PB83-236083

PILOT PROGRAM TO EVALUATE THE EFFECTIVENESS OF OSHA CONSTRUCTION STANDARDS AT THE POINT OF ERECTION

FINAL REPORT

James H. Pals
Joe D. Kane
Jody S. Marcello
Western Institute for Research and Education, Inc.
Denver, Colorado 80227

Ronald Stanevich
Project Officer - NIOSH
NIOSH #210-81-3008

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Appalachian Laboratory of Occupational Safety and Health
Division of Safety Research
Morgantown, West Virginia 26505

January 15, 1982

DISCLAIMER

The contents of this report are reproduced herein as received from the contractor.

The opinions, findings, and conclusions expressed herein are not necessarily those of the National Institute for Occupational Safety and Health, nor does mention of company names or products constitute endorsement by the National Institute for Occupational Safety and Health.

NIOSH Project Officer: Ronald Stanevich
Principal Investigator: Joe D. Kane

ATTENTION

PORTIONS OF THIS REPORT ARE NOT LEGIBLE. HOWEVER, IT IS THE BEST REPRODUCTION AVAILABLE FROM THE COPY SENT TO NTIS.

ACKNOWLEDGEMENTS

A wide number of people gave of their time and expertise to make this report possible. These people include safety experts, union officials, contractors, associations executives, and OSHA officials too numerous to name here. It is hoped that each will accept the gratitude of the project team for the hours of time spent and their willingness to thoroughly explore the research question.

PREFACE

Totally accurate usage of the English language sometimes requires that somewhat cumbersome terms be used. In order to improve the readability of this report, the liberty of simplifying terms was taken. Therefore, although it is quite clear that connectors may be either male or female persons, only the male pronouns (such as "he", "him", and "his") are utilized in the report.

ABSTRACT

Both labor and management in the construction industry are concerned with the enforcement of four OSHA construction standards (regarding the use of safety belts, nets, and training) at the point of erection. This concern prompted this project which is a pilot program to evaluate the effectiveness of these standards at the point of erection in steel and precast/prestressed erection. To accomplish this objective, nine erection sites of various kinds were visited; contacts were made with unions, contractors, associations, and various OSHA officials; and data was obtained regarding fall accidents occurring at the point of erection.

A wide variety of connection situations are encountered by connectors at the point of erection. Many of these differences result because of the diversity of steel and precast/prestressed concrete structures involved. The activities of connectors on various types of structures is presented in Chapter 3.

The need for mobility, the speed of the erection process, and the lack of attachment points often make it difficult to implement the safety belt and safety net standards. Many contractors and connectors prefer to rely on training.

It was determined that there is apparently a wide variance in the way these standards are enforced in various parts of the country. Further, the Courts and the OSHA Review Commission disagree concerning how citations for some of these standards should be handled. There is disagreement about whether or not the standards are vague, whether or not belts and nets are practical and feasible in certain situations, whether or not industry practice should be a controlling factor, and whether or not the general construction standards apply to steel erection. (Discussed in Section 4.1.)

Contractors have several incentives and disincentives for complying with these standards. These deal with such things as bid competition, costs, work efficiency, insurance, and labor force competition. (Section 4.2)

Safety belts can be used in a variety of situations, but falls into belts can injure a person and belts restrict the mobility of connectors. Nets, though more costly, can provide fall protection for workers moving form point to point. Net installation provides some problems, but these problems have been overcome in the use of perimeter nets on steel tiered buildings in one area of the country, and the use of nets on bridges is widely accepted. Training is largely accomplished on-the-job or by unions, though neither is formalized. The foreman a connector works under has a large influence on the training of a connector in safe work practice. (Sections 4.3, 4.4 and 4.5)

There is a great deal of variance among the various written standards (OSHA, Cal/OSHA, ANSI, Ontario, and U.S. Army Corps of Engineers). The OSHA standards are vague about training, do not provide guidelines for use when standard compliance is impractical, and do not specify exactly when a safety belt must be used. Also, there are several fall hazards not addressed in the standards. (Chapter 5)

It is recommended that guidelines be developed so that safety is established during the design stage, that OSHA enforcement be balanced nation-wide, that changes in the written standards be made to exclude gaps and voids, that federal agencies require fall protection in bid specifications, that a needs analysis be performed to provide objectives for connector safety training, and that a full-scale scientific study be conducted to determine the effectiveness of the standards. (Chapter 6)

This report was submitted in fulfillment of NIOSH Contract #210-81-3008 by Western Institute for Research and Education under the sponsorship of the National Institution for Occupational Safety and Health.

TABLE OF CONTENTS

TABLES

FIGURES

CHAPTER 1. BACKGROUND AND INTRODUCTION

1.1 BACKGROUND AND HISTORY OF THE PROBLEM

The use of iron in the construction of bridges and the special breed of men who erected them were two important contributing factors leading to the skyscrapers, domed stadiums, and space needles of today. Who erects structural steel thirty-five stories high, where historically the only available protection against falls was experience and ability? He is someone with an excellent sense of balance and no fear of heights— a connector. These people are unique individuals, even among the iron workers themselves. Not everyone is comfortable walking narrow beams at heights. Therefore, connectors are a special type of people who take great pride in their abilities to do what others fear and to work comfortably where others are uncomfortable.(1)

These connectors, because they position the first members in the structure, often have to place themselves where there is little support and where appearances would make it seem almost impossible for a person to work. In the early days of high bridge and steel connection work, there was little to insure the safety of the connector. In the years since, many improvements and have been made by both contractors and labor unions to change this situation and provide safety for these workers.

In 1971, the Occupational Safety and Health Act (OSHA) was passed to establish safety standards for industry and construction. Of necessity, the standards were written broadly, so that they would apply to a multitude of situations. The unique aspects of constructing tiered buildings with steel were recognized by OSHA, and Subpart R of the construction standards was written to specifically address this erection process. However, many of the more broadly written consensus standards, specifically those requiring the fall protection provided by safety belts, safety nets, and training, also applied to steel erection and to connectors.

Connectors and contractors have sometimes found it difficult to comply with standards requiring that a connector be attached by a safety belt and lanyard to the structure (29 CFR 1926.104). They argue that there is a need for connectors to remain mobile during the initial placement and connection of structural members, especially if one of these members should swing out of control in the direction of the connector. Additionally, the use of lanyards and lifelines may create tripping hazards, and there is often no structure overhead where a lifeline can be secured. Some contractors have found it difficult to provide safety nets (29 CFR 1926.105 and 29 CFR 1926.750(b)(1)(ii)), because, in many cases, the location of

such protection is constantly shifting due to the continually changing point of erection area as each member is attached to the structure. Therefore, in many cases, the time necessary to install, test, and remove the nets may exceed the time necessary to complete the erection process. Additional arguments state that nets might interfere with the movement of the crane and with the erection process itself. Because of these potential problems with the use of belts and nets, construction contractors, workers, and others believe that the most practical method of protecting connectors at the point of erection is through training (29 CFR 1926.21(b)(2)) and experience.

Some OSHA compliance officers interviewed during this project informally recognize that although connectors often work in hazardous situations, it is difficult to apply these broad standards to their unique activities. In many parts of the country, an informal understanding was reached to make allowances for connectors, while at the same time realizing that it is feasible for other iron workers to comply with these standards. As a result, few citations were issued for the failure to use fall safety devices to protect connectors.

While some of the problems with protecting steel connectors were recognized and allowances made for them, such has not been the case with precast/prestressed concrete connectors. Compared with the amount of time steel has been used in building construction, it was only recently that precast and prestressed concrete products began to be manufactured and erected into buildings. As this occurred, OSHA did not recognize the similarities with steel erection.

OSHA began to cite precast/prestressed concrete erection contractors for not using handrails to protect connectors at the leading edge of the erection.(2) As a result, members of this industry began to work with OSHA to explain their erection processes and that if a handrail is required on the leading edge of a roof, it would prevent the erection of the next member. Citations also resulted for the failure to use safety belts and nets to protect connectors.(3) Again, the industry responded by going to OSHA to explain how these devices limit the erection process. Some industry members pointed out that precast/prestressed concrete erection is similar to steel erection and that precast/prestressed connectors should be treated in a manner similar to steel connectors. One similarity, they argue, is the need for mobility if an emergency occurs, because the most dangerous situation in precast/prestressed erection is said to be a double tee swinging out of control. Again, net installation could take longer than the erection process and such nets would often have to be placed directly where a new member needs to be positioned. Additionally, the installation of nets in some cases appears to require the net installers to be exposed to a fall hazard for a longer period than the connectors would be if nets were not used.

In recent years, it has become obvious that there is a need to study how a connector in both steel and precast/prestressed erection might be protected and if the standards can be applied. In California, the California Occupational Safety and Health Administration (Cal/OSHA), union representatives, and contractors combined their efforts to rewrite some of the construction standards so that they would apply directly to connection work.(4) Other

recent activities in this subject area include a study by the National Erectors Association to determine the frequency of connector falls to the perimeter of tiered buildings.(5) A more recent study has been done by the Institute for the Iron Working Industry to examine falls from elevations.(6) The precast/prestressed concrete industry is also well aware of the problem, as demonstrated by their request for an OSHA variance regarding connector work and distribution by the Prestressed Concrete Institute of an audio/visual program dealing with safety in precast/prestressed concrete erection. There have also been recent developments in perimeter net systems by contractors and manufacturers, which may make their use more possible.(7)

These activities, among others, demonstrate an increased awareness of the problem and a stronger effort to solve it. Therefore, it is logical that a study be commissioned to examine the various points of view, assemble an overview of situations which fairly represent the difficulties of connectors complying with these standards, provide recommendations on how to solve these problems, and determine what additional research is needed and is feasible.

1.2 INTRODUCTION TO THE PROJECT

As stated in the project contract, the purpose of the project is as follows:

> The construction industry (labor and management) has expressed concern about problems due to implementation of standards (29 CFR 1926.21 (b)(2) Safety Training and Education; 29 CFR 1926.104 Safety Belts, Lifelines and Lanyards; 29 CFR 1926.105 Safety Nets; 29 CFR 1926.750 (b)(1)(ii) Temporary Flooring - skeleton steel construction in tiered buildings. *The full text of these standards is located in Appendix A.)* The industry contends that these standards cannot be effectively implemented in many instances at the point of erection. Point of erection is defined as that place where initial placement and connection of structural members occurs and where employees performing the initial connection are exposed within the swing radius of the member being erected. National Safety Council statistics (Accident Facts - 1978 edition) show that there were 2500 fatalities within the construction industry. Some of those fatalities may have resulted from point of erection operations.
>
> This contract was a pilot program to evaluate the effectiveness of the OSHA construction standards at the point of erection.

1.2.1 METHODOLOGY

This effort was designed to collect existing data to determine whether or not the accidents occurred as a result of a violation of one of the standards in question. In the early phases of the project, it became evident that there was very little literature and few previous studies specifically related to this problem. For this reason, site visits and informal contacts took on additional importance as sources of information. Nine geographically distributed on-site field investigations were conducted to examine the applicability of these standards to point of erection operations. During some of these visits, two members of the International Association of Bridge, Structural and Ornamental Iron Workers served as consultants. They were chosen because they have a combination of over forty years experience in the erection of steel and precast/prestressed concrete structures. Mr. Samuel D. Grimes, Sr., and Mr. Richard McMillan, these two consultants, provided detailed, practical knowledge from the connector's viewpoint regarding what is possible at the point of erection. This knowledge greatly aided in formulating the conclusions presented in this report.

Based on these efforts, this report presents information concerning whether or not the standards are effective. It also provides recommendations for new or revised procedures and practices for the protection of connectors in the situations where standards are determined to be ineffective. Gaps and voids in the standards and recommendations as to where additional research is needed to determine how to protect the connector are also presented.

1.2.2 PARAMETERS OF STUDY

This report is limited to discussion of information relating to the four standards stated in the purpose of the project as they relate to connector activities. The general personal protective equipment standard (29 CFR 1926.28(a)) is also considered because it is often cited in conjunction with the safety belt standard. (See Appendix A for text of standards.)

In order to focus and better define the type of information to be gathered and studied, the following parameters were established. The only situations studied were those where the connector should have been protected by one of the subject standards. Therefore, not included were situations where the connector worked off a ladder or scaffold, and thus was not subject to the requirements of the standards in question. Particular attention was paid connection situations where there would be a potential fall of over 25 feet, because the standards indicate that this is when fall protection should be provided. Only those types of structures and point of erection situations where such a hazard exists were studied.

1.3 PROJECT APPROACH

1.3.1 DATA COLLECTION

Many potential sources of accident data, relating to connector falls, were contacted. However, because this study is narrowly limited to one specific

type of work, it was determined that many of these sources could not isolate only point of erection accident data.

Of the potential sources, only OSHA was able to provide point of erection accident data. This was done through their computerized data base. A list of fatality/catastrophe events was compiled. From this list, potential point of erection accidents were identified and additional information was obtained from reports written by the inspecting compliance officer and maintained at the various OSHA Area Offices. These reports allowed the circumstances of these accidents and the type of work being done to be identified.

1.3.2 CONTACTS MADE

Unions, associations, contractors, and various OSHA officials were contacted as part of this study. The number and variety of contacts that were made helped insure the representation of all views.

Several unions were contacted in regard to point of erection situations encountered by their members. Discussions were held regarding standards compliance and training which might discuss point of erection procedures and safety. Unions contacted by phone or in person include the following.

- International Association of Bridge, Structural and Ornamental Iron Workers
- United Brotherhood of Carpenters and Joiners of America
- Laborer's International Union of North America

Connectors are primarily iron workers and the International Association of Bridge, Structural and Ornamental Iron Workers was most helpful to the project team. Members of the union and some of its business agents took time to discuss the erection procedures and safety aspects of point of erection work. For example, meetings were held with the union business agent from New Haven, Connecticut, with the union apprenticeship coordinator from Denver, Colorado, and with union officials from Phoenix, Arizona.

Telephone and personal contacts were also made with industrial associations, such as the following.:

- American Institute of Steel Construction
- American Institute of Timber Construction
- American Subcontractors Association
- Associated General Contractors of America
- Institute for the Iron Working Industry
- National Constructors Association
- National Erectors Association
- National Safety Council
- Prestressed Concrete Institute

Presentations outlining the goals and objectives of the project were made to the safety committees of the National Erectors Association and the Prestressed Concrete Institute. These associations and the Institute for the

Iron Working Industry were quite helpful and supported the project team by providing information about point of erection procedures and safety. The American Institute of Timber Construction was also quite helpful, especially in locating timber construction contractors.

In addition, a wide range of both large and small contractors in all parts of the country were contacted about the possibilities of making a visit to one of their construction sites. Although many were unable to help arrange a site visit, these contractors willingly discussed their point of erection operations with members of the project team.

Contacts were also made with various OSHA offices. OSHA offices in Hartford, Connecticut, and Denver, Colorado, were contacted and meetings were held with some of their officials and compliance officers. Several other OSHA officials were contacted by phone and supplied information. A meeting was also held with representatives of the Long Beach Office of the California Occupational Safety and Health Administration.

1.3.3 SITE VISITS

The construction sites visited were selected to include a cross section of relevant structures, to include approximately the same number of union and non-union jobs, and to insure geographic distribution. Attempts were made to arrange at least one visit in the Northwest and one in the Midwest, but it was not possible to coordinate visits in these areas with the project schedule.

Each site visit was designed to observe people working at the point of erection and explore if they can be effectively protected by the physical means of a safety belt or safety net or by proper training in safety techniques. Sequencing of the erection process was also documented to indicate if one sequence is superior to another. Activities at the point of erection were examined and conversations were held with point of erection personnel, job superintendents, and safety officers. The nine construction sites which were visited are listed in Table 1 on the following page.

As noted in the table, one timber construction job was visited. It was a one-story warehouse in which laminated wood beams were being installed to support the roof. These beams were raised by a forklift and set in steel brackets that held them in place. No one worked from the structure to make a connection. Therefore, on this job, connectors were not exposed at the point of erection.(8)

The president of the American Institute of Timber Construction identified several of the largest and most experienced timber construction contractors in the nation. An informal survey of these contractors revealed that the procedure described above is typical and that timber connectors are atypical among connectors. Rarely, if at all, is there fall exposure to a connector working at the point of erection. Most laminated wood beams are installed at a height of approximately 30 feet. Therefore, if workers do have to make the connection, they can be lifted in cages on forklifts or in baskets on cranes, or they work off scaffolds or approved work platforms. Also, when possible, laminated wood arches are connected on the ground before

TABLE 1. CONSTRUCTION SITES VISITED

Building Material	Type of Structure	Location	Members Being Erected	Union?
Steel	Multi-story building, perimeter nets in use	Hartford, Connecticut	Columns, beams, and decking	Yes
Steel	Multi-story building, perimeter nets not in use	Pittsburgh, Pennsylvania	Columns and beams	Yes
Steel	Bridge	Richfield, Utah	Girders	Yes
Steel	Communication tower	Idledale, Colorado	Columns, beams, and intermediate bracing pieces	No
Steel	Single-story warehouse, no intermediate floors	Pearland, Texas	Prefabricated columns and beams	No
Precast	Multi-story building	Copper Mountain, Colorado	Load bearing wall panels, double-tee floor members	No
Precast	Plant without intermediate floors	Stuarts Draft, Virginia	Columns, beams, and panels	No
Precast	Cooling tower, no intermediate floors	Newark, Arkansas	Internal columns and beams	Yes
Timber	Single-story warehouse, no intermediate floors	Chino, California	Laminated wood beams	No

they are raised, eliminating the need for connections to be made in the air.

Originally it was thought that timber connection work would present some of the same situations encountered by steel and precast/prestressed erection. However, this brief discussion highlights the fact that timber erection usually does not expose the worker at the point of erection, as do steel and precast/prestressed erection. There is no need, therefore, for safety belts or safety nets because workers use ladders or work platforms. For these reasons, timber construction was determined to be outside the scope of this study and is eliminated from further discussion in regard to these standards and the point of erection.

CHAPTER 2. OVERVIEW OF POPULATION AT RISK AND FALL ACCIDENTS

2.1 TRADES AND UNIONS INVOLVED

In steel erection, the connection work is done by iron workers, both union and non-union. The primary union representing these workers is the International Association of Bridge, Structural and Ornamental Iron Workers. In precast/prestressed erection, the connection work is done principally by iron workers, and also by carpenters and laborers. These workers may be union or non-union. The unions representing them are the International Association of Bridge, Structural and Ornamental Iron Workers, the United Brotherhood of Carpenters and Joiners of America, and the Laborer's International Union of North America.

