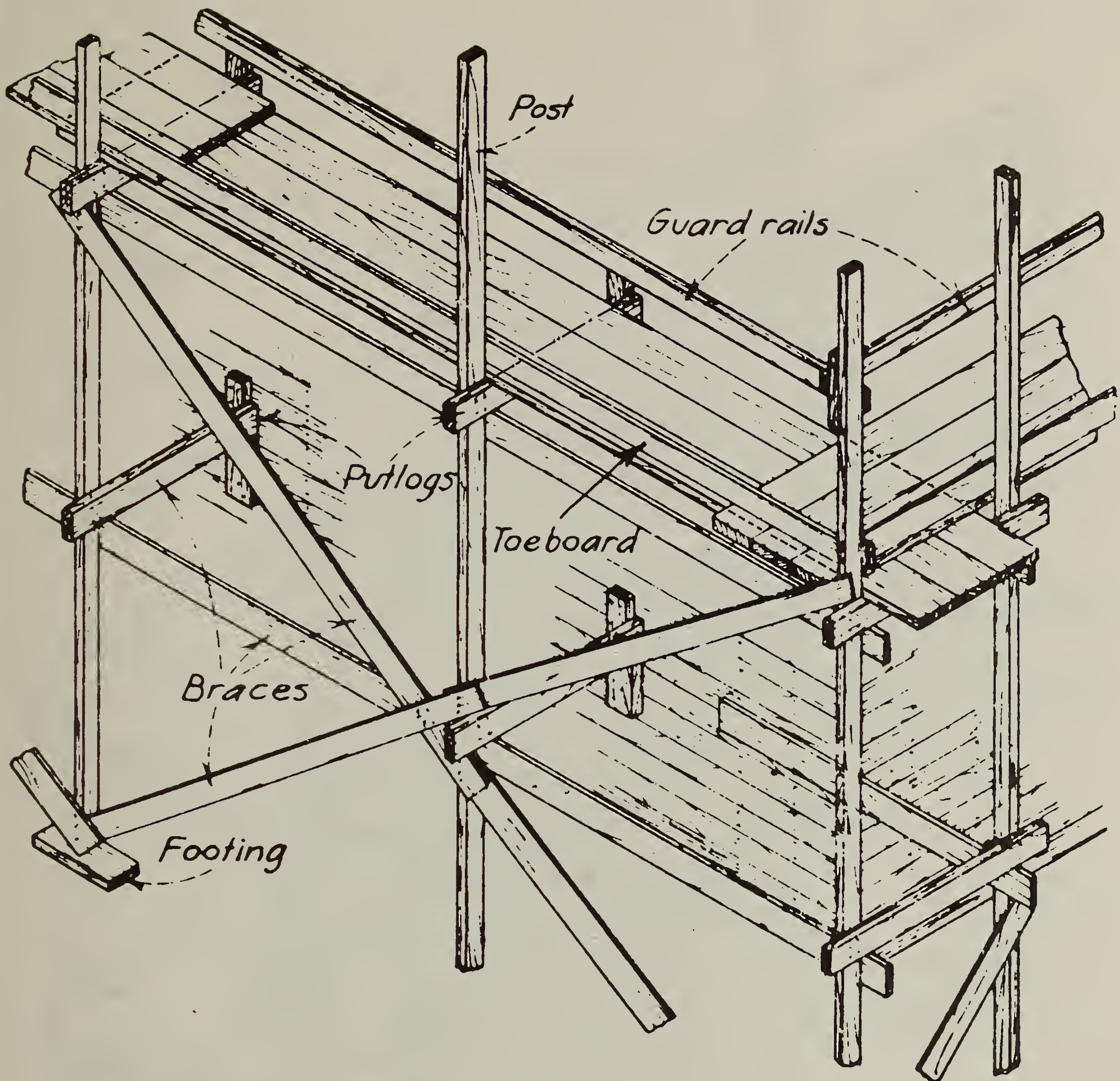
4. Lew, H.S., Fattal, S.G., Shaver, J.R., Reinhold, T.A., Hunt, B.J., Investigation of Construction Failure of Reinforced Concrete Cooling Tower At Willow Island, West Virginia, NBSIR 78-1578, Center for Building Technology, National Engineering Laboratory, National Bureau of Standards, Washington, D.C.

5. Eisenacher, E.A., Evaluation of OSHA Scaffolding Standards, Newport News Shipbuilding, Newport News, Virginia, January, 1979.

APPENDIX A

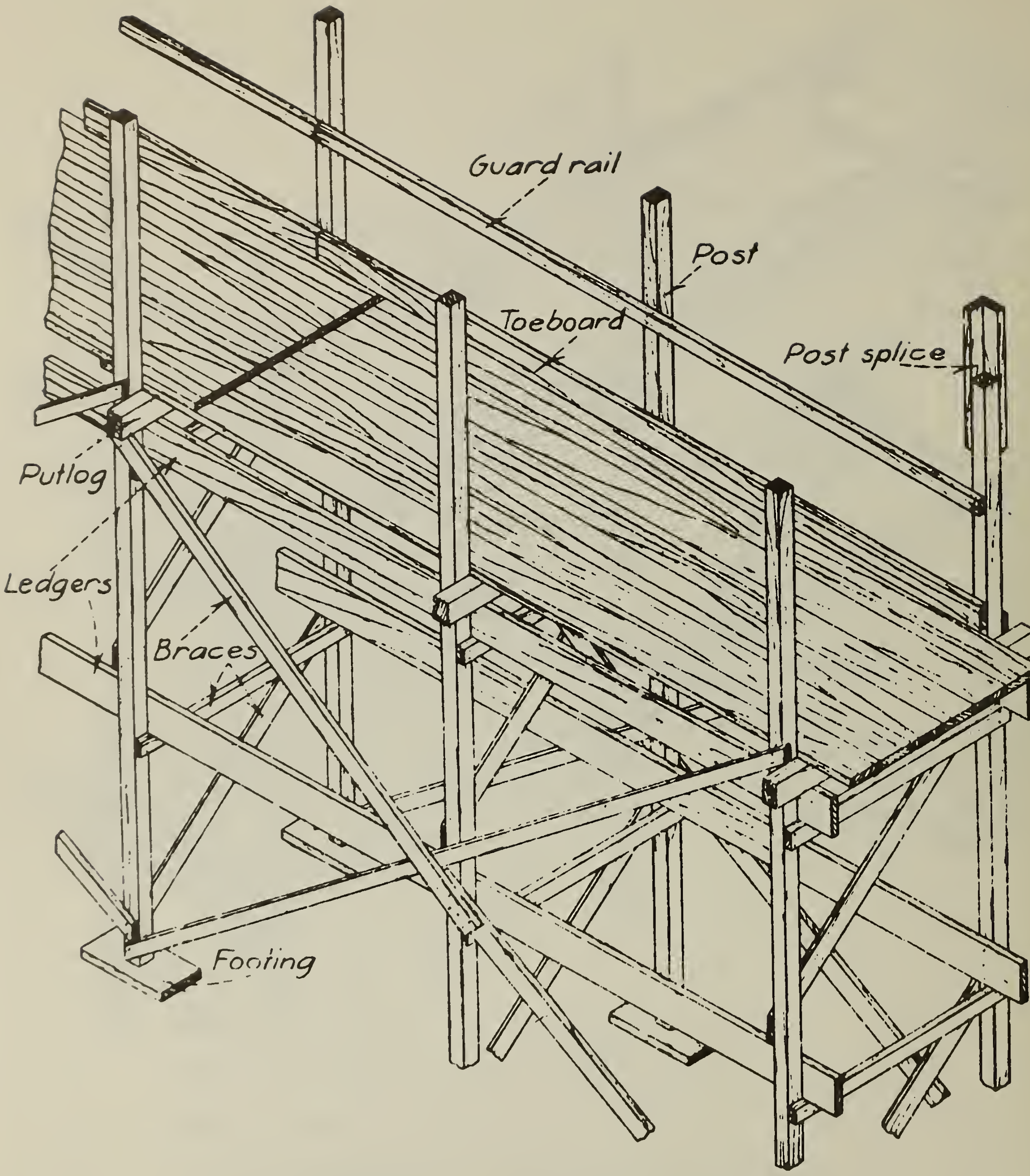
Twenty-One Major Scaffold Types Addressed By The Codes and Standards

TABLE OF CONTENTS



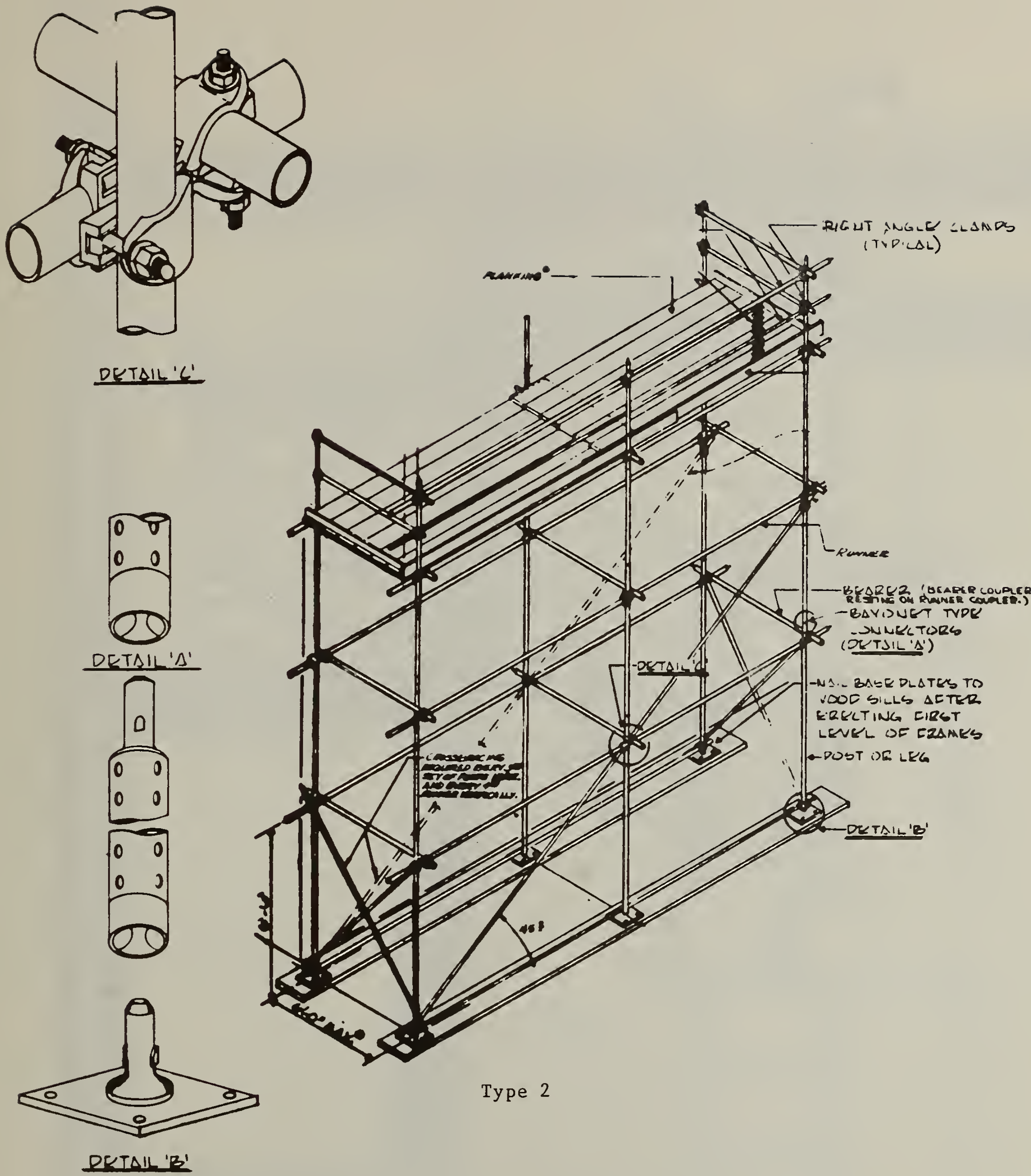
Type 1a

Figure A.1. Wood pole scaffold - (a) single post.