2.2 POPULATION ESTIMATES

An attempt has been made to estimate the total number of construction sites in categories where steel and precast/prestressed concrete would likely be used. These are presented in Table 2 on the following page. Based upon this information, approximately 11,374 sites existed in 1980. It was not possible to separate projects where steel or precast/prestressed concrete was used from similar projects using other construction methods. This information is provided in the Dodge Reports regarding current construction activity; however, access to these detailed reports could not be arranged at this time. The estimate is useful, however, in that it most certainly contains the sites where the connector is exposed to a fall danger at the point of erection and represents a high estimate.

The number of contractors who erect buildings of the type studied here was estimated by the National Erectors Association based upon U.S. Department of Labor figures and by the Prestressed Concrete Institute.(9)

TABLE 2. ESTIMATION OF TOTAL NUMBER OF CONSTRUCTION SITES

CONSTRUCTION TYPE*	TOTAL $ VALUE* OF PROJECTS	$ VALUE OF** AVG. STRUCTURE	# OF SITES
Office Buildings	10,500,000,000	20 Million	525
Stores and Other Commercial	11,600,000,000	3 Million	3,867
Manufacturing Buildings	6,800,000,000	3 Million	2,267
Educational Buildings	6,700,000,000	6 Million	1,117
Hospital & Health Buildings	4,950,000,000	15 Million	330
Other Non-residential Buildings	7,700,000,000	3 Million	2,567
Highways & Bridges	13,400,000,000	20 Million	670
Public Utilities-Powerhouses	15,500,000,000	500 Million	31
		TOTAL # OF SITES	11,374

*Source: 1980 F.W. Dodge Reports division of McGraw-Hill Information Systems Company

**Source: Estimated by the Institute for the Iron Working Industry.

TABLE 3 - TOTAL NUMBER OF ERECTION CONTRACTORS

Steel erection contractor - small	2,000
Steel erection contractors - large (those capable of running multiple sites)	500
Precast/prestressed erection contractors - small	1,550
Precast/prestressed erection contractors - large (those capable of running multiple sites)	250
TOTAL ERECTION CONTRACTORS	4,300

It is reasonable to assume that the two general categories of steel and precast/prestressed erectors overlap to some degree. However, again the estimate is high.

It is possible to estimate the size of the population of connectors from the number of projects. The number of sites for 1980 was approximately 11,374 (see Table 2). If this number is used and it is assumed that connection work on a job lasts an average of two months, that there are two connectors on each job, and that each worked ten months during the year, then it can be estimated that there were approximately 4549 people principally engaged in connection work during 1980. This number relates quite well to an estimate based on the current number of journeymen in the Iron Workers Union. There are 103,211 journeymen in the union(10) and one union official estimates that two percent of these are connectors(11), giving a total of 2068 connectors in the union. If this number is doubled to account for non-union connectors, it can be estimated that there are approximately 4128 total connectors.

No better estimate of this number is known because there are no statistics kept on this narrow portion of the construction industry. Even the Iron Workers Union itself cannot provide an exact number of their members who are connectors, because there are no distinct lines drawn between them and other iron workers.

2.3 CONNECTOR FALLS

Falls in the steel erection industry are a major cause of injury. For example, in the past few years, analysis of workers compensation claims paid by Liberty Mutual Insurance Company(12) and Employers Insurance of Wausau(13) show that the general category of falls on steel construction account for between 41 percent and 52 percent of the total claims paid by these companies. These figures include falls at the same level, falls from ladders, scaffolding, roofs, and elevated surfaces, as well as falls from steel.

It has proved difficult, however, to isolate data concerning only those accidents which have happened to connectors when working at point of

erection. Information was sought from a range of sources, including the Workers Compensation Supplementary Data System, Bureau of Labor Statistics, National Safety Council, etc. None of these sources could provide detailed enough information to isolate the specific activity of the worker at the time of the accident.

Only one source of U.S. data allowed connector accidents to be identified. This was the reports from fatality/catastrophe investigations conducted by OSHA. Such investigations are required whenever OSHA learns of a death or of an accident where a large number of injuries occurred. The detailed reports generated from the investigation are retained at the OSHA Area Office where the investigation was conducted. A summary of the data is sent to the OSHA Office of Management Data Systems in Washington, D.C., so that it can be entered into a computer. It must be emphasized that this data generally includes accidents that happened in a state where no state plan exists (i.e., twenty-nine states).

To locate connector fall cases, a computer search was ordered to obtain a listing of fatality/catastrophe events. It was limited to specifically identified Standard Industrial Classification (SIC) work groups where a citation was issued for one of the subject standards for the years 1978 through 1980. The following SIC code groups were identified as those most likely to contain contractors who erect steel and precast/prestressed products.

SIC code groups researched:

- 1522 General Contractors-Residential Buildings, other than single family
- 1541 General Contractors - Industrial Buildings and Warehouses
- 1542 General Contractors - Nonresidential Buildings, other than Industrial Buildings and Warehouses
- 1622 Bridge, Tunnel and Elevated Highway Construction
- 3272 Concrete Products except Block and Brick
- 3441 Fabricated Structural Metal

The standards in question were:

- 29 CFR 1926.21(b)(2) Safety Training and Education
- 29 CFR 1926.104 Safety Belts, Lifelines and Lanyards
- 29 CFR 1926.105 Safety Nets
- 29 CFR 1926.750(b)(1)(ii) Temporary Flooring

The information supplied from the computer search identified the OSHA Area Office where the investigation records are on file. The detailed

file of each investigation was then obtained from these offices. The description of the work being done at the time of the accident was reviewed to determine if the fall involved someone doing connection work.

2.3.1 FATALITIES LOCATED

A total of thirty-four fatality/catastrophe cases was identified by the search. However, the majority of these cases obviously did not involve steel or precast/prestressed connectors. Accidents occurred during demolition procedures, when walking to lunch across a helipad, when formwork gave way, when scaffolding collapsed, etc.

It is difficult to clearly identify every task that is associated only with the connection operation, as opposed to what another structural iron worker might be doing when working on another crew. If one used a strict definition of connection work, which would limit activities only to those involved with the placement of structural members at the point of erection, none of the fatalities would be defined as connector accidents. However, three fatalities occurred in circumstances where the person involved might have been a connector (1 fatality in 1979 and 2 fatalities in 1980). (Full descriptions of each case may be found in Appendix B.)

When the detailed files on these cases were requested from the various OSHA Area Offices, the Atlanta Area Office identified two non-fatality cases that are fairly typical of connector fall accidents. In these two cases, other steel standards than the one being studied here (29 CFR 1926.750(b)(1)(ii)) had been cited. Also, it was determined that in many situations, the general personal protective equipment standard (29 CFR 1926.28(a)) is cited in addition to or instead of one of the other standards under study. Therefore, the computer search was expanded to include the following standards (for the same three years and six SIC codes):

- 29 CFR 1926.28(a) Personal Protective Equipment
- 29 CFR 1926.750 Flooring Requirements
- 29 CFR 1926.751 Structural Steel Assembly
- 29 CFR 1926.752 Bolting, Riveting, Fitting-Up, and Plumbing-Up

This new search revealed fourty-four fatality/catastrophe accidents over the three-year period. However, none of these cases involved steel or precast/prestressed connectors.

2.3.2 NATIONAL ERECTORS ASSOCIATION STUDY

In 1975, the National Erectors Association surveyed its membership to determine the number of perimeter falls of two or more stories which

had occurred in the past ten years. Out of approximately ninety-four active erector members, a total of seventy-six responses from companies which erect multi-story structures was received (an 81 percent response). The results of the survey showed that only two connectors had fallen two or more floors to the outside of a building in the past ten years. In the same period, fifty-four of these seventy-six respondents estimated that 8,627,937 accident-free connector man-hours had been worked.(14)

There may be some doubt concerning how carefully each of the respondents reviewed each of the accident reports generated during the previous ten years. It is likely that some respondents relied, at least partially, upon people's memories to assemble their information. It should also be noted that interior falls, where the majority of the connection work is done, were not considered.

2.3.3 DATA SUPPLIED BY CONSTRUCTION SAFETY ASSOCIATION OF ONTARIO

The Construction Safety Association of Ontario in Canada maintains extremely detailed records on construction accidents. The Association was asked to perform a search to determine the number of connector fall accidents which had occurred in Ontario during 1979 and 1980. The results of this search and summaries of the accidents which did occur are contained in Appendix C.

This information indicated that no fatalities had occurred. Seven connector fall accidents occurred in 1980 and five occurred in 1979. This compares to a total of fifty-four fall accidents which happened to iron workers in 1980 and fifty-eight in 1979. None of the falls exceeded 20 feet; the shortest was 9 feet. It must be understood that the Occupational Health and Safety Act of Ontario specifically excepts workers from the requirement to use either safety belts or safety nets when performing connection work.

Ontario figures were used to develop an estimate of the number of iron worker connector fall accidents which occurred in the United States. (See Table 4.) This estimate, though rough, is the best and most comparable estimate possible with the information available. (Please note that the estimates provided above are based upon accidents involving only iron workers. No estimate could be developed for precast/prestressed falls.)

TABLE 4 - ESTIMATED NUMBER OF U.S. IRON WORKER CONNECTOR FALLS FOR 1979 AND 1980

	Total U.S. Construction Reportable Injuries / Total Ontario Construction Reportable Injuries		Number of Ontario Iron Worker Connector Falls		Estimated Number of U.S. Iron Worker Connector Falls
1979	250,000* / 14,522**	X	5**	=	86 Estimated U.S. Iron Worker Connector Fall Accidents
1980	240,000* / 14,441**	X	7**	=	116 Estimated U.S. Iron Worker Connector Fall Accidents

*Source: for 1979 figures - Accident Facts, 1980 ed., published by the National Safety Council.

for 1980 figures - Accident Facts, 1981 ed., published by the National Safety Council.

**Source: Construction Safety Association of Ontario.

CHAPTER 3. DESCRIPTION OF TYPICAL CONNECTION PROCEDURES

In order to consider the possibilities of using safety belts, safety nets, and training to protect connectors, it is first important to understand the functions that the connector must perform. It is also important to note the time necessary to accomplish each task and the length of time the connector is exposed to fall danger.

This section will detail several "typical" connection situations. The word "typical" is used with great reservation. The connector is seldom faced with any two situations that are exactly the same. Two beams connected next to each other will often present different problems. Connection plates may be slightly askew, holes may not line up easily, or because of the surrounding structure, the beam must be maneuvered differently to place it in the correct position. The situation is further complicated by the fact that there are an unlimited variety of structures in which steel and precast/prestressed products can be used. Architects and engineers are busy devising new situations daily. Therefore, while several scenarios are presented here, the reader should realize that the feasibility of using safety apparatuses cannot be decided based upon these descriptions alone.

3.1 GENERAL SAFETY FACTORS

The safety of a connector in steel or precast/prestressed construction depends on many factors beyond the presence of a safety belt or net. A connector's safety is dependent upon his skills and abilities, upon the rapport developed between two connectors working together, and upon the crane operator.

A connector is a unique individual who can work at great heights without fear. Neither is he bothered by moving about on the relatively narrow pieces of steel or precast/prestressed which must be negotiated to accomplish the connection task. It is important that the connector be agile and in excellent physical condition to assure his safety. In addition, the knowledge of the connection process, the ability to maintain balance, and the instinct of how to move should an emergency occur are intangible but vital attributes of most connectors.

It is usual that at least two connectors work as a team, one at either end of the member to be attached to the building. The safety of each connector depends on the other. They learn to anticipate what the other will do in a particular situation and have been credited with saving each other on numerous occasions.

Connector safety is also largely dependent upon the skill of the crane operator. This individual is swinging loads weighing many tons toward connectors perched on open steel or precast/prestressed, sometimes hundreds of feet

in the air. It is not unusual for the crane operator to place the load in a location that cannot be seen from the crane cab. It is for this reason that the popular iron worker expression is true: "The best crane operator is one who has never learned to think for himself." The safest crane operator is one who moves the load only when given a signal by a connector or a signalman. If the load is moved in a way that the connector does not anticipate, it can easily dislodge him from the structure. The presence of a crane operator who is skilled in maneuvering steel and precast/prestressed members has been described by connectors and supervisors as the most important single ingredient for preventing falls.

3.2 STEEL ERECTION

The steel columns, beams, and other steel items are fabricated in shops before being delivered to an erection site. Each member is designed for a specific place in the structure and the fabricator is responsible for placing holes in the proper position, attaching stiffener plates, lifting devices, connection plates, seat lugs, etc. In this way, ideally, the connector will only have to place each member in the proper position and attach it with bolts.

The fabricated members are then delivered to the erection site as called for by the site superintendent or project engineer. At the site, the raising gang sorts the steel (a process referred to as "shaking out" the steel) so that the proper member can be lifted to the connectors.

Steel erection work follows a basic pattern. The raising gang in combination with the crane operator is the first to handle structural steel. They are responsible for initially positioning the steel in the structure and placing enough bolts to secure the member temporarily, but not so many that the structure becomes completely rigid. (Examples of various steel shapes and types of connections are provided in Appendix D.) Slight adjustments in the structure will be necessary to allow other members to be put in place. It is their task to move forward quickly because their job must be completed before other iron workers and other trades can begin work. Typically the raising gang is made up of five or six structural iron workers: a foreman, one or two riggers, two connectors, and possibly a signalman.

The raising gang is followed by the bolt-up crew. These people are responsible for plumbing the members and permanently bolting them into place. A detail gang may also be used to attach such things as smaller miscellaneous members, perimeter cables, permanent ladders, grating, and prefabricated stairs. Permanent metal decking might also be installed by these people or by a subcontractor.

There are basically four types of steel erection projects which expose connectors to a fall of 25 feet or more.

1. Tiered buildings (multi-storied or high rise)
2. Bridges
3. High-roof structures such as warehouses, aircraft hangars, convention centers, or stadium buildings
4. Special structures such as towers, tracking dishes, and other unique designs

3.2.1 STEEL-TIERED BUILDINGS

On a steel-tiered building, the first section to be erected is the core, which is generally in the center of the structure and contains elevator shafts, stairwells, and perhaps ventilation shafts. Two floors of this portion of the structure are put in place by the connectors. After it is plumbed by the bolt-up gang, the top or second floor is decked solid using permanent steel decking or wood planks.

While this section is being plumbed, bolted, and decked, the connectors are installing the surrounding structure two floors at a time. As each section is completed by the connectors, other crews will begin plumbing, bolting up, and decking that section of the structure. The connectors will then begin erecting steel for the third and fourth floor core. Since the second floor of the core area has already been decked, the connectors are working over a solid floor.

The work progresses in two-story jumps until all floors have been erected. The bolt-up gang will plumb and bolt the second story of each addition before bolting and plumbing the intermediate floor. This allows the uppermost floor to be decked as rapidly as possible. The bolt-up gang will then work on the intermediate floor while the connectors continue upward. In this way, all crews are kept busy and do not have to wait for each other to finish various parts of the work.(15)

The following discussions of erection techniques concentrate on the tasks to be performed and the positions of the connectors. Estimates of the time necessary to perform each task and the period of time the connector is exposed to a fall are provided. These are based upon field observations made during the site visits and the experience of the project team. The times presented are meant only to provide an indication of how rapidly a task can be done. They are not meant to present definitive measures of the time taken. No consideration is given to the types of fall protection measures which might be used, as this will be covered in Chapter 4. The period of fall exposure is based only on the amount of time when a fall would be possible if the worker was not protected. The reader should not conclude from these figures that fall protection cannot or is not provided during the period of fall exposure.

3.2.1.1 Column Installation

Columns are usually two stories in height. The first columns are bolted to concrete pads, footings, or casings at ground level. There need be no exposure to a fall when doing this task, as several rigging devices are available which allow the crane to be released from the column by a worker at ground level. These usually involve a shackle attached to the column by a pin connected to a tag-line, which extends to the ground after the column is set. When the line is pulled, the pin is removed from the shackle and the crane is released from the column. (See Figure 1.)