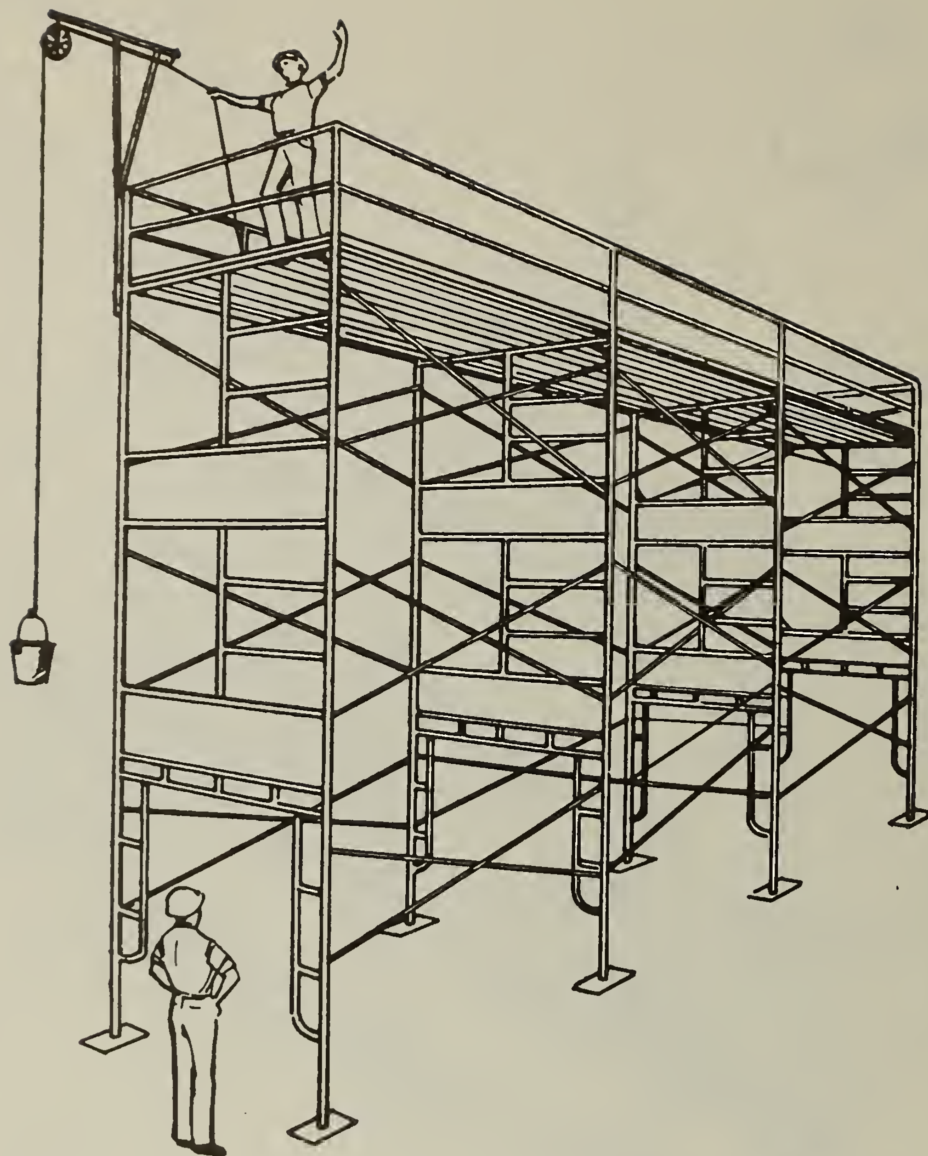
Type 1b

Figure A.2. Wood pole scaffold - (b) independent post.



Type 2

Figure A.3. Tube and coupler scaffold.



Type 3

Figure A.4. Fabricated tubular frame scaffold.

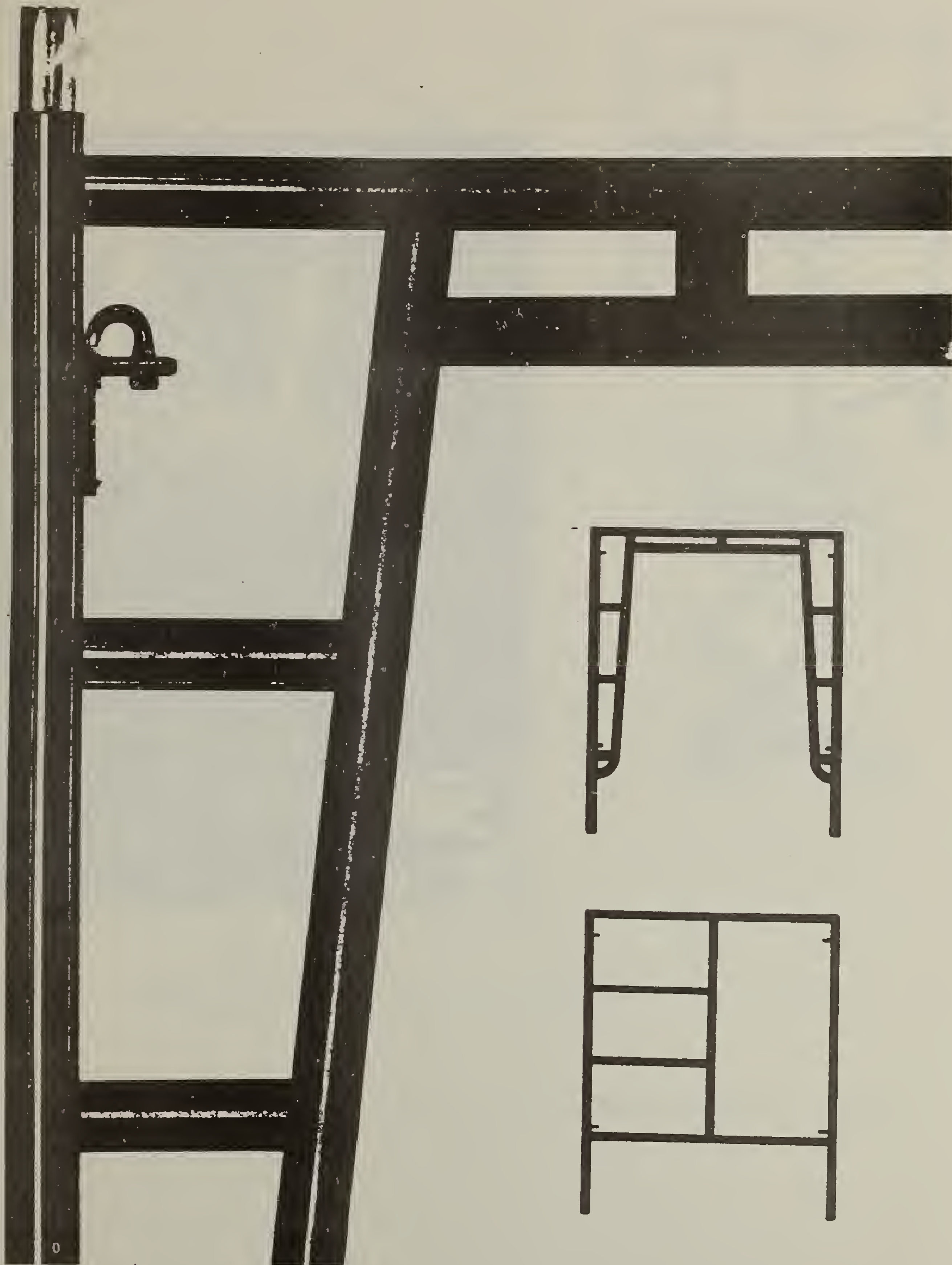
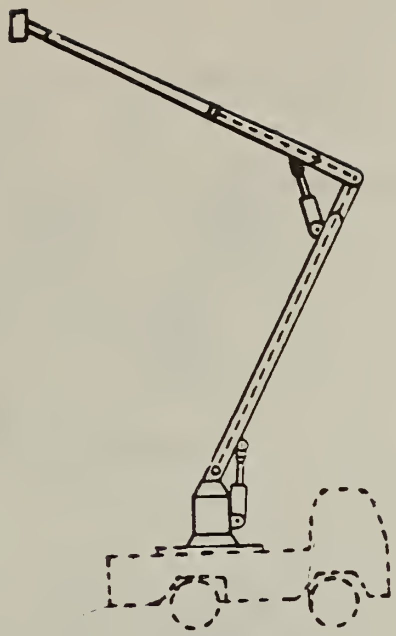


Figure A.5. Tubular frame subsystems.

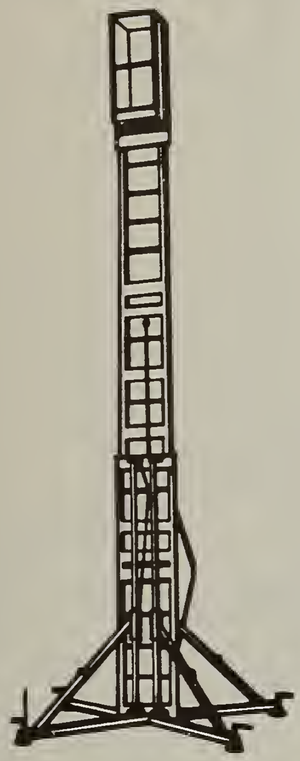
(a) Type 4

(b) Type 4

Figure A.6. Manually propelled mobile (a) ladder stand and (b) scaffold (tower).