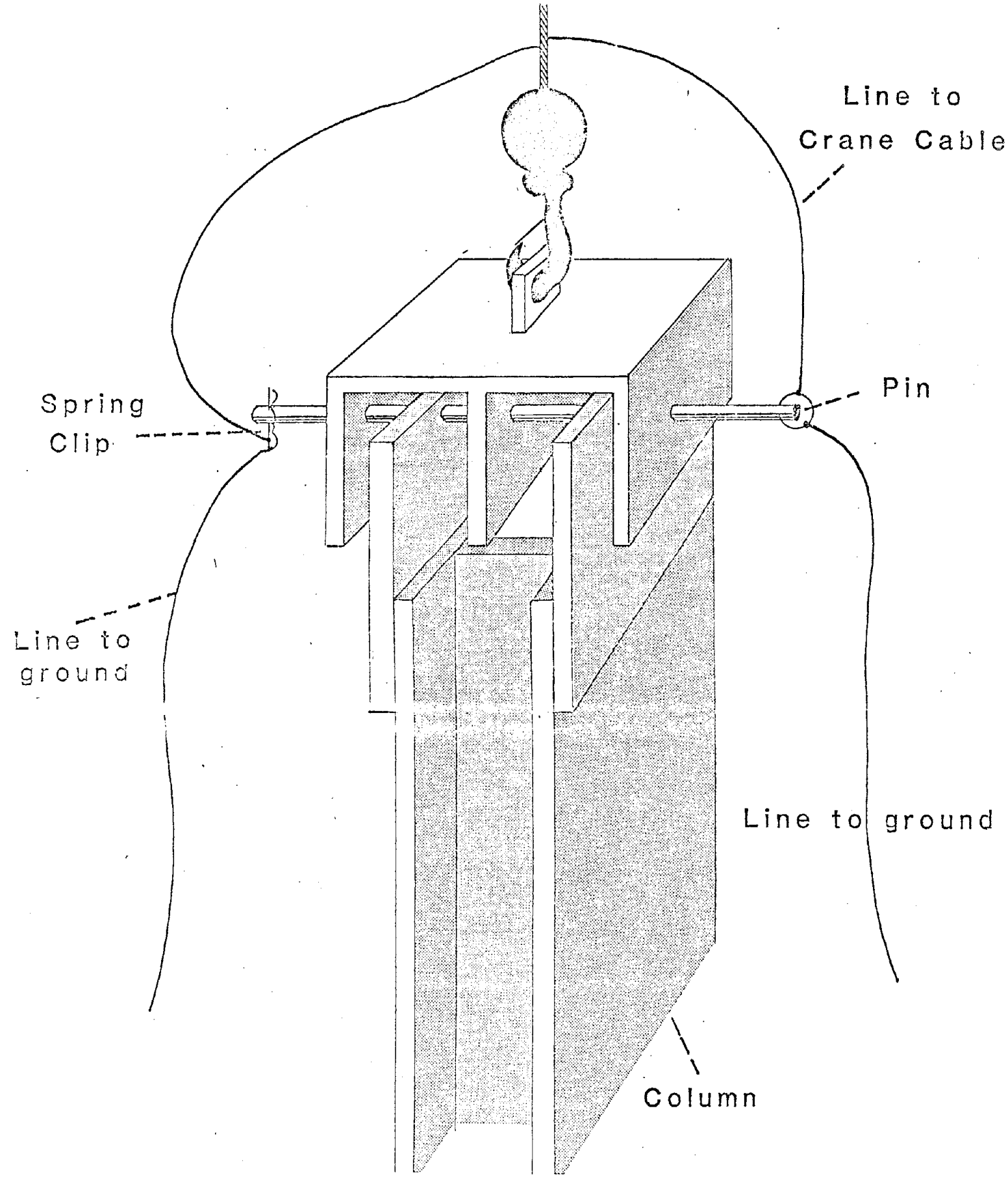


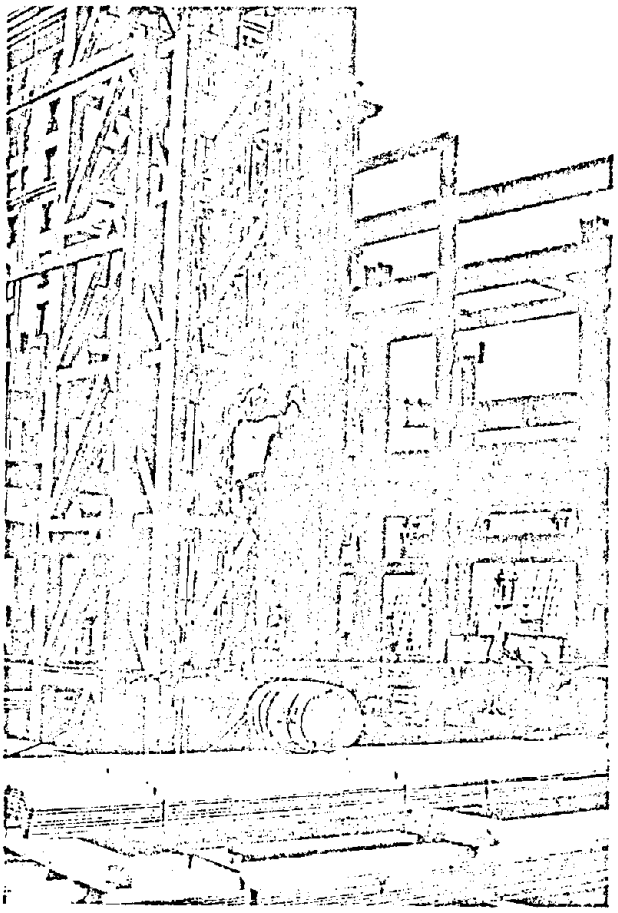
FIGURE 1 - Rigging Device For A Column Which Allows Rigging To Be Unhooked From The Ground

Description of Task	Time Required For Task	Period of Fall Exposure
In the upper part of the structure, each column splice is designed to be a few feet above the adjoining floor. Therefore, the connectors are usually working off a deck to make the column connection. They could be exposed to a perimeter fall off the edge of the deck when perimeter columns are placed.	4 - 12 min.	4 - 12 min.
This is not to say that the decking has always been completed around a column or that a "slip pin" shackle (or other device which can be released from the ground) is always used. If this is the case, a connector will climb a ladder or the column to release the rigging.	1 - 3½ min.	½ - 1¼ min. if column is climbed

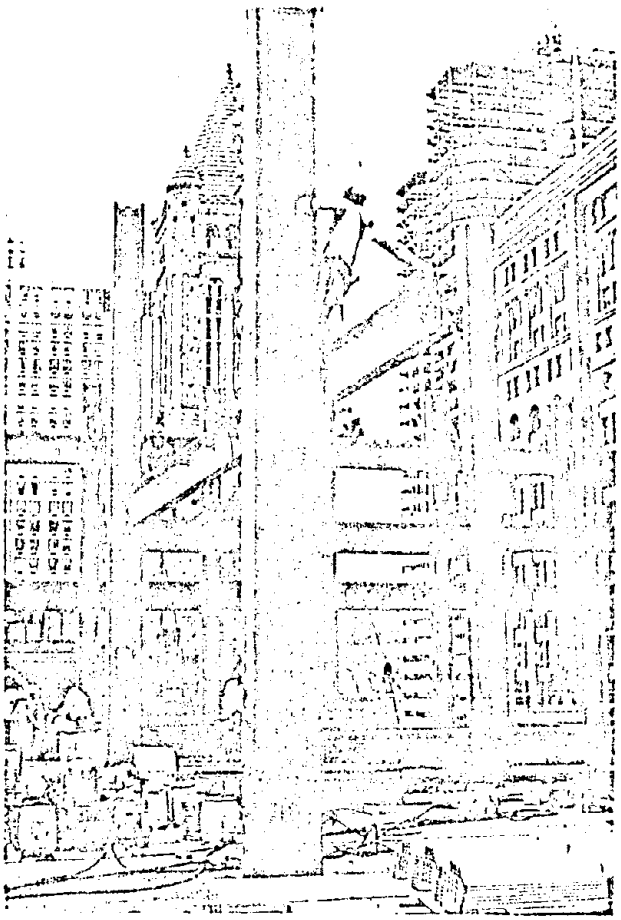
3.2.1.2 Connection of Structural Beam

Beams can be connected to either the flange or the webs of a column. Two types of connection arrangements are typical. The first utilizes two "L"-shaped brackets welded to either side of the web at the end of the beam. Holes in these brackets align with holes in the column so they can be bolted together. Alternately, the "L"-shaped connection brackets are welded to the column with space left between them where the end of the beam web can be placed. The beam web is maneuvered between the brackets and the holes in the brackets are aligned with holes in the beam web so bolts can be attached. (See diagrams in Appendix D.)

Description of Task	Time Required For Task	Period of Fall Exposure
Connectors climb opposite columns to the first connection point (approximately 12 feet).	1 min.	30 seconds as he moves higher
Connectors stand on flanges or stiffener plates fabricated to the column around the connection point or grip the column with their knees to wait for the beam to be lifted to them. (The beam may be lifted from the ground or from the uppermost deck.) If one of the connectors can see the crane operator, he will signal by hand to guide the member into position. If the crane operator cannot be seen, a radio or telephone will be used for communication.	1 - 5 min.	1 - 5 min.

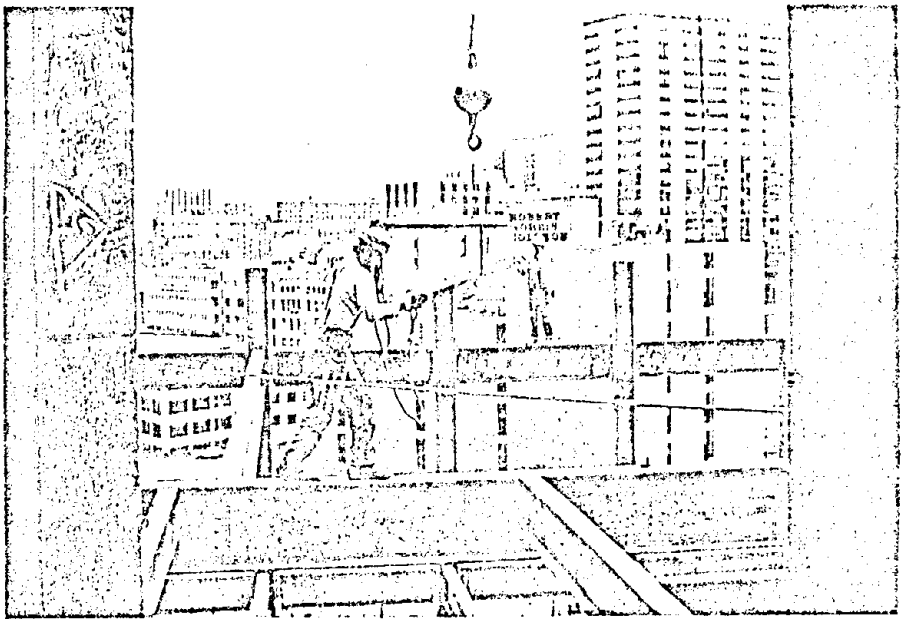


Picture 1 - A connector climbs a column to the connection point.

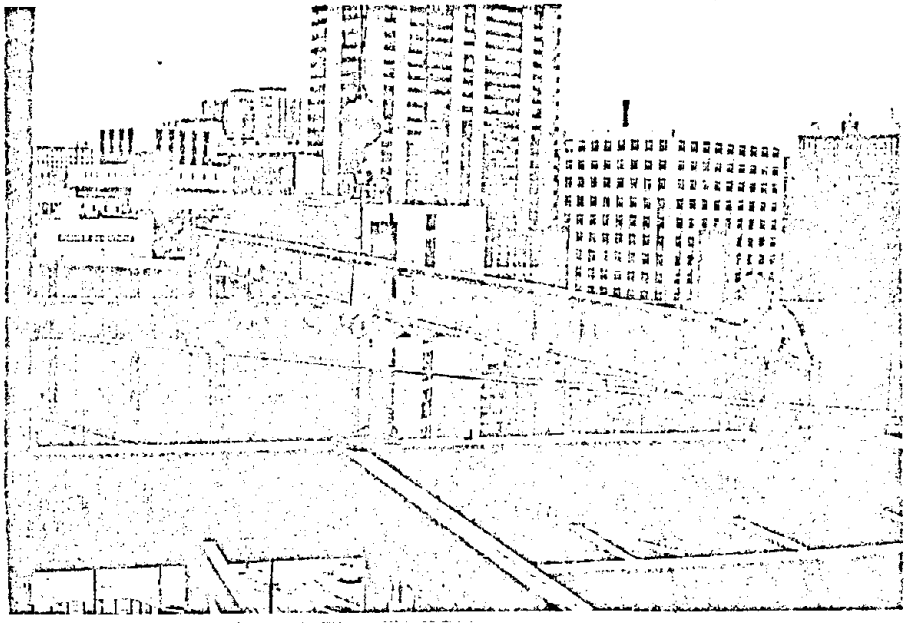


Picture 2 - The connector in the foreground is standing on a connection lug reaching for the incoming beam. The other connector has already positioned his end of the beam between the flanges of the column.

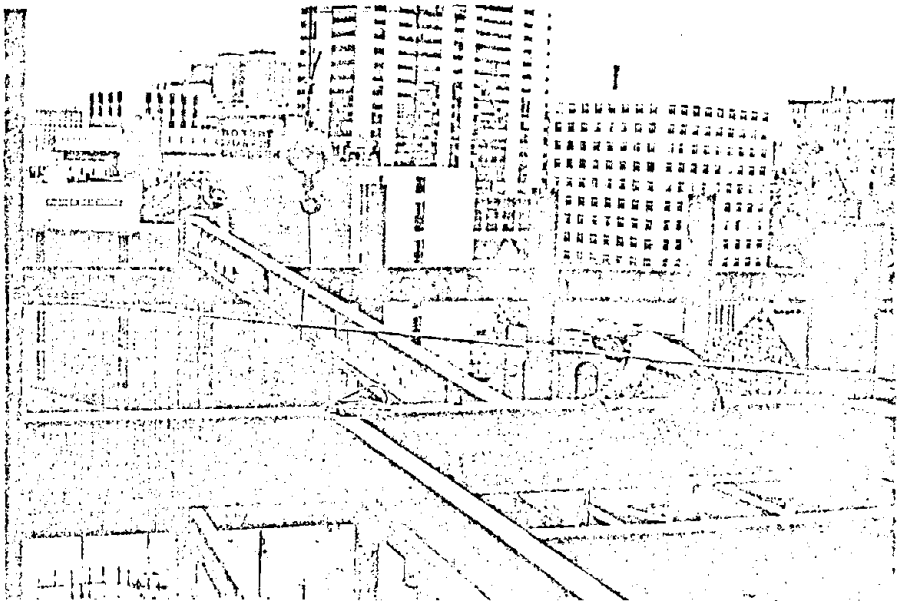
Description of Task	Time Required For Task	Period of Fall Exposure
Connectors watch for the beam as it is swung by the crane. (A tag-line might be attached to the beam on the ground. If so, it is caught either by a man on the deck below, to aid in getting one end to the connector, or it is caught by the connector himself.) One connector will catch the beam and swing the opposite end to the second connector on the opposite column. One of the connectors will then signal the crane to place the beam in position and use one end of a spud wrench to insert through one of the bolt holes between the beam and the column. This will hold the beam in position temporarily.	1½ - 2 min.	1½ - 2 min.
Alternately - If a beam line has been installed, the connector will often have to move along the beam line to catch the incoming member. To do this, he may walk or coon (i.e., straddle the beam and walk the bottom flange) along the beams and maneuver around columns for a distance of 20 feet or more. Once he has caught the beam, he will walk back along the beam line holding onto the incoming beam until the other connector can also reach it.	1 - 3 min.	1 - 3 min.
Alternately - If the beam must be connected inside the flanges in a column or another beam, the incoming beam may have to be angled by the connectors to slip the ends inside the flange to the connection point. The connector could have to move 10 to 20 feet in any direction along the structure to accomplish each task.	½ - 1½ min.	½ - 1½ min.
The connector then sits down astride the beam while he places two bolts (to prevent the beam from rolling) and tightens them with his wrench to hold the beam in position.	2 - 5 min.	2 - 5 min.



Picture 3 - Connectors working on opposite beam lines, catch an incoming beam and walk it to the position where it will be connected.



Picture 4 - After the first connector places his end of the beam inside the column flanges, the connector in the foreground must angle the beam so his end can be placed between the flanges of the beam on which he is standing.



Picture 5 - The beam is now between the flanges and is being pushed back approximately five feet to the connection point.

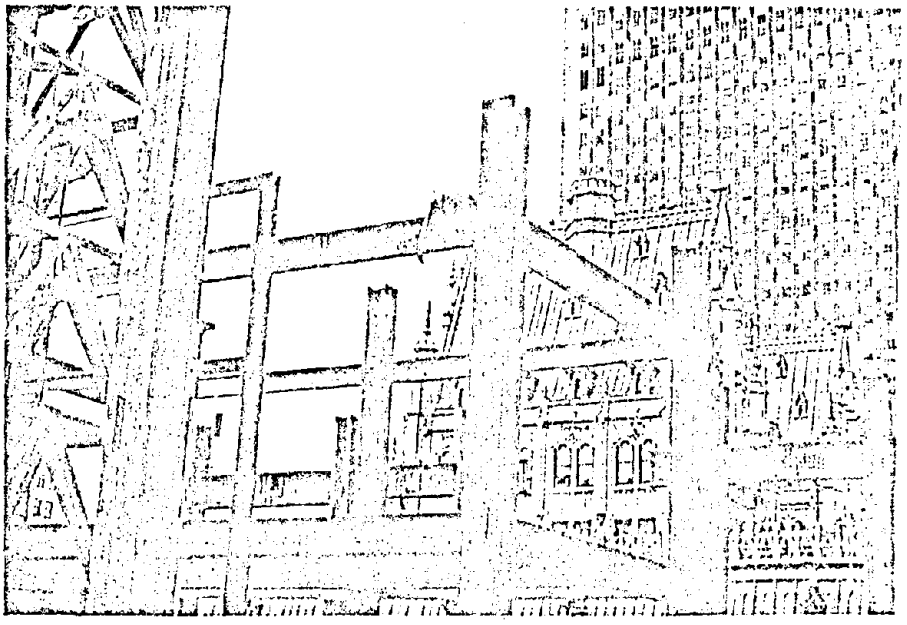
Description of Task	Time Required For Task	Period of Fall Exposure
If one connector is having trouble attaching his end of the beam, the second connector may walk or coon across the beam, maneuver around the rigging, and go to the across other end to help his partner.	1 - 1½ min. depending on length of beam	1 - 1½ min.
If the connection is difficult, the connectors may use a pry bar to maneuver the beam or a hammer to drive a barrel pin into a bolt hole to help align the connection.	1 - 5 min. depending on difficulty of connection	1 - 5 min.
It is also possible that other members of the raising gang may have to loosen the column so it can be repositioned to allow the beam connection to be made.	3 - 10 min.	3 - 10 min.
Once the beam is securely attached to the column, one or both connectors will walk or coon out on the beam to release the rigging.	½ - 1 min.	½ - 1 min.
The connectors will then move to the next connection point, either by walking along existing steel beams or by climbing the columns, and wait until the next beam is raised.	1 - 5 min.	1 - 5 min.

3.2.2 STEEL-BRIDGES

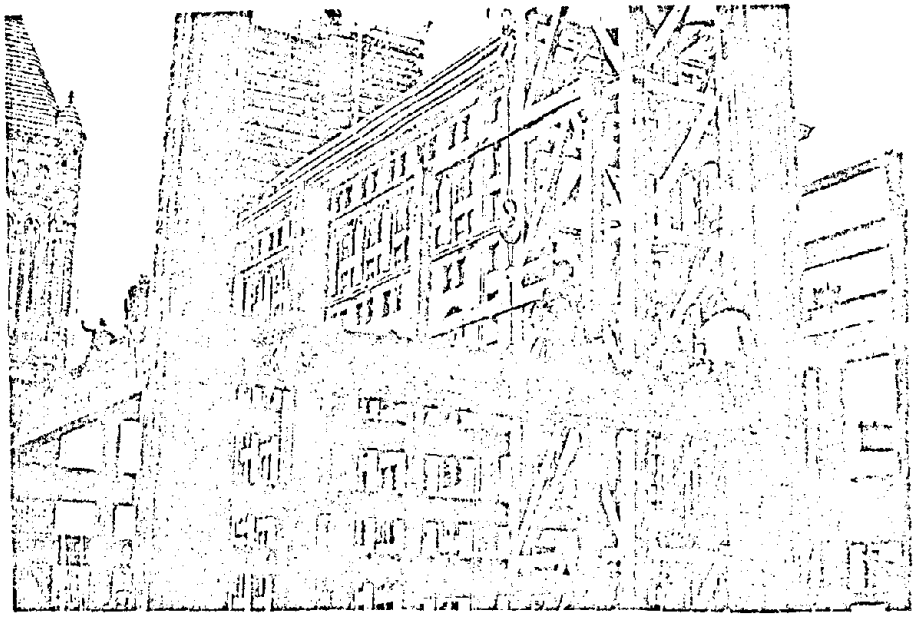
A wide variety of steel bridges are constructed, ranging from small highway overpasses 25 to 30 feet above the ground, to gigantic structures spanning canyons and rivers. The variety of bridge types includes:

- Simple beam bridges spanning approximately 80 feet
- Plate girder bridges fashioned by bolting, welding, or riveting together a series of plates to span 200 to 400 feet
- Orthotropic deck-plate bridges which add a steel deck to plate girders so both function together as a unit to span up to 800 feet
- Truss bridges which arrange individual members in triangular shapes to carry heavier loads

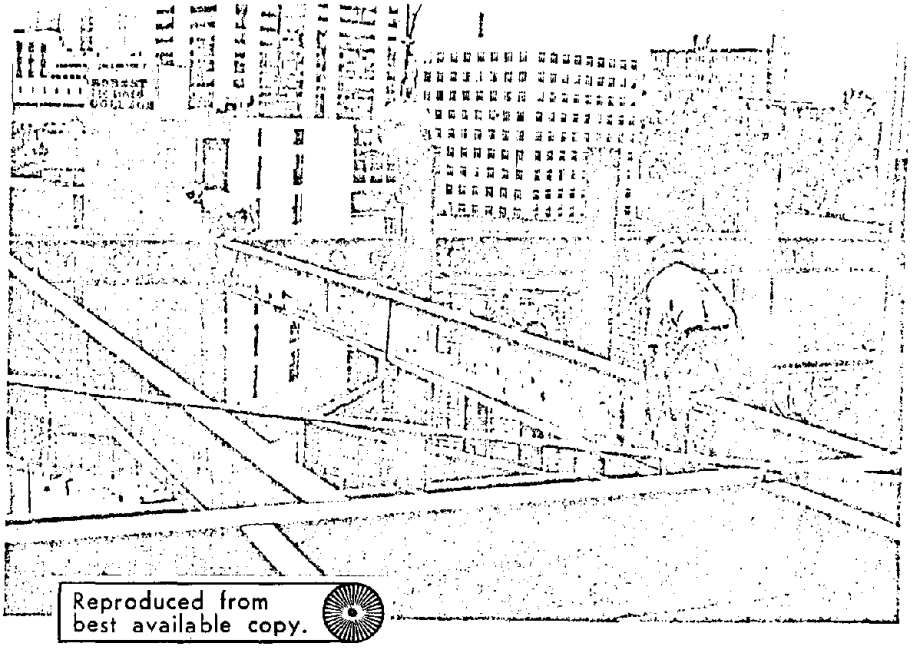
Picture 6 - The connector sits astride the beam to place two bolts into the connection.



Picture 7 - If one connector has trouble, his partner may go to his aid by moving along the beam, and maneuvering around the rigging.



Picture 8 - After the beam is secure, a connector will "coon" out the beam to release the crane rigging.



- Arch bridges utilizing curved plate girders, "box" girders, or curved trusses to develop compression throughout the entire structure
- Suspension bridges where bridge decking is suspended from huge cables sometimes spanning more than 4,000 feet between towers(16)

The requirements for connectors working on these types of structures vary widely and change as each new bridge is designed. The site studied during this project utilized steel girders set on concrete piers to span a canyon approximately 200 feet deep. A ground crane was used to lift each girder to the connectors.

Girders measured 16 inches across the top flange and varied in depth from 6½ to 8½ feet between the flanges. At the time of the visit, two 92½-foot girders spliced together were being erected into a 185-foot space at the center of the bridge to complete the span. The following discussion will illustrate the types of procedures which are used in bridge erection of this type.(17)

3.2.2.1 Girder Splice

Description of Task	Time Required For Task	Period of Fall Exposure
Girders are prepared on the ground by bolting together two girders 92½ feet in length. One end of the cross bracing is bolted to the second and fourth of the five to be erected.	10 - 32 hrs.	0
Two connectors walk from each end of the bridge along the top flange of the erected girders to reach the connection points on each side of the opening.	1 - 3 min.	1 - 3 min.
One connector at each end remains on the top flange, and the second connector takes a position on the lower flange of the girder where the connection will be made. This second connector may place a plank between two girders resting on the lower flanges to provide a temporary work platform.	2 - 6 min.	2 - 6 min.
Alternately - On larger girders, a swing stage, consisting of a wooden platform suspended from the side of the girder by ropes, may be used.	15 - 30 min.	15 - 30 min.

Description of Task	Time Required For Task	Period of Fall Exposure
The girder is lifted from the the ground. A tag-line attached to the girder is used to maneuver the girder into position in the bridge.	2 - 4 min.	2 - 4 min.
The top connector on one end of the bridge (usually opposite where the tag-line is being hooked) will move across the width of the bridge on the erected beams, usually on a plank or wood deck provided as a work platform, to catch one end of the girder. He will then walk the girder across the width of the bridge to the connection point.	1 - 3 min.	1 - 3 min.
The girder is then lowered to the connection point so that one end of the girder can be placed between the gusset plates which will attach the girders together.	1 - 1½ min.	1 - 1½ min.
Both connectors work to position the girder, hold it in position with a sleever bar or other device, and position the gusset plates so they can be bolted to the new girder. (Prior to raising the girder, one gusset plate is bolted to the side of the erected girder so that half of it extends past the end. The second gusset plate is held to the other side of the erected girder by one bolt, in such a way that it does not extend beyond the end. The new girder is then positioned beside the first gusset plate, at the end of the erected beam, and the connectors either rotate the second gusset plate or unbolt and move it so that the new beam is sandwiched between the plates.)	10 - 30 min.	10 - 30 min.
When one end is in position, the second end is maneuvered so that the connectors can also position it correctly and move the gusset plates so they can be bolted in place.	10 - 30 min.	10 - 30 min.

Description of Task	Time Required For Task	Period of Fall Exposure
Unlike the process used in tiered buildings, bridge connectors will often place and tighten all the bolts in the connection before they finish. This means that perhaps 200 to 300 bolts will be placed before the connectors leave their position. During this process, the connectors work on opposite sides of the girder.	4 - 6 hrs.	4 - 6 hrs.

3.2.2.2 Attachment of Cross Bracing

The second beam to be raised will have cross bracing attached to it loosely, approximately every 20 feet along the length of the girder. When the girder is lifted, the cross bracing will be folded back against it. After the girder is connected in place, the connectors will fold out each of these braces and attach them to the first girder that was erected, to form a diaphragm between the girders.

Description of Task	Time Required For Task	Period of Fall Exposure
The connectors walk along the flange of the girder to the point where cross bracing will be installed. Alternately, depending upon the distance between the flanges, one or more connectors may also walk along the bottom flange.	1 - 3 min.	1 - 3 min.
When at the connection point, connectors will work on the top and bottom flanges and on planks placed between the girders on both flanges to measure and align the girders so the bracing can be installed. To adjust the position of the girders, "come-alongs" may be used.	5 - 25 min.	5 - 25 min.
The cross bracing will then be bolted to the girders on either side.	10 - 20 min.	10 - 20 min.

3.2.3 STEEL-PREFABRICATED BUILDINGS

Prefabricated steel buildings make use of standardized steel components which are manufactured in mass quantities. The designer chooses from the predetermined shapes and sizes available to develop a building design. The buildings are

atypical in that the structural steel framing is lighter and is used across only one dimension of the building. Much lighter steel pieces, called purlins, are connected across the other dimension of the building (between beam lines). They are designed only to support the wall or roof sheeting. Much of the eventual strength of the building depends upon the installation of this metal sheeting, and until it is installed, the structure is relatively unstable.

This building system is often used for warehouse-like structures where the roof is 25 to 30 feet from ground level. The connection process for this type of structure is described below.(18)

3.2.3.1 Erection of Columns and Wall Purlins

Description of Task	Time Required For Task	Period of Fall Exposure
The connectors install the perimeter columns by lifting them with a crane and bolting them to concrete footings.	5 - 10 min.	0
These are then stabilized by using guy wires.	7 - 20 min.	0
As the column installation proceeds, they are plumbed and the purlins, which will support the wall sheeting, are attached them. These purlins are placed approximately four feet apart up the side of the wall. The purlins are often light enough to be carried and lifted into position by two connectors. A block and tackle attached to the tops of installed columns can also be used to aid in raising the upper purlins. The connectors often climb and stand on the installed purlins to reach the next connection point. Purlin installation advances rapidly, as very few bolts are needed to secure them in place. Ladders also can be used to reach the connection points.	5 - 10 min.	0 if working from ladders; 5-10 min. from purlins

3.2.3.2 Connection of Roof Beams

Roof beams are attached to the perimeter and interior columns by one of two methods. The first method is as follows:

Description of Task	Time Required For Task	Period of Fall Exposure
An erector may choose to raise the roof beams in sections and bolt them together in the air. One connector will climb a ladder or the wall purlins to reach the top of the perimeter column.	½ - 1 min.	½ - 1 min. if climbing purlins
The interior columns are often simply poles several inches in diameter. Therefore, the second connector may have to work from a scaffold or mechanical platform.	½ - 1 min.	0 if work platform is correctly constructed
The beam is raised by the crane and maneuvered into position.	½ - 1½ min.	½ - 1½ min. if connection on open steel
The connectors attach the beam to the columns.	2 - 10 min	2 - 10 min. if on open steel
As the work progresses, the connector at the perimeter will walk or coon along the length of the erected beam to reach the next connection point.	½ - 1 min.	½ - 1 min.
The second connector will reposition his work platform to the next interior column, so the next beam section can be placed.	2 - 5 min.	0

The second alternative involves the connection of multiple beam sections on the ground prior to lifting them as a single unit. Depending on the width of the building, the entire length of the beam span may be assembled in this way.

The connectors either climb the wall purlins or position a mobile platform at the top of the perimeter columns, on both sides of the building and at interior columns where it is important that connections be made to stabilize the beam.	2 - 10 min.	2 - 10 min.
Two or more cranes are used to raise the entire beam assembly to the connectors.	3 - 7 min.	3 - 7 min. if on open steel

Description of Task	Time Required For Task	Period of Fall Exposure
The connectors will align the bolt holes and bolt the beam. Often the connector will install all the bolts into the connection before leaving his position.	3 - 10 min.	3 - 10 min. if on open steel
Connectors will then move along the beam line to connect all the internal columns or will move platforms and ladders so they can climb to the tops of these columns.	10 - 25 min. depending on width of span	10 - 25 min. if working from beams
As each beam line is erected, two or three roof purlins are attached to begin developing lateral stability between the beam lines.	5 - 15 min.	5 - 15 min.

3.2.3.3 Connection of Roof Purlins

Description of Task	Time Required For Task	Period of Fall Exposure
Connectors climb ladders or the wall purlins to reach previously installed roof beams.	½ - 1 min.	½ - 1 min.
They then coon out along the beams to the peak of the roof.	1 - 1½ min.	1 - 1½ min.
The crane lifts a bundle of roof purlins from the ground, and it is landed just below the peak of the roof. One connector moves out on the bundle to release the sling attached to the crane.	2 - 4 min.	2 - 4 min.
Connectors positioned on opposite beams take each end of a purlin and coon back along the beam, sliding the purlin with them to the installation location. In doing this, they will have to maneuver around and over the purlins that were previously installed to help stabilize the beams.	1 - 2 min.	1 - 2 min.
The installation of the purlin requires only a few bolts and is relatively rapid.	1 - 3 min.	1 - 3 min.

Description of Task	Time Required For Task	Period of Fall Exposure
The connectors then coon back along the beams to obtain the next purlin to be installed, and the process is repeated.	1 - 2 min.	1 - 2 min.

3.2.4 STEEL-TOWER

A communication tower is an example of the unique types of structures which a connector may be asked to assemble. Connection tasks can be complicated by the location of the tower which may be at the top of a building, already hundreds of feet in the air, or on a mountain where access for heavy equipment is limited. Towers are assembled using two basic techniques. The first is to erect the tower piece by piece. The second is to assemble complete sections on the ground. A crane then lifts these completed sections into position on the tower.

In general, tower construction requires connectors to work from smaller, more flexible members. Many times the members are light enough to be raised by means of a block and tackle attached to the uprights of the tower. The erection sequence presented here is based upon the erection of a 65-foot microwave tower.(19)

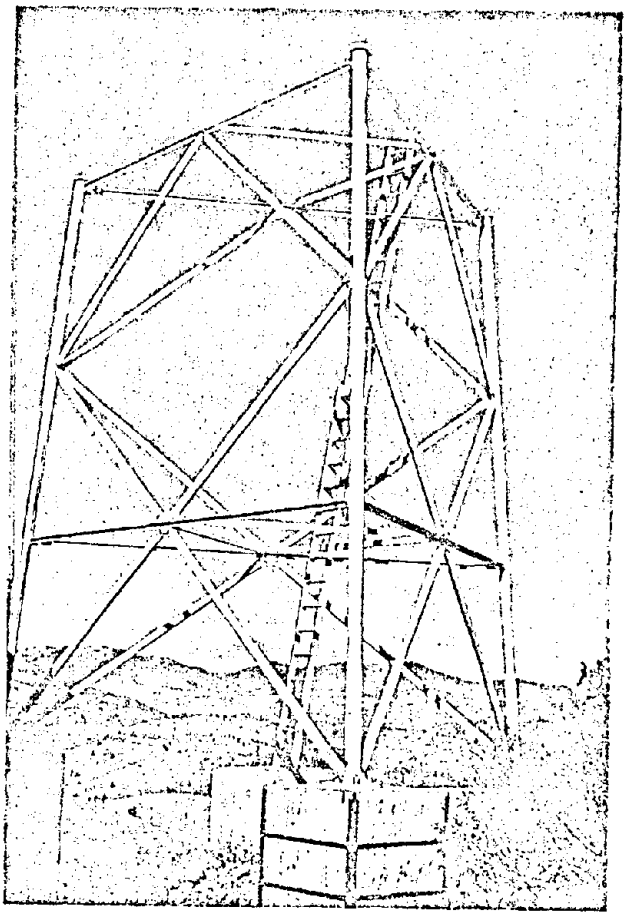
3.2.4.1 Erection of First Section

Description of Task	Time Required For Task	Period of Fall Exposure
A crane is used to raise the vertical members and attach them to the concrete footings. The connector may have to use a ladder or other device to climb to the rigging and release the upright member from the crane.	5 - 10 min.	0
Horizontal members are then put in place. On the lower sections, connectors can use ladders to climb to the connection points.	10 - 20 min. for each member	0

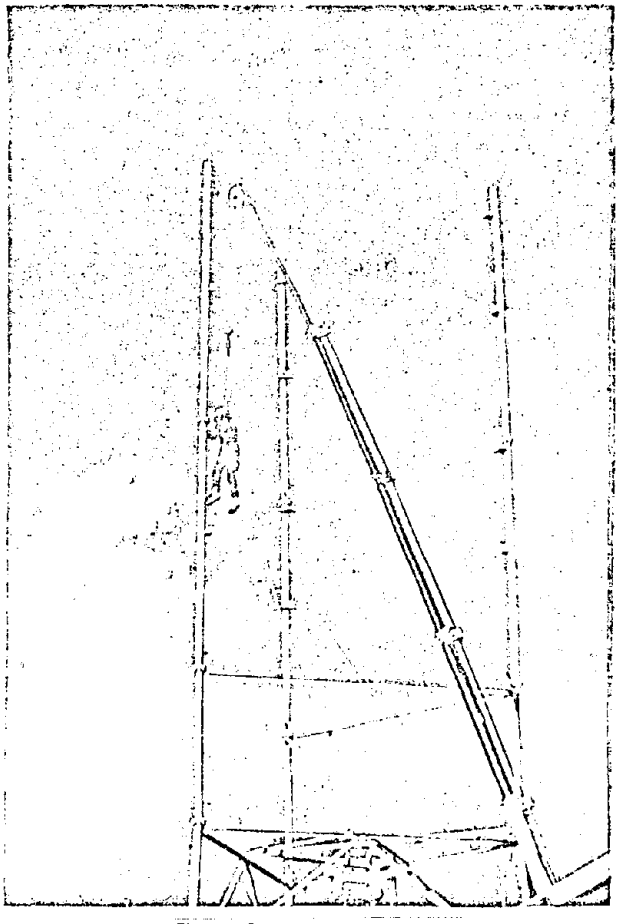
3.2.4.2 Connection of Upright Members at a Height

After the first section has been completed, additional uprights will be connected. To perform this task, connectors can work from ladders or can position themselves on scaffolding placed on the cross bracing of the lower section.

Picture 9 - The lower section of a tower shows the attachment of the upright members to the concrete footings.



Picture 10 - A connector is lifted by the crane to attach a block and tackle to the upright above the location where the next cross member will be attached.



Description of Task	Time Required For Task	Period of Fall Exposure
The crane lifts the upright to the connector.	½ - 2 min.	½ - 2 min.
The connector signals the crane to position the uprights and bolt the connection to the lower sections.	5 - 12 min.	5 - 12 min.
A crane may lift a connector, in a boatswain's chair, to disconnect the choker, or rigging which can be disconnected from the ground may be used.	1 - 3 min.	0

3.2.4.3 Connections of Horizontal Members

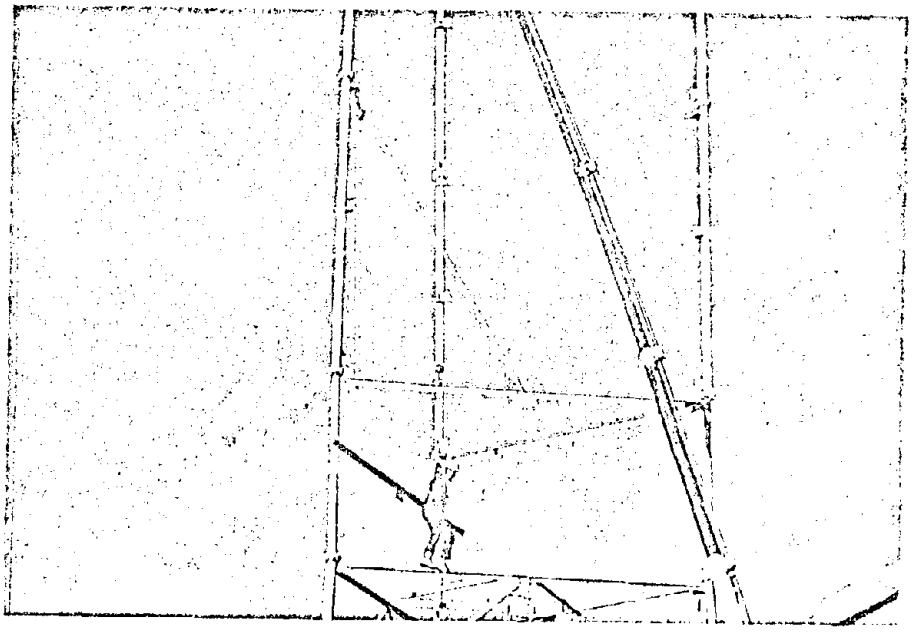
When all the uprights for the new section are in place, the horizontal members are installed between them, all the way to the top of the section, to make it stable. It is sometimes difficult for a connector to climb to the next connection point as it may be out of his reach when standing on the existing structure. In such cases, a harness or boatswain's chair is employed and a crane is used to lift the connector.