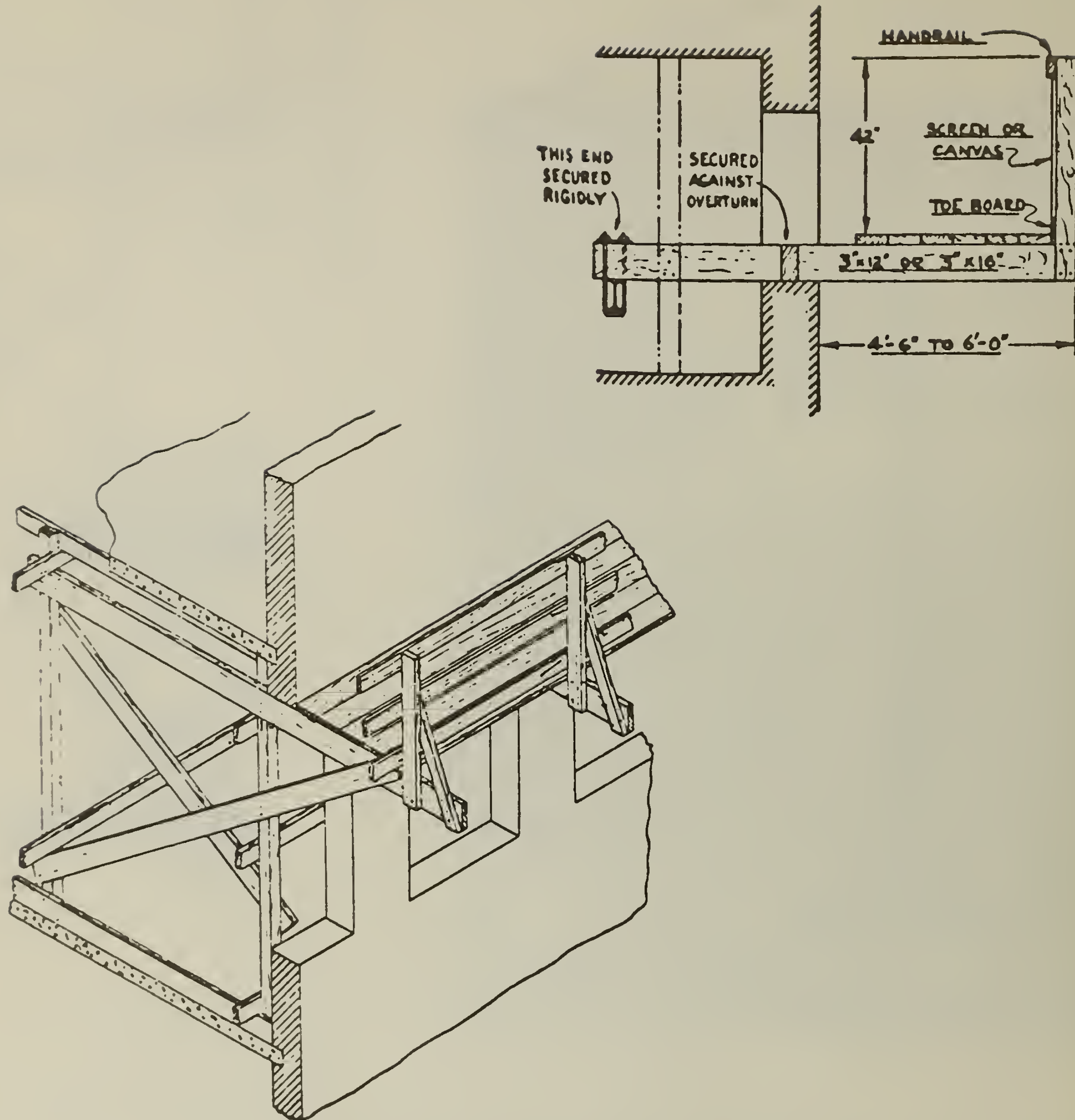
(a) Type 5



(b) Type 6

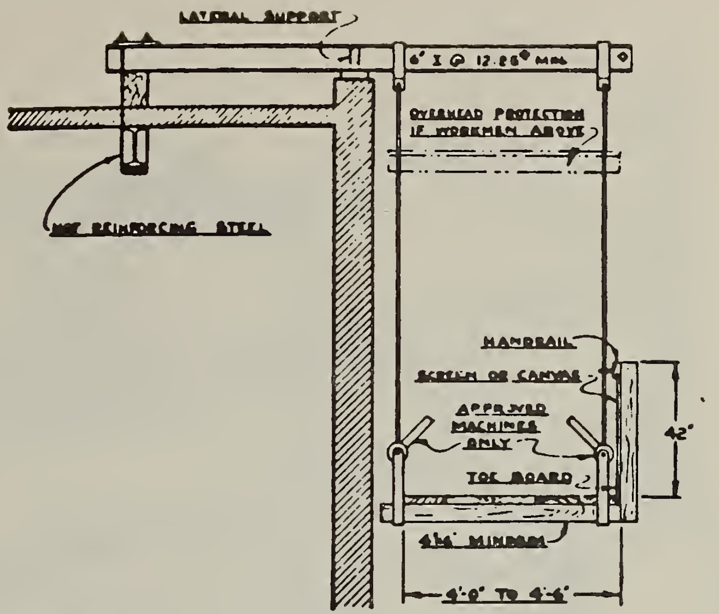
(c) Type 7

Figure A.7. (a) Vehicle-mounted elevating and rotating, (b) telescoping, and (c) self-propelled elevating work platforms.