Description of Task	Time Required For Task	Period of Fall Exposure
The connector will first attach one or more block and tackle arrangements above the connection points on the uprights.	2 - 5 min.	0
The line from the block and tackle is attached to the end of the horizontal member to be erected. People on the ground raise this member to the connector.	1½ - 4 min.	0
The connector positions the member and bolts it in place. He is moved from one point to the next by the crane.	4 - 10 min.	0

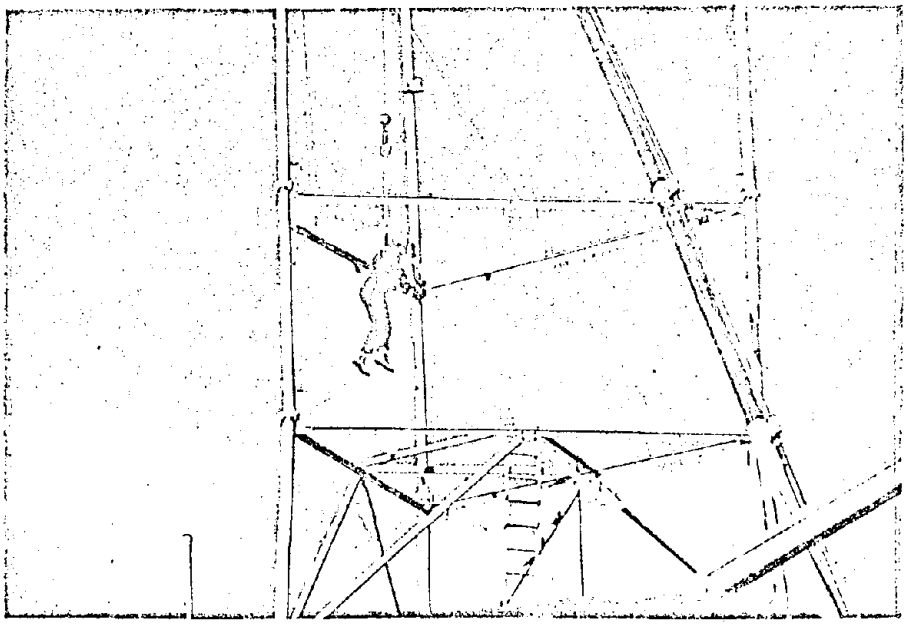
3.2.4.4 Connecting of Cross Bracing

Description of Task	Time Required For Task	Period of Fall Exposure
Two connectors climb to the installed horizontal member where cross bracing is to be erected.	2 - 4 min. depending on height	2 - 4 min

Picture 11 - One end of the cross member is attached to the line from the block and tackle. The other end is carried by the connector as he is raised by the crane.



Picture 12 - The connector bolts the end he raised to the upright. He will then be positioned so he can bolt the opposite end to the structure.



Description of Task	Time Required For Task	Period of Fall Exposure
Boards or scaffolding is raised and placed across the horizontal members to provide a temporary work platform.	5 - 15 min.	5 - 15 min.
A cross brace member is lifted by the connectors using hand lines or using a block and tackle.	½ - 1½ min.	½ - 1½ min. if working from open plank
The member is light enough that the two connectors can carry it along the scaffolding or planks and place it into the proper position.	1½ - 5 min.	1½ - 5 min.
The member is bolted into the structure and the process is repeated.	2 - 6 min.	2 - 6 min.

3.3 ERECTION OF PRECAST/PRESTRESSED CONCRETE STRUCTURES

Precast/prestressed members are usually manufactured in a plant and trucked to the erection site. Each member is designed to be placed in a specific location in the structure. The coordination between the shipping department in the plant and the erectors at the site is critical to assure that the appropriate members are delivered when they are needed. Due to the length of some precast/prestressed members, special load permits must often be obtained to allow the member to be trucked to the site. Such permits often have stipulations which restrict moving the load during inclement weather conditions anywhere along the route or during specific hours of the day. This can unexpectedly delay the delivery of these members to the site. The erector may find it necessary to revise the erection plan when this occurs. This can mean that connectors may be required to work from the surface of a narrow beam instead of the wider surface of a deck or roof member that would have been installed, had a timely delivery been possible.

The erection of precast/prestressed concrete components is somewhat similar to the erection of steel in that the members are specifically fabricated, trucked to the site, hooked to the crane, and lifted to connectors working on the structure. The processes differ in that precast/prestressed members weigh many times more than steel members (e.g., a 25-foot long steel beam weighs approximately 875 pounds, while a 25-foot concrete beam weighs approximately 18,000 pounds), are often quite large (e.g., 8 by 10-foot wall panels and 8 by 50-foot double tee floor sections), and are normally connected to the structure by welding together steel plates embedded in the concrete members instead of using bolts. This aspect requires the connectors to spend more time plumbing the members, before tack welding them into the structure, than would be done on a steel structure. (Examples of various precast/prestressed products and diagrams of connection detail are provided in Appendix E.)

The erection crew consists of a foreman, a hook-up man, and two or more "connectors" who work at the leading edge of the structure to attach the concrete members. (While the term "connector" is not widely used when referring to precast/prestressed erectors, the term will be adopted for use here, in the interests of clarity.) One or more welders will follow the connectors to weld together the steel plates (embedded in the concrete members). When a substantial part of the structure is in place, a finishing crew will begin grouting between wall panels and around the base of columns to complete the precast/prestressed erection phase.

Here again it must be emphasized that every structure where precast/prestressed products are used requires the connector to perform unique tasks. The descriptions below are meant as examples only.

3.3.1 PRECAST/PRESTRESSED COLUMN AND BEAM ERECTION

Buildings are seldom framed with precast/prestressed columns and beams without also having other types of precast/prestressed products which will be installed, such as wall, floor, or roof panels. Therefore, these products may be used in combination with other types of precast/prestressed products to form the structural support. For example, several lines of precast/prestressed columns and beams may be used along one dimension of the structure; however, tee products which will form the floor or roof provide lateral structural support between the beam lines.

To begin the erection process, the erection contractor establishes the elevation of the concrete footings where columns are to be placed. A stack of square metal shims is placed on each footing to assure that the top of each column will be level.

3.3.1.1 Erection of a Precast/Prestressed Column

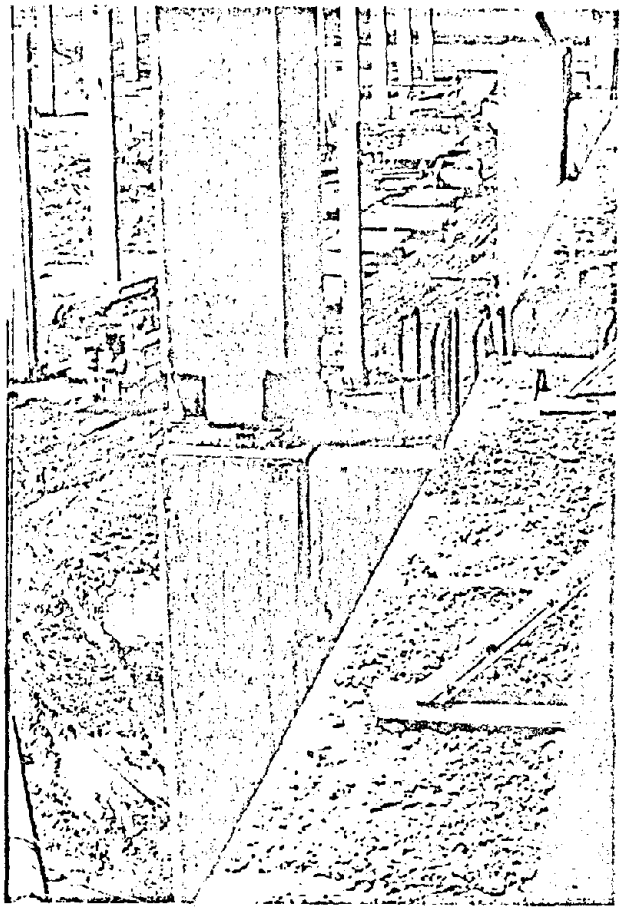
Description of Task	Time Required For Task	Period of Fall Exposure
A lifting loop (made of steel strand formed into a loop and attached to the rebar cage cast inside the column) is attached to the crane hook. The column is lifted so that it hangs vertically.	1 - 4 min.	0
Connectors signal the crane to align the column over bolts which are cast into concrete footings. The connectors guide the column onto the bolts as it is lowered. Nuts are placed on the bolts and tightened to secure the column. The foreman or field engineer will use a transom or	7 - 15 min.	0

Description of Task	Time Required For Task	Period of Fall Exposure
level to plumb the column and the connectors will shore it in place using adjustable pipe shores.		
A connector will then use a ladder to climb to the top of the column and unhook the crane. If the column is extremely tall, a boatswain's chair attached to the second line on the crane may be used to raise a connector so the crane can be unhooked.	1 - 3 min.	0
Alternately - If the column is being placed on an upper level of the structure, the decking around it is generally erected before it is placed. Therefore, the connectors can work from the concrete deck when maneuvering the column and lowering it to the connection point.	7 - 15 min.	0
Alternately - Connectors will also place columns at elevated locations in the structure along the perimeter of the building and beside open shafts or stairwells. At these times, they are exposed to a fall off the edge or into the shaft.	7 - 15 min.	7 - 15 min.

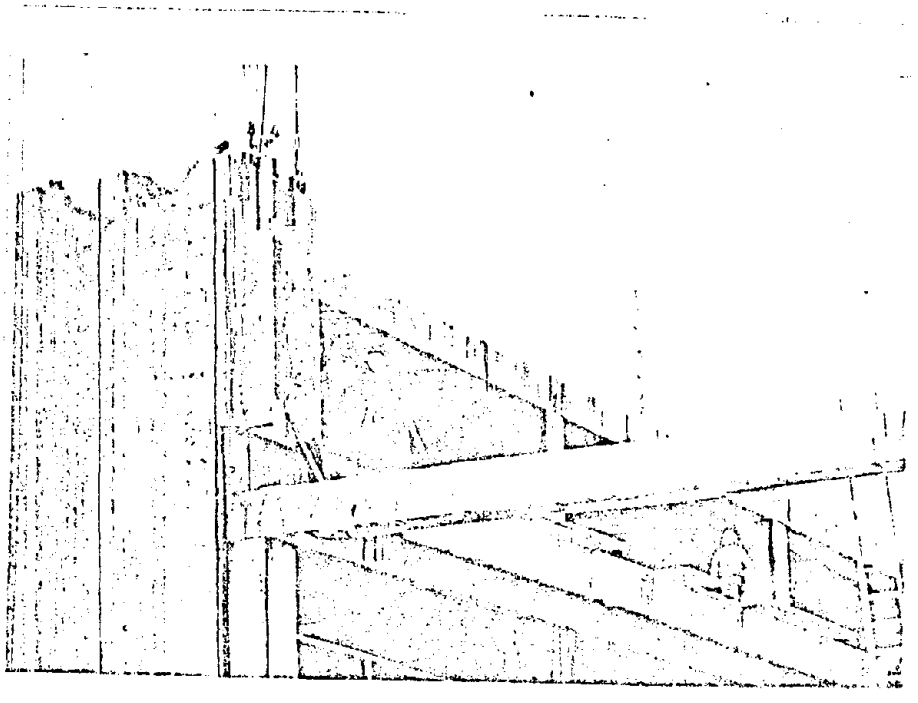
3.3.1.2 Erection of a Precast/Prestressed Beam

Description of Task	Time Required For Task	Period of Fall Exposure
The crane hook is attached to lifting loops cast into the beam and it is raised to the connectors.	1 - 4 min.	0
A cross section of a precast/prestressed column is usually square, and the measurement of each side may vary between 12 and 24 inches. The connector cannot climb these columns as he does a steel column. Therefore, a ladder, placed on the ground or	½ - 1 min.	0

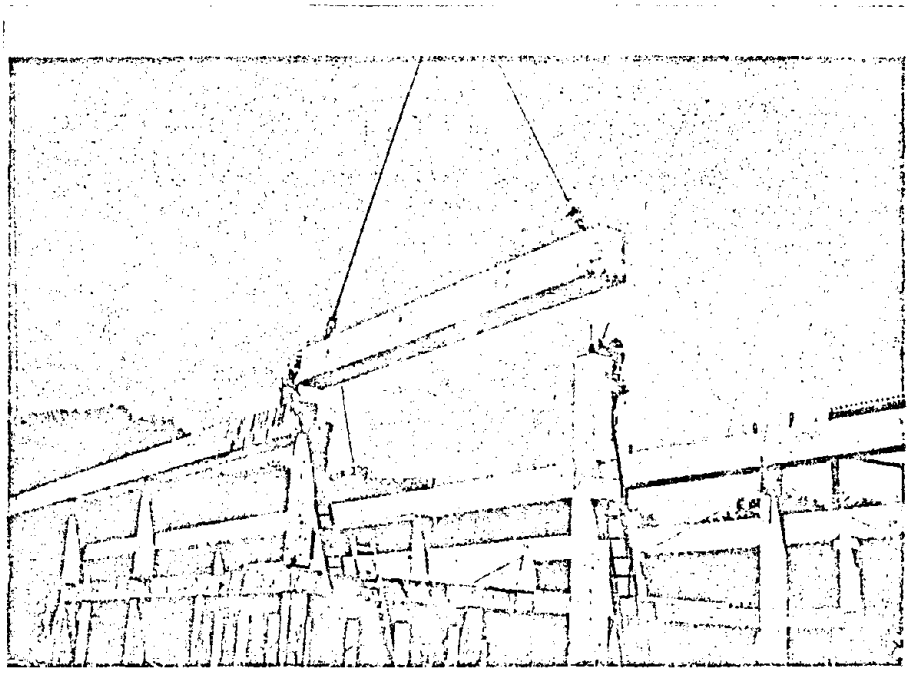
Picture 13 - Prestressed concrete columns are bolted to the columns in the lower part of the structure.



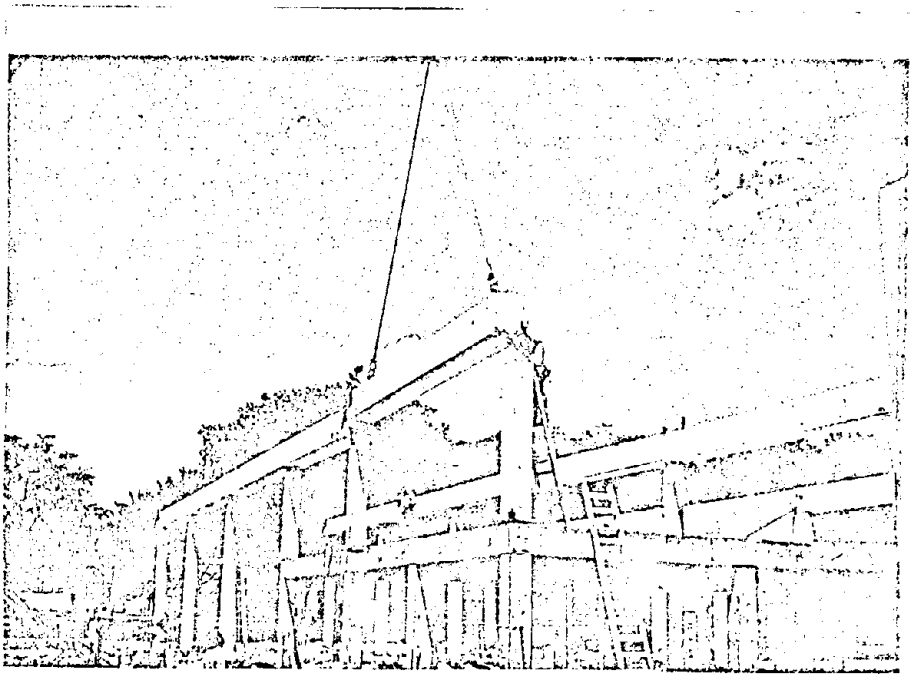
Picture 14 - Whenever possible a prestressed deck member is erected to provide a work platform for the connectors. In this case an 8 foot wide double tee was put in place so the wall panels above it could be installed.



Description of Task	Time Required For Task	Period of Fall Exposure
an adjoining deck, is used to reach the connection point on a column. The connectors climb ladders, placed against the columns between which the beam will be placed, to the connection point.		
One connector signals the crane operator to swing the piece into position. The connector reaches for the beam and helps maneuver it to the connection point. The beam is normally set on top of the column or on small shelf-like structures, called haunches, which protrude horizontally from the columns to accept the large beam.	1 - 3 min.	0
The second connector, on a ladder at the opposite column, also guides his end into position.	½ - 1½ min.	0
The connectors measure to assure that the beam is in the correct location.	1 - 4 min.	0
If the beam must be moved, the connector uses a metal bar to pry the member into place.	1 - 6 min.	0
When the beam is in position, a metal plate, cast into the bottom of the beam, and an adjoining plate, on the top of the column or on a haunch, are welded together by the connector.	2 - 5 min.	0
One connector will now climb up on the beam, release the rigging, and walk to the end where the next connection will be made.	½ - 2 min.	½ - 2 min.
Here he sits down to await the next beam.	4 - 10 min.	4 - 10 min.
The second connector will place his ladder against the opposite column to prepare to install the	4 - 10 min.	0



Picture 15 - One connector works from the top of the erected pre-stressed concrete beam. The second is working from a ladder resting against the columnn.



Picture 16 - The beam is "lowered" into position so it rests on top of the columns.

Description of Task	Time Required For Task	Period of Fall Exposure
next beam. This process of one connector working from the installed beam and another working from a ladder will continue as each beam is installed.		
Alternately - The process can be slightly complicated when the design requires that holes in each end of the beam be lowered onto dowels which are cast into the tops of the columns. This situation extends the connection time somewhat.	2 - 10 min.	2 - 10 min. if working from erected beam at perimeter

3.3.2 PRECAST/PRESTRESSED LOAD BEARING WALL PANELS

Precast/prestressed wall panels can be designed simply as enclosures which are attached to structural precast/prestressed members or a steel structure. They can also be designed to carry the weight of the building without the need for further structural support. The first category is generally referred to as architectural wall panels. While these are normally installed at the perimeter, they are installed after the structural work is completed and the people attaching them are normally working from a substantial deck within the building.

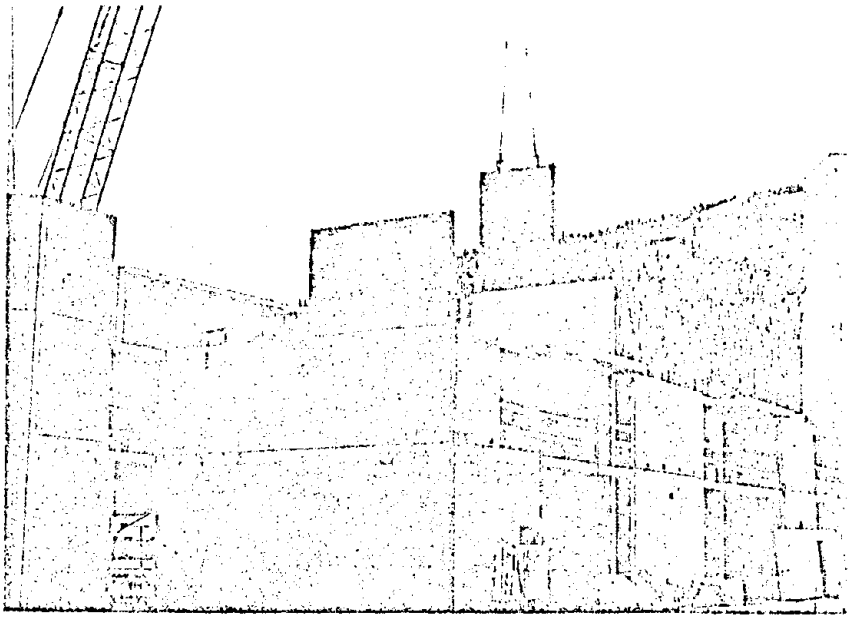
The second category is load bearing wall panels. They are installed as structural members as the erection of the building progresses. Therefore, many of the fall exposures and protection problems encountered in other structural work are common to erecting this type of product as well. It should be noted that while these wall panels are structural, many also have carefully prepared textures or exposed aggregate surfaces which will be exposed in the final structure.

A load bearing wall panel is normally erected after the flooring on a particular level has been installed adjacent to the wall panel location. This allows the connectors to work from a substantial floor during the erection procedure. Fall exposure is encountered only when a panel is erected at the perimeter of the building or around a shaft. This process is described below.

Description of Task	Time Required For Task	Period of Fall Exposure
The connectors gather and place shims on the deck where the panel will be placed to provide a level support.	2 - 8 min.	1 - 3 min. while placing shims
The connectors will then stand on the floor and wait until the crane swings the wall panel to their position.	2 - 10 min.	0

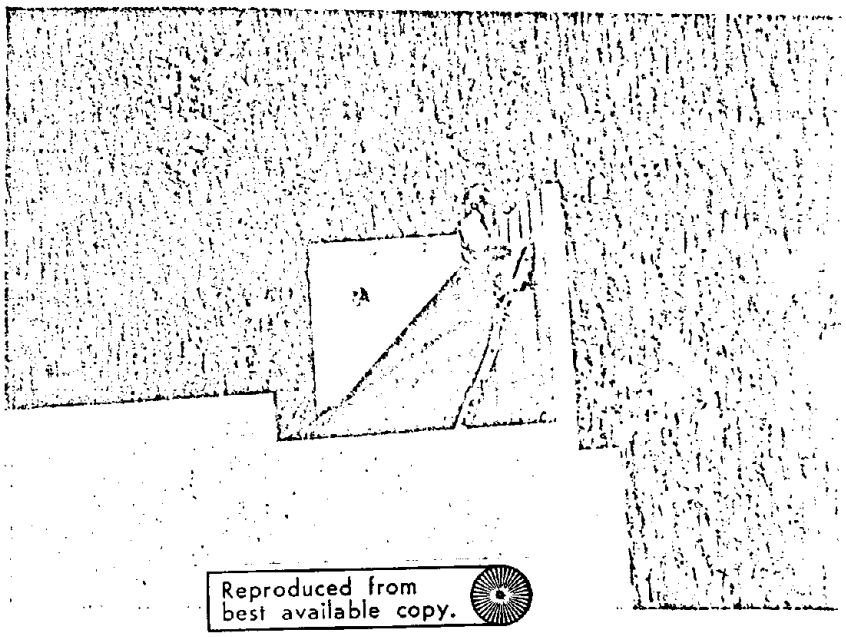
Description of Task	Time Required For Task	Period of Fall Exposure
During this time, one connector will signal the crane operator using either a radio or hand signals. If hand signals are used, he will walk to a point on the structure where he is in full view of the crane operator and can see the member being raised. This could mean that he will walk out along a beam line or will walk to the perimeter, or close to the perimeter, of the floor structure.	½ - 3 min.	¼ - 3 min. depending upon where the signal man must be located
The panel is swung over the structure to the erection location and is lowered over the deck so the connectors can reach it. The connectors take hold of either end of the panel and move to the perimeter to guide the panel as it is lowered by the crane.	1 - 4 min.	¼ - 2 min. at perimeter
When the panel is set down, it is plumbed, using a hand level or transom. This work can sometimes be done behind the panel so the connector is not exposed to a fall.	2 - 6 min.	0
Alternately - It may be important to determine if the exterior surface of the panel is level. To accomplish this, a connector leans out while holding the panel with one hand and places the level against the outer surface.	2 - 6 min.	½ - 2 min.
The panel may have to be barred into final position. This is done either behind the panel or at the end of the panel along the building perimeter.	½ - 4 min.	½ - 4 min. if at perimeter
The connectors now weld the panel to plates embedded in the deck and may use pipe shores to secure the panel. This task requires the connector to work on hands and knees behind and at the end of the panel.	5 - 12 min.	2 - 5 min. at perimeter

Picture 17 - The connector standing on a solid deck swings the incoming prestressed concrete wall panel 180° to position it properly.



Picture 18 - The panel is lowered to the deck so it can be plumbed. The connector works with the foreman (on the ground at the right) who uses a transom to aid in plumbing the member being installed.

Picture 19 - A welder can do a substantial part of his work from a ladder placed against the back of the panel.



Description of Task	Time Required For Task	Period of Fall Exposure
One connector may also have to climb a ladder to the top of the panel to weld it to an adjacent panel.	3 - 6 min.	0
After welding is completed, a connector will place a ladder against the back of the panel and climb to the top so that he can unhook one of the rigging hooks.	½ - 1½ min.	0
He may then walk along the top of the panel to the location of the second hook to release it.	½ - 1 min.	½ - 1 min.
Alternately - The connector may elect to move the ladder to the location of the second hook.	1½ - 2 min.	0
Alternately - Hook attachments may also be placed on the interior side of the panel. These will be released using ladders.	½ - 2 min.	0
The connectors then return to the deck to await the next wall panel.	3 - 9 min.	0

An alternative process, which is used where tall wall panels are being erected on concrete footings, follows somewhat the same procedure. In this case, however, a connector may work from the top of the erected wall panel.

Description of Task	Time Required For Task	Period of Fall Exposure
The connector will sit astride the wall panel waiting for the next panel to be positioned by the crane.	2 - 8 min.	2 - 8 min.
The top connector helps to guide the panel into position and will use a clamp to attach the top of the new panel to the erected panel and hold it in position.	1 - 3 min.	1 - 3 min.
When the panel is secure, the connector will walk or slide along the top of the panel to the opposite side, and the process is repeated.	½ - 1 min.	½ - 1 min.

3.3.3 PRECAST/PRESTRESSED ERECTION OF FLOOR OR ROOF MEMBERS

A number of shapes and sizes of precast/prestressed members can be used for floors or roofs. Among these are single and double tee members (typically 8 feet wide and up to 124 feet in length). These floor members can be placed between beam lines, load bearing wall panels, or masonary walls. Often beam lines or load bearing wall panels have been set and shored in place to receive the floor members. These members are used to provide lateral stability to the structure, and they are usually erected as the building progresses. That is, a load bearing wall panel is set on either perimeter of the building, and a double tee floor panel is set between them to provide lateral support. This is a unique aspect of many precast/prestressed structures, because the flooring at each level must be installed as the erection process proceeds, to stabilize the structure.

When possible in a multi-story building, the erection sequence is planned so that a stairstep pattern is followed. That is, two floor members are placed at level one before the first member is placed at level two. The erection progresses by adding one or more members to each floor in succession. In this manner, the connector working at the leading edge on level one is exposed to a fall of one level to the ground. When the connector moves to level two, the piece (perhaps 8 or more feet wide) just erected on level one, extends in front of him. He is exposed to a fall hazard of only one level.(20)

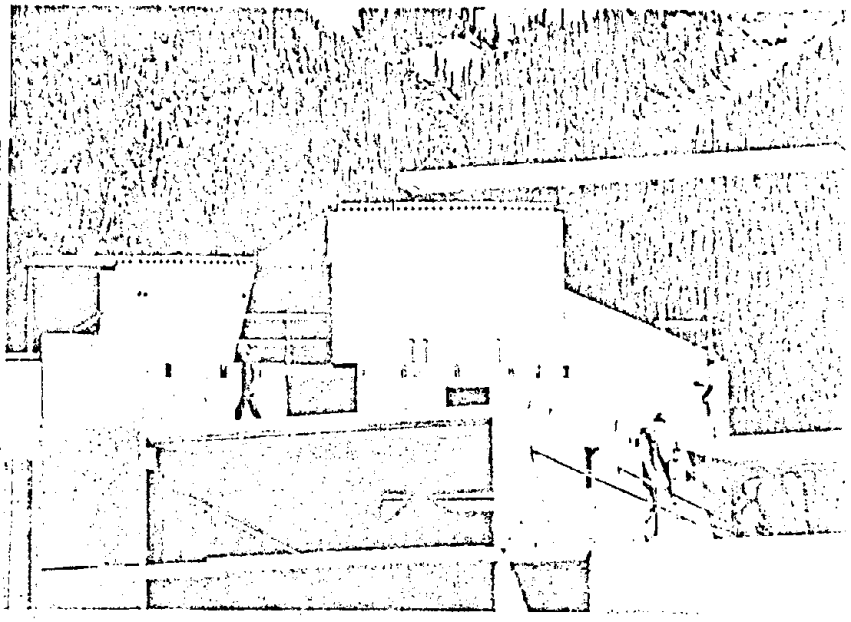
Description of Task	Time Required For Task	Period of Fall Exposure
When erecting the first member of a floor, the connectors place ladders against the walls of the structure but remain on the deck below, away from the incoming member, until it is positioned by the crane.	2 - 10 min.	0
The crane swings in the first member. It can often be maneuvered by a tag-line until it is almost in the proper position. It may set on top of two beams or haunches cast into the interior sides of wall panels, or an angle iron which has been welded to metal plates embedded in the wall panels.	½ - 3 min.	0
At this point, the connectors will climb the ladders to the level of the floor member and guide it into final position.	1 - 3 min.	0
The connectors then weld the panel to stabilize it.	5 - 12 min.	0

As the floor erection progresses, the connectors work from the top of the erected floor.

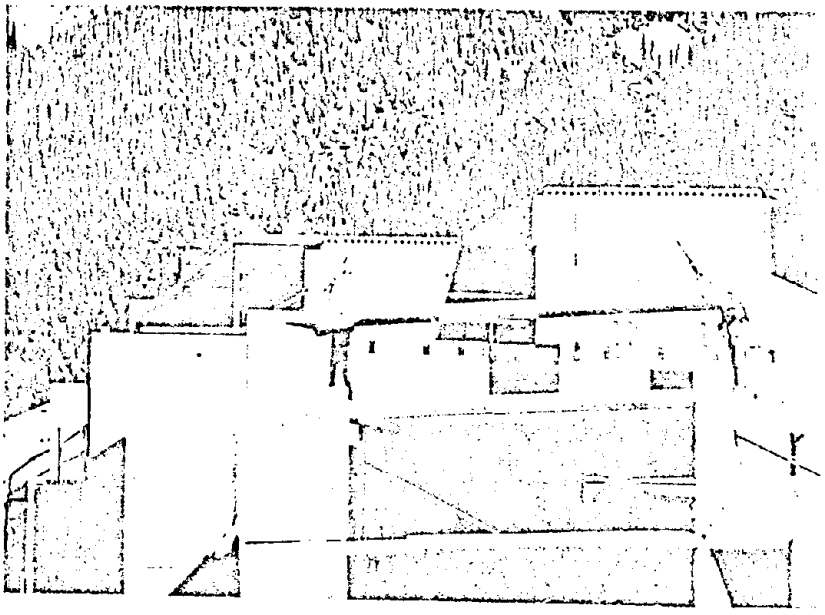
Description of Task	Time Required For Task	Period of Fall Exposure
The next member is swung to the connectors by the crane and lowered to approximately shoulder level. The connectors grasp the member and walk forward guiding it into position at the forward edge of the last member erected.	½ - 1½ min.	¼ - 3/4 min. as connectors move members forward
When the member is set into position, the connectors are no longer exposed to a fall danger because they are now welding together the adjoining plates in the two members. By installing the new panel, they have extended the floor 8 or more feet in front of them.	4 - 10 min.	0
When the panel is secured, the connectors will typically detach four hooks from lifting loops embedded in the member. To do this they walk on the flat surface of the member.	½ - 1 min.	¼ - ½ min. to detach hooks closest to leading edge
Alternately - Due to lack of room on the site, a considerable amount of maneuvering may be involved in placing a floor member. The member may need to be swung around 90° or more before being lowered into place. The member is lowered to the connectors' shoulder height, and they physically guide the member around as they walk across the erected deck.	1 - 4 min.	0 - 2 min. should connectors walk close to the leading edge
Measurements must be made to to assure the member is placed in the proper position. This could require a connector to move out along a beam line to measure from the next column back to the member being installed.	1½ - 10 min.	0 - 4 min. if measurements are made along beam line

In performing this work, it is normal that the two connectors will move back and forth along the length of the member, to help each other measure and bar the member into position. The connectors are constantly crossing each other's paths during this process.

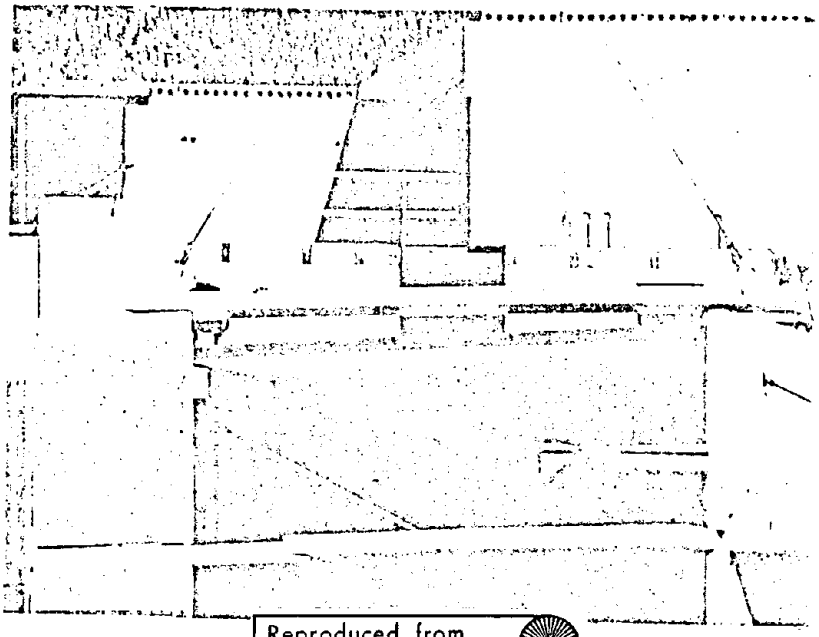
Picture 20 - A hollow core floor panel is swung over the structure toward the connection location.



Picture 21 - The panel is lowered to two connectors, working on top of a solid deck. They are partially blocked from a fall as the panel is lowered in front of them.



Picture 22 - The connectors guide the panel as it is lowered into position in the floor. When the panel is down the connectors have extended the deck four feet in front of them.



3.4 OBSERVATIONS

As is demonstrated in all the erection situations discussed above, for both steel and precast/prestressed, the connector is extremely mobile while making a connection. The attachment of the members he is placing in the structure takes relatively little time in most cases. In a single day, a steel connector may attach twenty to forty pieces into a tiered building. A precast/prestressed erector may place eighteen to thirty-five members into a structure in that same period of time. The connector may potentially advance a structure of load bearing wall panels and interconnecting roof tees some 30 to 80 feet. During this time, the portion of the structure where the connector works is stable, but not permanently bolted or welded, nor are all the structural members in place. Since his job is to assemble the structure, there is often no completely secure spot where fall protection equipment can be attached and there is no overhead structure because it has not yet been installed.

While the above discussions provide some understanding of how various erection processes work, they do not present even a majority of work situations. Each structure is different and each beam, column, or wall panel can present the connector with a new task which must be performed if the building is to be erected.

CHAPTER 4. FEASIBILITY OF COMPLIANCE WITH SUBJECT STANDARDS

Several factors are included in an examination of the feasibility of complying with the subject safety standards. One factor is the apparent lack of uniformity in the way in which they are enforced. Another is the number of citations for these standards which are contested before the OSHA Review Commission and the courts. Related to this is the fact that the Review Commission and courts have disagreed on some points resulting from these cases. A final factor is the feasibility of providing protection in various point of erection situations and whether or not the connectors themselves believe they can use protection in all situations.

4.1 REVIEW OF OSHA ENFORCEMENT OF SUBJECT STANDARDS

4.1.1 ENFORCEMENT VARIANCE

A clarification of OSHA policy is necessary to establish uniformity in OSHA enforcement practices. OSHA recognizes that there is an enforcement problem with regard to these standards being applied to connectors. OSHA has held meetings and written several directives regarding this.(21)

Based upon conversations with various OSHA officials and union representatives, and as evidenced in a recent court case(22), it is apparent that Connecticut and Washington, D.C., are two areas of the country where the use of perimeter netting on steel tiered buildings is consistently enforced. It is apparent that the use of these nets is not as consistently enforced in other parts of the country, because perimeter nets are seldom used elsewhere.

There is also variance in the enforcement of the requirement for the use of safety belts. Region VIII OSHA recognizes that steel and precast/prestressed connectors must remain mobile and that there may be a greater risk to them if they are tied off than if they are not. The Region also recognizes that connectors often work where nets cannot be used. Region VIII established a regional policy for all precast/prestressed connectors in a letter to Stanley Structures of Colorado (an erection contractor). The letter states that employees engaged in precast/prestressed connection work in elevated areas are not required to be tied off. (See letter in Appendix F.)