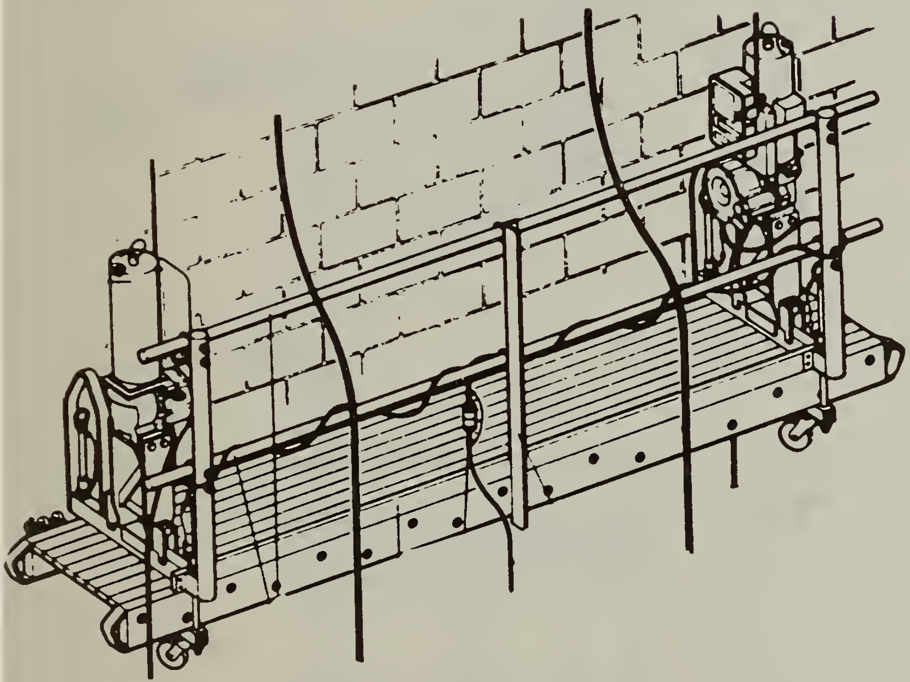


Type 8

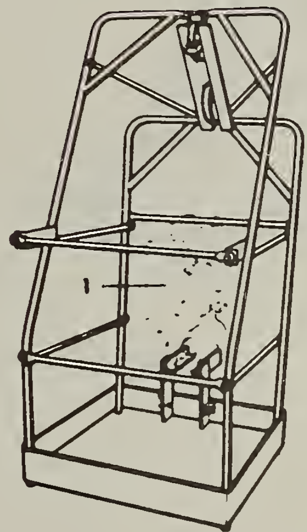
Figure A.8. Outrigger scaffold



(a) Type 9

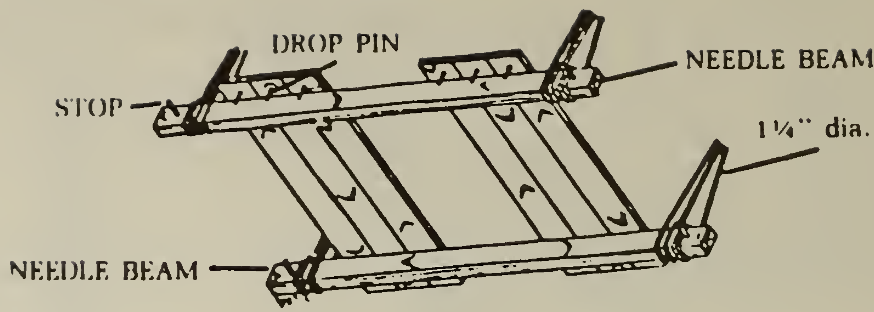


(b) Type 10

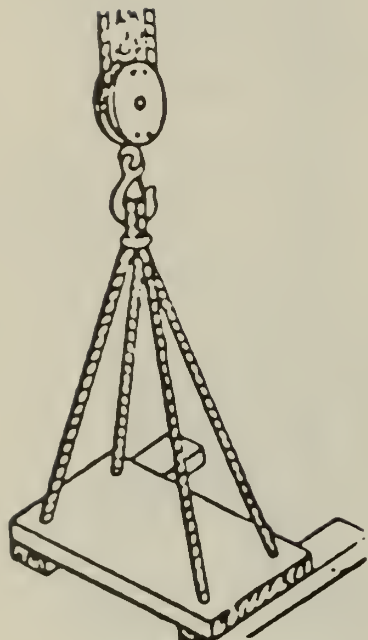


(c) Type 11

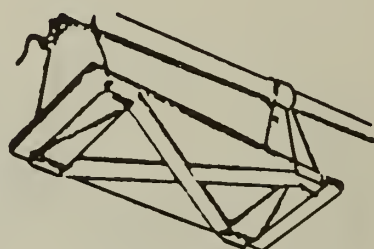
Figure A.9. (a) Adjustable multiple-point (masons' or stone-setters'), (b) two-point (swinging), and (c) single-point suspension scaffolds.