There is a general perception among union officials and contractors alike that an enforcement variance exists between union and non-union jobs. They feel that an inappropriately high proportion of OSHA compliance inspections

take place on union sites. OSHA does not single out union sites; however, several factors outside OSHA's control could lend some credence to this perception. OSHA must respond to employee complaints lodged with them. For example, in fiscal year 1978-1979, 25 percent of the OSHA inspections in the industries studied were complaints.(23) Union workers, who are perhaps more aware of OSHA safety standards and their rights to seek enforcement of them, may tend to lodge a higher percentage of these complaints to correct safety problems. A second factor is that, in several parts of the country, union companies tend to build more of the types of large projects where serious fall exposures are encountered. A random sample of these sites would naturally contain more union projects. OSHA officials in Hartford, Connecticut, however, feel that the variance is not unduely wide. They estimate that they inspected 54 percent union jobs and 46 percent non-union jobs in 1980.(24) This estimate compares quite well with the actual number of union and non-union inspections made nationwide for the years 1977 to 1980, as evidenced in Table 5.

TABLE 5 - NUMBER OF UNION AND NON-UNION OSHA INSPECTIONS IN SIC CODES 1522, 1541, 1542, and 1622* OVER A FOUR-YEAR PERIOD**

FISCAL YEAR	NUMBER OF UNION INSPECTIONS	NUMBER OF NON-UNION INSPECTIONS	TOTAL INSPECTIONS
1977	1638 (56.0%)	1288 (44.0%)	2926 (100%)
1978	1642 (54.2%)	1389 (45.8%)	3031 (100%)
1979	2012 (53.5%)	1746 (46.5%)	3758 (100%)
1980	3321 (56.1%)	2595 (43.9%)	5916 (100%)

*SIC Codes: 1522-General Contractors-Residential, other than single family; 1541-General Contractors-Industrial Buildings and Warehouses; 1542-General Contractors-Nonresidential Buildings, other than Industrial Buildings and Warehouses; 1622-Bridge, Tunnel and Elevated Highway.

**Source: OSHA Office of Management Data Systems, Washington, D.C.

These figures show that there were approximately 10 to 12 percent more union inspections in these SIC Codes in each of the four years. These four SIC Code industries account for the majority of erection work. Based on these figures, one cannot actually conclude that this proportion is unduely wide, unless the number of union and non-union construction projects is also known for each year. If there are actually more union projects, for example, the proportioning of inspections may be correct.

There is also some confusion about whether both the general construction standards (29 CFR 1926.104 and .105) and the steel erection standards (29 CFR 1926.750, .751, and .752) can be enforced on steel erection jobs. The

steel erection standards do not specifically require the use of safety belts for connection work; however, they do for planking and plumbing operations. They also make no provision for the protection of employees working at the perimeter of a building prior to the erection of a perimeter cable. However, OSHA's general standards do require protective measures in addition to those set forth in the steel erection standards, but there is no mention or reference of these general standards in the steel erection standards.

4.1.2 OSHA REVIEW COMMISSION AND FEDERAL COURT DECISIONS

There have been numerous cases before the OSHA Review Commission and the courts involving the standards in question.(25) The following table shows the number of cases involving each of the four standards for the years 1972 to 1979.

TABLE 6 - NUMBER OF CASES INVOLVING EACH STANDARD
1972 THROUGH 1979

STANDARD	NUMBER OF CASES
29 CFR 1926.21(b)(2) - Safety Training and Education	16
29 CFR 1926.104 - Safety Belts, Lifelines and Lanyards	19
29 CFR 1926.105 - Safety Nets	78
29 CFR 1926.750(b)(1)(ii) - Temporary Flooring Skeleton Steel Construction in Tiered Buildings - Requiring Nets	17

A review of these cases indicates that many citations for failure to use safety belts are also issued under 29 CFR 1926.28(a) Personal Protective Equipment. Therefore, cases were also studied when this standard was cited in connection with one of the subject standards, so as to better determine exactly when such protective devices are and are not required.

Before proceeding with a discussion of the decisions in these cases, it must be noted that very few of these cases involved situations where connection work was actually taking place. However, many of them involved situations which are closely related to connection work.

4.1.2.1 Safety Training and Education

There were sixteen cases during the years 1972 to 1979 that involved the safety training and education standard (29 CFR 1926.21(b)(2)). However, none of these cases was identified to have been a case in which the safety training standard was violated or cited in regard to connection work. Apparently, this standard is seldom being cited in relation to connection work, or these citations are not being contested.

4.1.2.2 Vagueness of Fall Protection Standards

There is some confusion as to whether or not the general personal protective equipment standard (29 CFR 1926.28(a)) is unenforceably vague because it does not specify when and how protective devices must be used. The Review Commission has consistently held that it is not unenforceably vague, despite the fact that the courts have ruled otherwise. The Fifth Circuit U.S. Court of Appeals has stated that the standard requires only those protective measures which industry practice would clearly deem appropriate under the circumstances.(26) For example, the court has recently said that an employer cannot be forced to guess at what equipment is required, because if he includes the cost for such equipment in a bid and others do not, he will be at a competitive disadvantage. Furthermore, if he does not include the cost in his bid and is later required to use protection, he may suffer cost overruns. The court noted that the Commission cannot simply ignore industry practice and find an employer in violation of the general personal protective equipment standard. Instead, the employer must have been given specific knowledge about what is required in the circumstances under which he is working.(27)

4.1.2.3 Safety Belts, Lifelines, and Lanyards

As a result of the Review Commission holding that the general personal protective standard (29 CFR 1926.28(a)) is not unenforceably vague, the Commission has consistently held that this standard may be applied to require use of tied-off safety lines by employees subjected to a fall hazard.(28)

4.1.2.3.1 Strength of Standard

In no case involving a citation for failure to use a safety belt when working at a height has the safety belt standard (29 CFR 1926.104(a)) been upheld on its own. Where citations have been upheld, the general personal protective standard has also been cited or the citation has been amended to this more general standard. The safety belt standard does not specify when the use of safety belts, lifelines, and lanyards is required; it simply states that they be used only for employee safeguarding.

Other parts of the safety belt standard (29 CFR 1926.104) have been upheld by themselves where the citation involves misuse of the equipment. For example, in a case where safety belts and lanyards were used, but were not tied off above the worker, 29 CFR 1926.104(b) was upheld because it requires that "lifelines shall be secured above the point of operation." In another case, 29 CFR 1926.104(d), requiring a maximum fall distance of 6 feet when a lanyard is in use, was upheld by itself in a case where the allowed fall distance was 12 feet.

4.1.2.3.2 Employer Responsibility

The Commission has held that, although an employer is generally responsible for violations either created by supervisory employees or within their actual or constructive knowledge, an employer may defend by showing that it took

all feasible precautions to prevent the occurrence of the violation.(29) Therefore, in cases in which an employer issued safety belts and specifically required their use, but an employee was observed without a belt; the situation is said to be an isolated incident and the employer cannot be held in violation of the standard. However, if the employer, supervisor, or foreman had knowledge that the belt was not in use, the employer was held to be in violation. The employer cannot have a policy of providing belts, but leaving it to the employee's discretion as to when to use them. When an employer does this, he has not taken all feasible measures to preclude the violation.

4.1.2.3.3 Practicality of Using Safety Standards

The Review Commission and the courts recognized that the use of safety belts may be practical only for some employees at some times and not for all employees at all times. The recognition of this fact has been applied to mean more specifically that safety belts are practical while workers are sitting and working on beams, but not while they are traversing on beams, which is the substantial portion of a workday for connectors. This is primarily due to the fact that employers have been able to successfully argue for the need for quick mobility. Several times when this argument has been used, the citation for violation of the safety belt standard has been vacated. In these cases, it has been recognized that the use of safety belts can present a greater hazard to connectors than would working without them. One case prior to 1979 could be identified as involving connection work in prestressed concrete construction. In this case, the use of safety belts and lanyards was proven to be more hazardous than working without such protection, because tied off workers were not able to move out of the way of swinging double-tee floor members. This was also a ruling in a more recent case.(30)

Even though this recognition has been given, the Review Commission and courts have held that some form of fall protection must be provided for workers while they move along the beams. This has generally been interpreted to mean that nets be used to protect these workers. Contrary to earlier decisions, the Review Commission, in two 1979 cases, held that safety belts could feasibly be used by workers cooning or straddling beams, even if it meant their movement would be slowed by the necessity of constantly attaching and detaching their lanyards.(31)

One specific case requires detailed discussion here. In this case, the employer was in the process of erecting structural steel for a building in La Porte, Texas. A steel connector working 55 feet above the ground on a beam fell to his death when the beam and a vertical column to which it was attached collapsed. The employer was cited under the general personal protective standard for failure to require its connector to wear and use safety belts.

In the case, it was noted that the employer required its connectors to wear protective equipment and to tie off properly when at rest. It was also noted that the duties of a connector require almost constant mobility in order for him to receive and place the steel, make the required bolt connections, and avoid being hit by a swinging steel member that makes an unusual movement.

Coupled with these facts was the evidence that there was no place to install a lifeline above the point where the accident occurred. The only structure to which the worker who fell could have been tied off was the beam on which he stood or the adjacent column, both of which fell. The evidence presented in this case convinced the Review Commission to rule that the citations should be vacated.(32)

4.1.2.3.4 Industry Practice

In one recent case, the Fifth Circuit Court threw out OSHA safety belt citations against two employers, one of which is a prestress concrete erector. It attacked OSHA's failure to conform to earlier rulings by this same court in which they specified that safety belts are not required where the industry practice is not to wear them. The court also attacked OSHA's argument that all obvious hazards require safety belts. More specifically, the court held that a prestressed concrete erector could logically come to the conclusion that an employee's constant awareness of the danger of falling from the perimeter provides sufficient protection on flat surfaces. Such workers would not mistakenly expect the edge to be guarded or perform their work in such a way to create the possibility of a fall.(33)

4.1.2.4 Safety Nets

4.1.2.4.1 Use on Bridges

The Review Commission has upheld that nets be used on bridge construction jobs where there is substantial probability that death or serious injury would result if they were not used. The defense that the nets would be overly expensive and impractical to use on such a job has been rejected.

4.1.2.4.2 Practicality and Use

The Review Commission has consistently held that where it is impractical, infeasible, or impossible to use alternative protective devices (i.e., temporary floors, scaffolds, catch platforms, ladders, or safety belts and lifelines), safety nets must be installed to protect against falls, especially when a fall would result in death or serious physical harm. This has been ruled in cases involving erection of a multi-storied powerhouse facility, a single-story plant, a three-story precast concrete building, and multi-storied steel buildings. Most of these cases involved the use of interior nets. However, in one case, perimeter nets were required for workers walking the perimeter beams at the seventeenth floor of a multi-storied building.

Where lifelines, safety belts, or lanyards are actually in use, nets are not required. For example, in a case where employees were laying steel beams 97 feet above ground, it was found that the net standard was not violated since the employees were wearing safety belts.(34)

4.1.2.4.3 Greater Hazard and Impossibility

Where the employer could raise defenses and establish that the erection of nets was impossible, that their use would make work impossible, or that their use would result in a greater hazard, the employer has not been held to have violated the standard. For example, where the operation of the cranes directly under beams being erected in a bridge structure was proven to make the erection of safety nets impossible, the citation was vacated.(35) Also, where the employer could show that the installation of nets would interfere with the movement of materials up through the interior of the building, the same conclusion was reached.(36) In the case discussed previously where the employer was erecting a steel building in La Porte, Texas, the use of nets was proven infeasible at the stage of construction during which a worker was killed, because the structure at that stage would not support nets. In a more recent case, it was also recognized that when the duration of the time required to erect a safety net exceeds the duration of time of employee exposure, the value of such protection is negated.(37)

In the opposite situation, where the employer could not prove impossibility or greater hazard and OSHA has been able to prove otherwise, the employer has been held to have violated the standard. For example, OSHA has proven feasibility and less hazard by showing that an erection derrick can be used instead of a crane to install columns, thereby making the use of nets possible.(38) In another case, OSHA was able to prove feasibility when it showed that preplanning regarding the construction method could have been carried out, so that the building could have been constructed differently and safety nets erected.(38)

4.1.2.4.4 Industry Practice

The steel erection industry practice in most parts of the country is not to use safety nets. However, the Review Commission has consistently held that this does not entitle the employer to an exception to the standard and that such nets should be used to protect connectors and other workers from falls.

4.1.2.5 Steel Erection

4.1.2.5.1 Single-Story Buildings

The Review Commission has consistently held that the steel erection standards (Subpart R of the OSHA Construction Standards) apply only to tiered buildings and not to single-story buildings. Loft-like and open bay structures are not subject to the Subpart R standards. Warehouses, open framework towers that do not contain permanent floors, and power plants with floors which do not have the consistency and uniformity of conventional tiered buildings have also been included in such rulings.

Although the steel erection standards do not apply to these types of structures, the general construction standards, such as the general personal

protective standard (29 CFR 1926.28(a)) and the safety net standard (29 CFR 1926.105), do apply to them.

4.1.2.5.2 Applicability of General Standards

There has also been some question as to whether or not the general construction standards apply to steel erection, since the erection of steel tiered buildings is governed by a specific standard. The Review Commission has held that the specific standard requiring nets (29 CFR 1926.750(b)(1)(ii)) applies to the erection of steel tiered buildings and that the more general net standard (29 CFR 1926.105) does not. This is based upon section 29 CFR 1910.5(c)(1) Applicability of Standards which requires that where a particular standard can be specifically applied to a condition, it must prevail over other general standards that also might be applicable.

This problem was highlighted in a recent case in which the employer was cited for violating standards 29 CFR 1926.105(a), 29 CFR 1926.105(c)(1), and 29 CFR 1926.750(b)(1)(ii), while erecting a six-story steel structure in Fairfax, Virginia. These citations resulted from the compliance officer's various observations of connectors and other workers being exposed to perimeter falls from 30 to 95 feet. All of these workers were protected by nets from falls to the interior of the structure. The connectors were at the perimeter, of course, in order to connect steel members being raised by the crane. The compliance officer stated that in all the situations he observed, the connectors should have been tied off or protected by exterior nets. Another compliance officer who was present at the worksite during the inspections, however, stated that he would not have issued a citation for the failure of the connectors to tie off. He stated that it is dangerous for connectors to tie off because the steel being lifted by the crane might get out of control and the connectors might not be able to get out of the way.

At one point, the company president stated that it was impossible to string nets because they would have interfered with the erection of the structure. At another point, he stated that it would have taken a long time to install exterior nets and that the employees installing them would be exposed to a fall. However, another witness outlined various methods by which perimeter nets could be used and stated that their use is feasible.

The Commission concluded, then, that the area could be netted and pointed out that a fall could have resulted in death or serious physical harm. Therefore, the Commission ruled that the citation for violation of 29 CFR 1926.750(b)(1)(ii) should be affirmed.

Regarding the citation for the more general net standard (29 CFR 1926.105), it was noted that there is some question as to whether or not this general standard can apply to steel erection. Evidence showed that the use of perimeter nets is unknown and not required in the steel erection industry or by compliance officers, because the steel erection standards (Subpart R) make no reference to their use. This fact requires that the employer must assume the burden of guessing what is intended in the standards. The Tenth Circuit Court of Appeals has held that this should not be the case. Therefore, the Commission ruled that the employer was not given fair notice that the general net standard applied to its steel tiered structure, if it in fact did apply, and that this standard was not violated.(40)

However, if the two standards do not apply to the same condition, a steel erector can be cited for the more general standard. In fact, there are numerous cases where a steel erector has been cited for the failure to use safety belts, and it has been upheld. Therefore, according to the Review Commission, steel erectors are covered not only by the specific steel erection standards, but also by the more general construction standards when they do not deal specifically with the same thing. This was supported in 1979 by the U.S. Court of Appeals for the Fourth Circuit which rejected an employer's claim that the steel erection industry is covered exclusively by the specific steel erection standards.(41)

4.1.2.5.3 Vagueness

The Review Commission has also held that the steel erection standard requiring nets (29 CFR 1926.750(b)(1)(ii)) is not void for vagueness, even though it leaves the employer with determining which means must be used to install appropriate nets.(42)

4.2 STANDARDS COMPLIANCE - DISINCENTIVES AND INCENTIVES

Perhaps the most important incentive to provide fall protection to the worker is the very natural desire, on the part of any employer, to protect employees from injury. No employer wants to be in the position of having to face the fact that someone was seriously injured on their job. However, there are limits to what can be done to provide such protection. When a protection system requires an expenditure which threatens to limit the employer's ability to stay in business, and thus provide employment, some compromise will be found. In areas where employees may seldom be injured and where the employees themselves often see no need for protection, few incentives for providing that protection are recognized. The issue of requiring the use of nets or safety belts for connectors is just such a situation in many parts of the country.

4.2.1 DISINCENTIVES

Providing a fall protection system can be an expensive undertaking. For example, estimates for installing net systems provided by the U.S. Army Corps of Engineers for various projects show that these costs might vary between .3 and 3.4 percent of the total cost of erecting a bridge.(43) These costs can be compounded, depending on the type of structure, if a large amount of crane time is required, or if the erector must be on the site a longer period of time due to the special installation required.

Contractors who are bidding for construction work are acutely aware of the fact that the standards in question are not enforced for connectors in most areas. Therefore, they are relatively certain that their competition will not be including the cost of such protection in the bids they submit. To remain competitive, the contractor will not include this cost in his bid and will not provide the protection.

Competition is also a factor on a broader basis. For example, if it were determined that connector fall protection would be required on all precast/prestressed construction but not steel construction, an inequity would be created. If this were the case, it is possible that building owners would prefer to build steel buildings so they would not have to pay the extra expense of this protection. This could potentially effect an entire segment of the construction industry by placing them at a disadvantage.

Labor force competition is also a factor in determining if the standards will be implemented. As discussed previously in this chapter, there is a general perception among union officials and contractors alike, that an inappropriate number of OSHA compliance inspections take place on union sites compared to non-union sites. If this perception is true, there is a feeling that OSHA could force more union contractors to provide connector fall protection, which in turn would mean that their bids must be higher. Therefore, union contractors could be placed at a disadvantage in winning work against non-union contractors.

The cost of providing various types of fall protection is also increased by the fact that there are still many situations involving connectors where a readily installed and feasible protection system has not been developed. This means that the contractor must design a system to fulfill a unique need. Designing such a system does not directly increase the efficiency of the erection process; and in these times of high interest rates and tight money, does not aid the contractor in performing effectively for the building owner.

Still another disincentive is the knowledge that many connectors (both union and non-union) will not utilize the protection system without constant pressure from management. This was demonstrated by conversations with contractors and connectors during several site visits where protection measures were available. Connectors tend to feel confident in their skills and abilities and resist efforts to make them attach themselves to the structure. Therefore, little incentive is present for the contractor to design an elaborate system of protection.