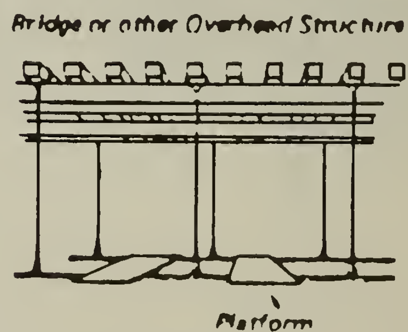
(b) Type 13



(a) Type 12

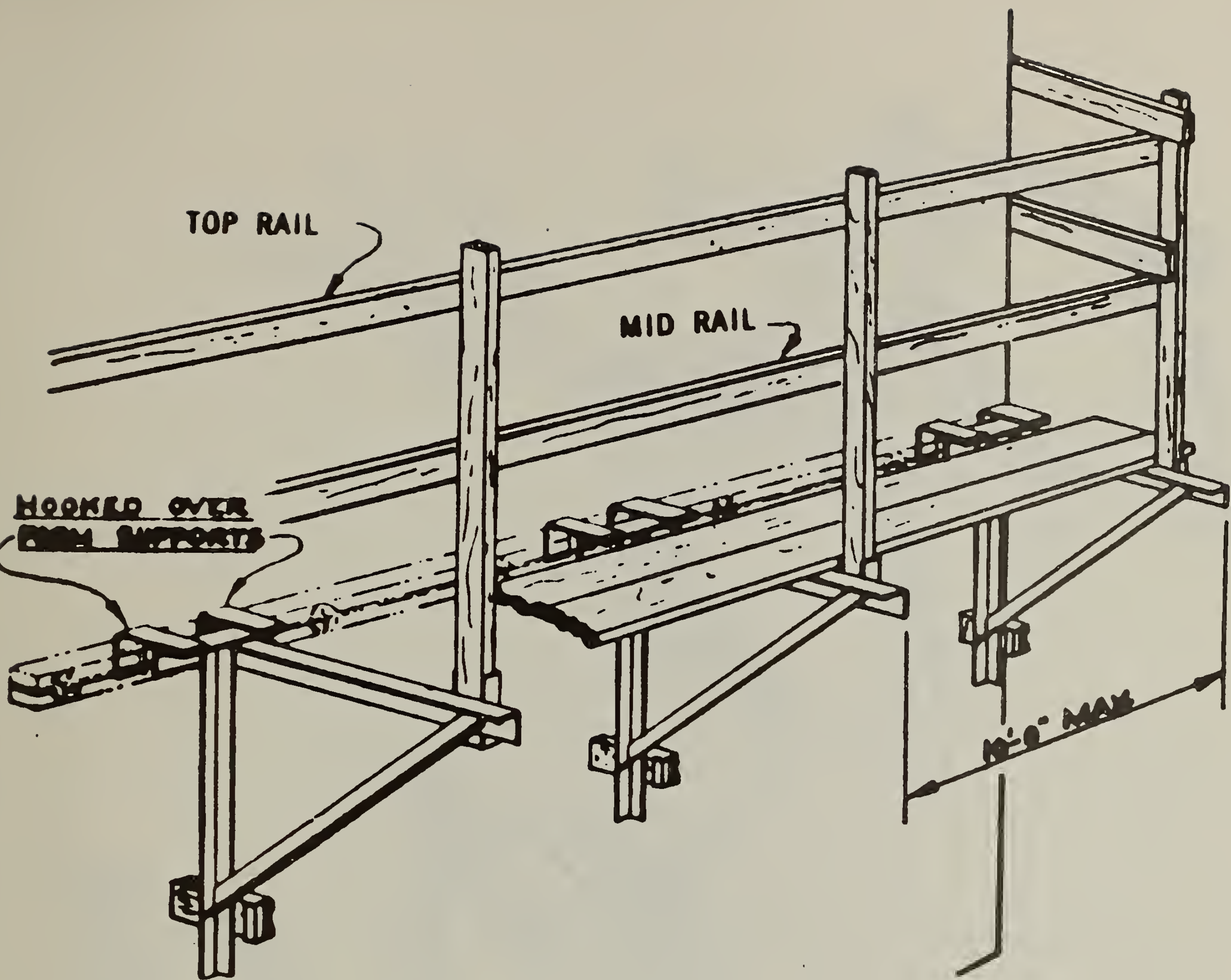


(c) Type 14



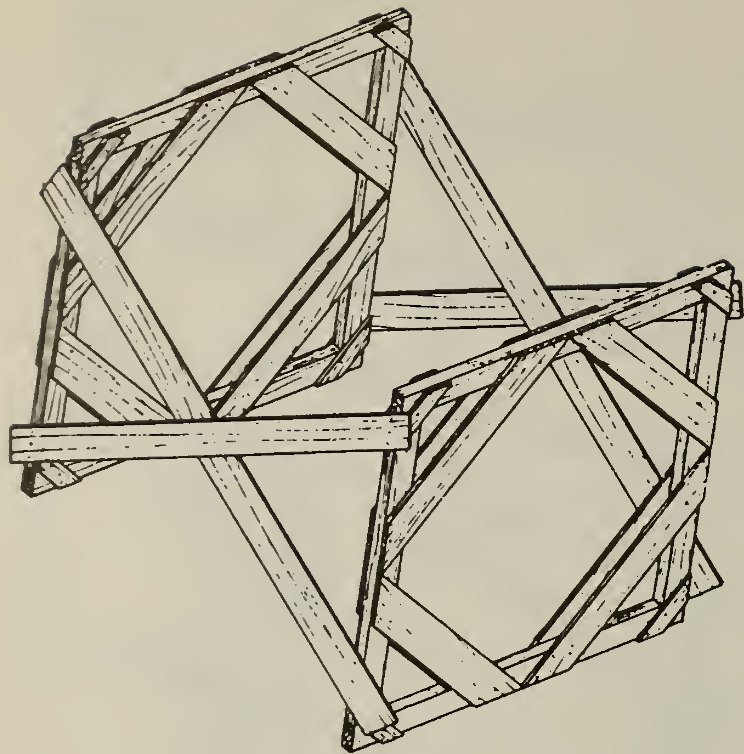
(d) Type 15

Figure A.10. (a) Boatswain's chair, and (b) needle beams, (c) float or ship, and (d) catenary scaffolds.

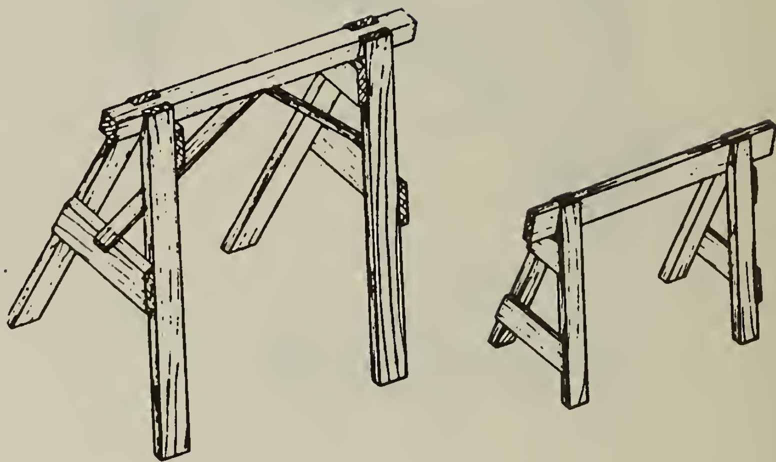


Type 16

Figure A.11. Bracket (carpenters' bracket) scaffold.

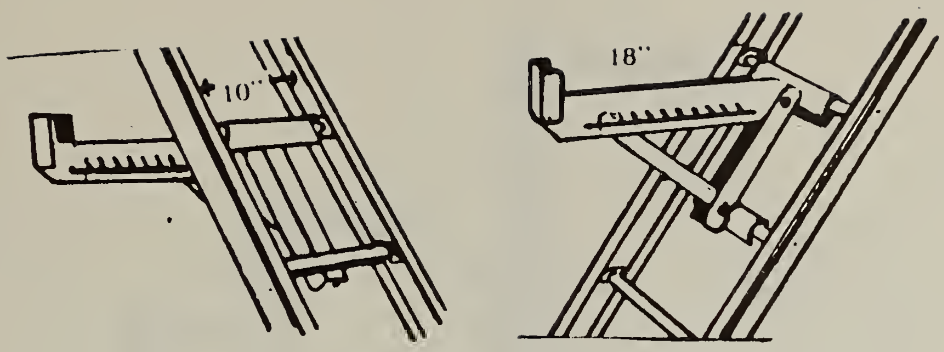


(a) Type 17

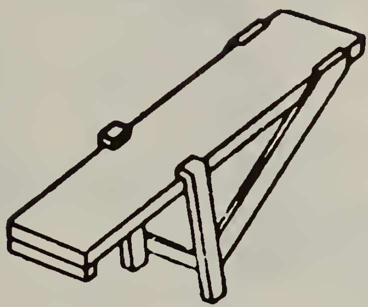


(b) Type 18

Figure A.12. (a) Square (bricklayers' square) and (b) horse scaffolds.

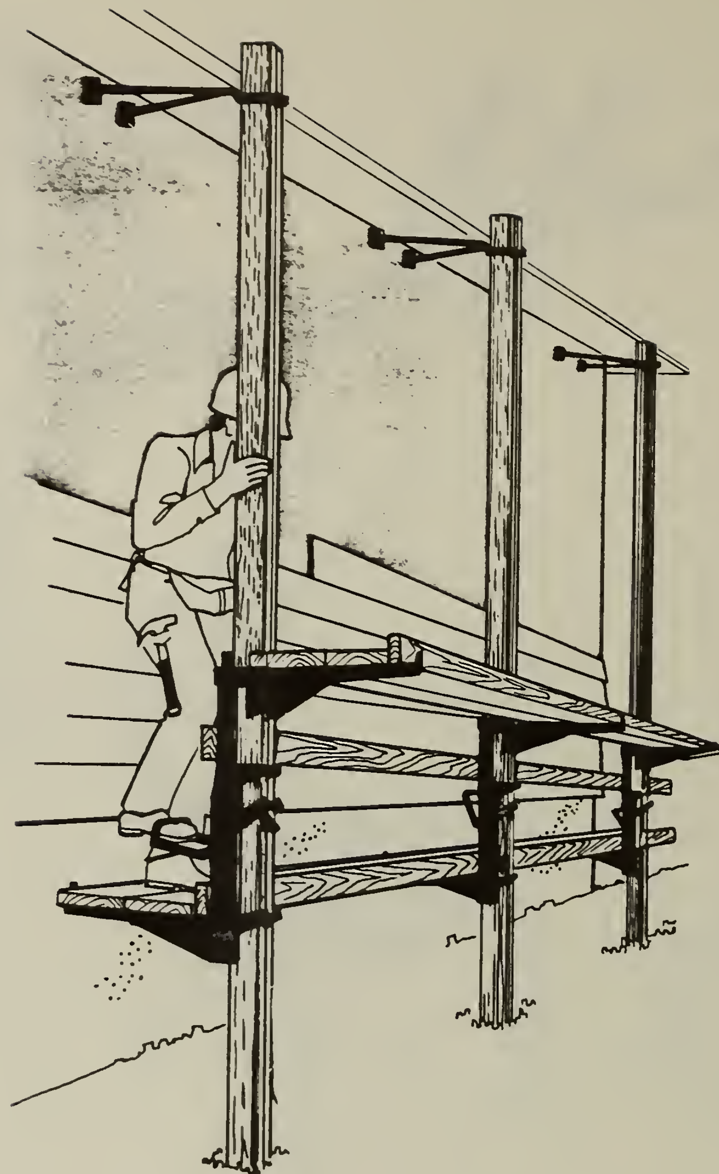


(a) Type 19



(b) Type 20

Figure A.13. (a) Ladder jack and (b) window jack scaffolds.



Type 21

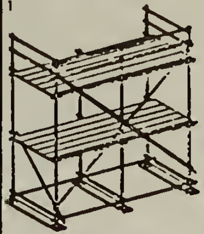
Figure A.14. Pump jack scaffold.

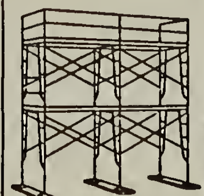
INSTRUCTIONS:

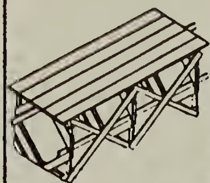
A. From the scaffolds pictured below, identify the one which most closely resembles the scaffold you were working on. Then circle the number in Section I *(on page 1)* which corresponds to that scaffold.

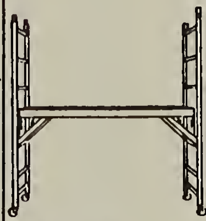
B. If the type of scaffold you used does not resemble those pictured, draw or describe the scaffold in box # 17 below and circle # 17 in Section I *(on page 1)*.

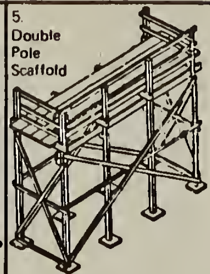
Self-Supported Scaffolds

1

Tube & Coupler Scaffold

2.

Welded Tubular Scaffold

3.

Bricklayers Square Scaffold

4.

Ladder Scaffold

5. Double Pole Scaffold


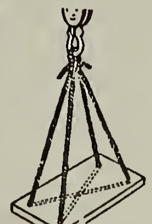
Suspended Scaffolds

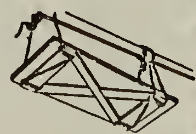
6.

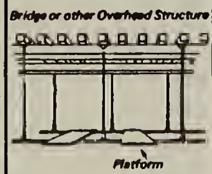
Two Point Suspension Scaffold

7.

Single Point Scaffold

8.

Boatswain's Chair

9

Float Scaffold

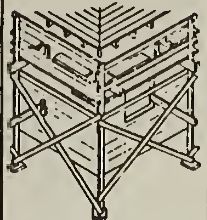
10


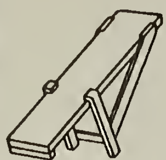
Catenary Scaffold

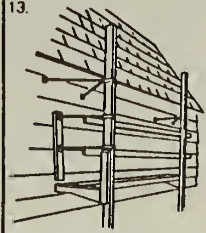
17. Other Type of Scaffold

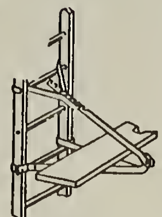
(Use back if necessary.)

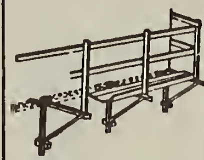
Scaffolds Supported By Structure or Other Methods

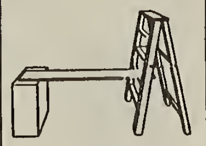
11.

Single Pole Scaffold

12

Window Jack

13.

Pump Jack Scaffold

14.

Ladder Jack Scaffold

15.

Bracket Scaffold

16.

Improvised Scaffold

APPENDIX B

Types of Scaffolds Identified in the Questionnaire of the Work Injury Survey of the Bureau of Labor Statistics

NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 79-1955	2. Gov't. Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE Analysis of Scaffolding Accident Records and Related Employee Casualties			5. Publication Date January 1980
			6. Performing Organization Code
7. AUTHOR(S) S. George Fattal, Christopher Mullen, Hai S. Lew, Bernard J. Hunt			8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, DC 20234			10. Project/Task/Work Unit No.
			11. Contract/Grant No.
12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)* National Institute of Occupational Safety and Health Department of Health, Education and Welfare Washington, D.C.			13. Type of Report & Period Covered
			14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report analyzes the causes of scaffold accidents involving employee casualties based on existing records of such incidents. Where possible, the causes are identified with system failures, environmental factors or human factors. System failures are further subdivided into categories to pinpoint the exact nature of the event that triggered the accident. The study provides an insight into the major safety-related aspects of scaffolding practices and points out the types of remedial measures that should be instituted to mitigate the frequency and consequences of scaffolding incidents. Simultaneously, it identifies critical research needs to develop the technical basis for the improvement of the safety aspects of scaffolding practices.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Accidents, accident statistics; construction regulations; construction safety; employee casualties; environmental hazards; human factors; occupational safety; scaffolds; scaffold failures.

18. AVAILABILITY ☒ Unlimited	19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED	21. NO. OF PRINTED PAGES
☐ For Official Distribution. Do Not Release to NTIS		
☐ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003-	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price
☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161		

USCOMM-DC