In many situations, there is a very real question concerning whether the connector is safer with the protection dictated by these standards or without it. Most connectors interviewed during the course of this project discussed several situations where they felt they were able to avoid an accident or save their lives, because they were able to move quickly away from a dangerous situation without being hampered by a safety belt tied to the structure.

Finally, there are several situations where the installation of a special lifeline or a net system would require the connector to be exposed to a fall hazard for a longer period of time than the time necessary to make the connection. (These situations and the feasibility of utilizing the protection required by these standards will be explored in more detail in later sections.)

4.2.2 INCENTIVES

A number of claims have been made by advocates of fall protection concerning

the benefits to be derived from providing fall protection on the job. Two major arguments are proposed. First, the contractor can demonstrate to the workers that he is concerned about their safety by providing fall protection equipment and enforcing policies for the use of that equipment. In turn, this will make the employees better disposed toward the contractor; therefore, they will do a better job. Secondly, connectors will work faster and more efficiently when they know that they are protected from a fall injury. Therefore, the project will be built more quickly. While the logic of these claims seems appropriate, no formal studies have been done which would support or deny these conclusions.

The workers' compensation insurance system provides some incentives to comply with the fall protection standards. There is a relationship between the number of accident claims and the amount of premium which is paid or refunded to a contractor. Therefore, any accident that is avoided has the effect of controlling the amount paid in insurance premiums. However, the workings of this system are not well understood, particularly by smaller companies. Often the premium for such insurance is treated as an absolute cost of doing business, rather than as a cost that can be reduced.

A more direct incentive is sometimes provided by insurance companies when they examine the potential losses presented by a particular erection project or react to an accident which has occurred on an insured project. An insurance company can recommend that fall protection be used. It can also require that protection be used if the contractor is to continue to be insured by that company. Such an ultimatum is a relatively infrequent occurrence. However, such a suggestion was recently made to a contractor following an accident on a bridge erection project. As a result of this request, a fall protection system was devised which allowed iron workers to tie off with safety belts or work over a net during at least 98 percent of the time spent erecting two interstate highway bridges.(44)

Employers also have an incentive to avoid the possibility of law suits resulting from claims by injured employees and/or their families concerning negligence on the part of the employer by not providing appropriate protection. Recent decisions in some states, such as Iowa, have extended the liability for such negligence. They allow the managers and foremen responsible for supplying and enforcing the use of protective devices to be sued personally in the case of serious mishaps.

The workers' compensation insurance system implemented in this country was devised to protect both employers and employees from the uncertainties of such suits. It insures that the costs resulting from occupational disabilities are paid without regard to any fault involved. The laws enacted in many states have served to relieve employers of liability from common-law suits involving negligence.

> Under workers' compensation acts employers generally are exempted from damage suits. Where an employee rejects the act, and sues an employer who has accepted it, the employer usually retains the three common-law

> defenses. Conditions for rejection of the act often are so severe as to make the privilege virtually inoperative.(45)

In states where this is true, the law may function as somewhat of a disincentive for providing expensive safety devices, in that the employer is insulated from any extremely punitive economic claims.

However, recent judicial developments modify this picture.

> Courts on opposite sides of the country chipped away at the exclusive remedy rule. The Massachusetts Supreme Judicial Court allowed the children of an injured worker to sue the employer for damages resulting from the 'loss of companionship and society' of an injured parent in Ferreter v. O'Donnell's Sons, Inc. The California Supreme Court decision in Johns-Manville Products Corp. v. Contra Costa Superior Court also allowed a damage suit for an employer's fraudulent concealment of hazardous exposure to asbestos. And in Williams v. International Paper Co., early in 1981, a California jury awarded a worker $825,000 damages against his employer on the ground that, as a self-insurer, the company acted in a dual capacity and thus was subject to a higher standard of care for job safety.(46)

In addition, solutions to some of the specific disincentives discussed previously have been found. For example, recently some safety equipment manufacturers have begun developing and marketing standardized installations for perimeter nets which can be used in a wide variety of tiered buildings. If this trend continues, the economic impact of providing fall protection to erectors will decrease.

Enforcement policies might be standardized to a greater degree by OSHA. This could provide a greater incentive to contractors to explore the options available and devise new solutions to the problems of protecting connectors from falls. However, there is some question as to whether OSHA inspections alone will be sufficient to change the practice of all contractors. OSHA currently employs 1200 inspectors to cover about 70 million employees and 5 million workplaces throughout all industry.(47)

The situation which has developed in Connecticut is worthy of special note because of the unique cooperation arrangement that has evolved between the OSHA Area Office and the local Iron Workers Union. Both OSHA and the two Iron Workers locals in Connecticut require the use of perimeter nets on buildings over two stories in height. OSHA construction compliance officers make a point of visiting any steel building they observe where nets are not being used. The Iron Workers locals simply refuse to allow iron workers to work where they are exposed to a fall hazard without nets below them. The local agreement between the union and the Associated General Contractors of Connecticut states:

> Planking, decking and nets, covering a radius of at least ten (10) feet, shall also be provided not more than two floors or a maximum of twenty-five (25) feet beneath all points on all buildings, bridges, and other structures while workmen are working at such points.(48)

The combined effect of the stance taken by both the union and OSHA has served to make perimeter nets a fairly standard feature on steel tiered buildings in Connecticut. Numerous systems have been devised by various contractors to allow these nets to be installed and moved up the building as the erection progresses.

Several circumstances have contributed to making this system work. First, most of the large structural steel projects in Connecticut are erected by union iron workers, according to the New Haven, Connecticut, local union business agent.(49) This helps to decrease the concern that requiring such protection will place union contractors at a disadvantage compared to non-union contractors when bidding for work. In other parts of the country where the union position is not as strong, it is more difficult to unilaterally require this protection.

Second, over the years it has become widely understood that contractors working in Connecticut must provide this protection. Therefore, contractors submitting competing bids know they should include the cost of installing netting. The union business agent tries to reinforce this knowledge when possible, by contacting contractors whom he knows are bidding for work in his local area to alert them to the fact that he will require the use of nets on the jobs.(50) These factors help to decrease the possibility of a contract being awarded based upon the economic differential of not including net protection in the bid.

To be certain, the policies developed in Connecticut do not achieve 100 percent compliance. However, they have encouraged many contractors to devise protection systems and many connectors to cooperate in using these systems. Through this joint effort and the ingenuity of many contractors in devising systems which can be utilized efficiently, the State of Connecticut has achieved greater compliance than any other area of the country. A similar program is being used in Washington, D.C., and is being contemplated in New York.(51)

The bid disincentives of providing nets have also been controlled to some degree by policies followed by the U.S. Army Corps of Engineers. Safety specialists employed by the Corps of Engineers review designs before bids from contractors are sought. These people determine where items such as safety nets should be required when building the project. These requirements are then included in many of the bid specifications issued by the Corps of Engineers. Therefore, all contractors who submit a bid for a particular project know in advance that the protection must be provided and the requirement will be part of the contract executed with the successful bidder.(52)

Expanding upon this concept, it may be appropriate that all federal agencies contracting for construction work adopt a similar policy.

This could be done by modifying the federal construction rules and regulations so that bid specifications would include requirements for any safety system which could significantly increase cost. In this way all contractors would prepare their bids on the same basis. There would be no advantage to the contractor who does not include the cost of these safety devices. In fact, there could be a significant disadvantage if the contracting agency takes steps to assure that these devices are used during the project.

4.3 FEASIBILITY OF USING SAFETY BELTS

OSHA standard 29 CFR 1926.28(a) Personal Protective Equipment states: "The employer is responsible for requiring the wearing of appropriate personal protective equipment in all operations where there is an exposure to hazardous conditions...." This standard seems to allow OSHA to cite an employer for allowing any worker to be exposed to a fall without being protected by a properly secured safety belt. It is therefore technically possible to write a citation for a connector who is working over a solidly planked floor less than 25 feet below if a safety belt is not used. Although how far above a floor the connector may work before personal protection is required has not been clearly established.

There are many questions concerning the feasibility of a connector using a safety belt and whether a safety belt protects a connector or places him in potentially greater danger. Before exploring these issues, however, it is first necessary to consider the benefits and limitations of the safety belt as a protective device.

4.3.1 BENEFITS OF SAFETY BELTS

The safety belt is used to attach a worker to a substantial structure when working at a height. Should the worker fall, the distance of the fall will be limited to the length of the lanyard extending between the worker's belt and the anchorage to which the opposite end of the lanyard has been attached. Because the safety belt and lanyard are items which can be carried with the individual, they can provide fall protection in a wide range of situations. Their use does not usually require extensive preparations on the part of the contractor, because the lanyard can be tied to any substantial anchorage. When the worker moves to a new location, he can tie off the lanyard and be protected.

The fact that often an elaborate installation is not required and no expensive apparatus must be assembled to use a safety belt, makes it an economical protective device. Merely the cost of purchasing a safety belt, when compared to the cost of obtaining and installing a section of safety net, makes it a more feasible item to obtain and use.

When compared with nets, a safety belt can provide protection in many more situations. A safety net may only be attached to a structure which will support the weight of the net and will also withstand the impact of someone falling into it from 25 feet above. In contrast, the structure

supporting a safety belt must withstand only the force of a 6-foot fall. A net must also be installed in such a way that a person falling into it will not come in contact with any structures below the net. This limits the net's use to areas where sufficient vertical space is available.

4.3.2 DRAWBACKS OF SAFETY BELTS

The safety belt normally used by an iron worker is a single, 2-inch wide strap worn around the waist. The belt doubles as a tool belt carrying a scabbard for spud wrenches and one or more bolt bags. A 6-foot lanyard made of at least ½-inch nylon is either spliced permanently to the belt or is hooked to a "D" ring attached to the belt.

The farther a worker falls, the greater the speed and the more impact the body sustains when it is caught in the belt. Obviously, the shorter the fall distance, the less the chance of being seriously injured by being caught in the belt. No definitive studies for construction safety belts exist which indicate what the maximum distance can be. For example, the British Standards Institute in 1967 felt that a person wearing a safety belt should not be subject to a fall greater than 2 feet.(53) An article in the 1981 edition of Best's Safety Directory agrees that 2 feet is the maximum free fall distance suggested when wearing a safety belt.(54) On the other hand, the Occupational Health and Safety Act of Ontario allows a fall of 1.5 meters (5 feet) into a safety belt, so long as an arrest force of 8 kilonewtons is not exceeded.(55) OSHA standards, of course, allow a 6-foot fall into a safety belt.

The 6-foot fall distance would appear to be a compromise between protecting the worker and allowing the worker enough maneuverability to make the use of the belt practical. The 6-foot distance would seem appropriate based upon fall cases reviewed by a study of personal fall equipment conducted in 1977 by the National Bureau of Standards. In this study, 35 cases were located where the equipment was properly used and the fall was arrested by a safety belt.

> Most falls were reported to have involved free falls of from 1.2 to 2.4 m. (4 to 8 feet) and presumably involved fall-safety systems using body belts. The few injuries that were received came from contacts with other surfaces during the fall.(56)

Most of the sources discussed above agree that a 6-foot fall can be withstood more easily by a worker wearing a full-body harness rather than a safety belt. The body harness is designed to spread the shock load, resulting from a fall, over the shoulders, thighs, and seat area rather than just the pelvic girdle area where a safety belt is worn. There may be some benefit to considering the use of a full-body harness for iron workers using personal fall protection. However, such a conclusion would appear to be premature without more definitive information.

Perhaps the most important point to understand is that falling into a belt is, at the very least, uncomfortable. If the fall distance is great enough, injury or death can occur as a result of being "saved" by the belt. Therefore, it is advisable for the person using the safety belt to tie off in such a way as to limit the potential fall distance as much as is practical.

4.3.3 USE AND DESIGN OF LANYARD

Because 6 feet is the maximum allowable fall distance, by OSHA standard, lanyards are usually 6 feet in length. However, they can be longer than 6 feet, so long as they are attached in such a way that the maximum fall distance is limited to 6 feet. For example, a 9-foot lanyard may be used if 3 feet of it is to be wrapped around a column.

The distance between the belt and the anchorage is determined, in part, by the design of the lanyard. A 6-foot lanyard with a snap hook at the end allows the lanyard to be looped around an anchorage and attached to itself. It also permits the worker to snap the hook at the end of the lanyard to any handy attachment point, such as a bolt hole. In the latter case, the entire length of the lanyard is used, which maximizes the fall distance. This is not a problem where 29 CFR 1926.104(b) can be followed, which requires attachment "above the point of operation".(57) A connector, however, is often working at the top of the erected structure where no overhead attachment points exist. Therefore, if a connector is to be tied off, the only anchorages which are available are often at or below the level of his waist. Snapping the hook at the end of the lanyard to the structure at waist level assures a fall of at least 6 feet. Should the attachment point actually be below waist level, the fall distance would be increased.

If a snap hook is not provided, the worker will normally tie the lanyard to an anchorage using a knot which will not slip, should the worker fall. This allows the worker to tie a knot anywhere along the length of the lanyard and potentially limit the fall distance to considerably less than 6 feet.

Allowing the worker to attach the lanyard using a knot requires that the worker be adequately trained to tie a knot which will remain secure should the worker fall. This can be a serious problem. The National Bureau of Standards study observed:

> At least half of the fall data obtained involved fall safety devices that were not correctly secured to an anchorage, i.e., the falling worker did not remain linked to the anchorage under the impact of the fall. These falls generally resulted in fatalities....(58)

Regardless of the means of attachment used, it is important that the worker be trained to use it properly. It must be attached in such a way that the fall distance is limited to the greatest degree possible commensurate with the maneuverability needed to accomplish the job.

Manually adjustable length lanyards, with a snap hook at the end, are also available and might be considered for iron worker use.

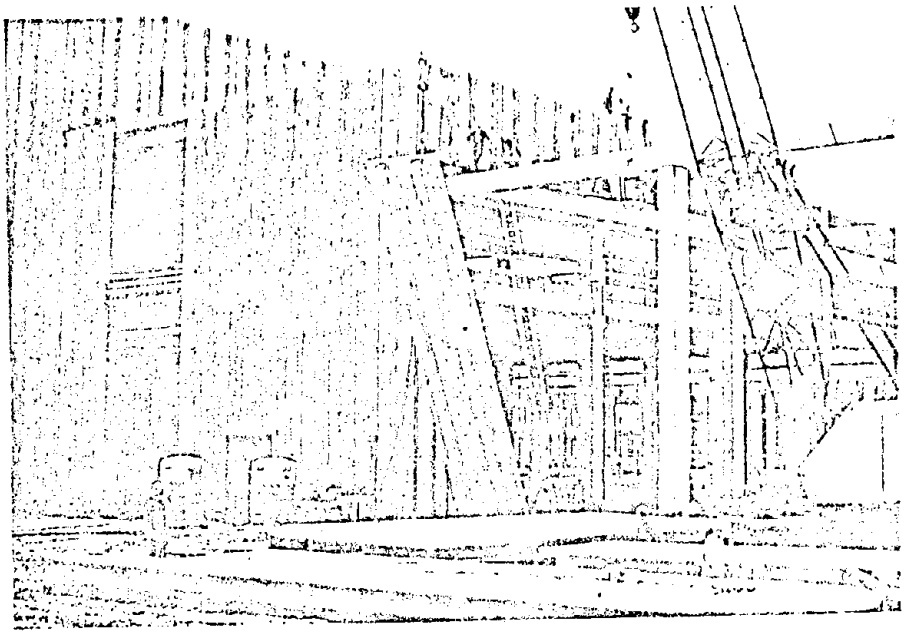
The material used for a lanyard is important. The standard requires that nylon or an equivalent material be used. One of the reasons for this is the shock absorbing characteristics of nylon rope. When a falling worker is caught in the belt, the force will cause the nylon rope to elongate. This acts to cushion the force of the fall.

When working around welding operations (as is done in precast erection) or when the lanyard is often tied to abrasive anchorages (such as concrete), wire rope is sometimes used. Hot slag from welding operations can fall into and nestle within the strands of nylon rope. The damage that results can easily be overlooked during a cursory inspection of the lanyard. Wire rope is narrower, less susceptible to catching slag, and any damage caused by heating the rope is more easily detected. Wire rope is also less susceptible to wear caused by wrapping it around abrasive surfaces or sharp edges. However, wire rope will not elongate to cushion a fall. If wire rope is to be used as a lanyard, it is advisable to utilize a shock absorbing system to absorb the impact of the fall. Such shock absorbers are available commercially. In a fall, the shock absorber works by transmitting the impact force to cross-stitching in nylon webbing, progressively breaking fibers, thus dissipating energy. These devices are normally contained in what appears to be a small packet which can be attached between the lanyard and the safety belt.

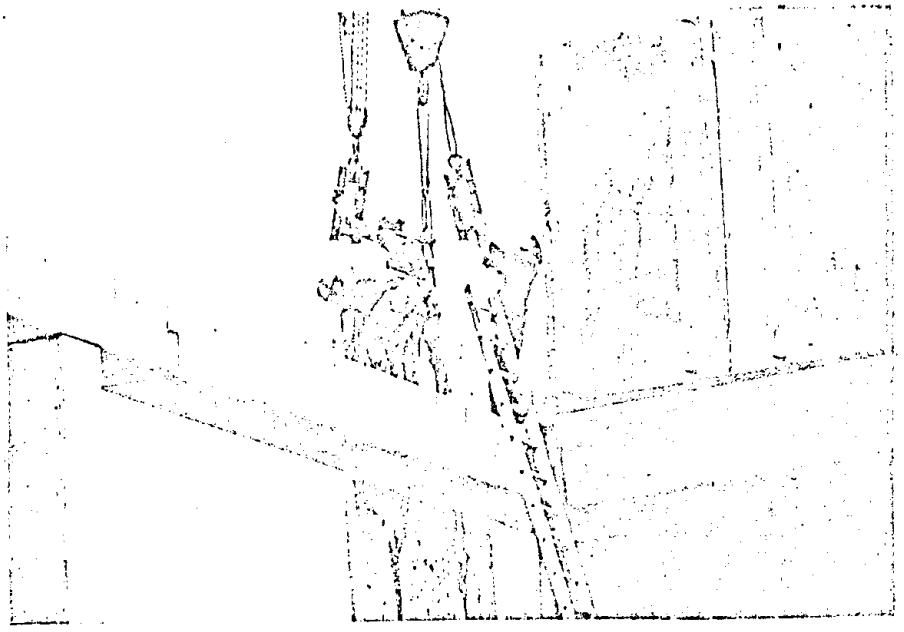
The attachment of the lanyard to the safety belt is also of critical importance. Where one end of the lanyard is attached to an anchorage, the opposite end should be attached to the safety belt at the small of the back. In this way, should the worker fall, the impact would bend the body forward in a jack-knife position. If the lanyard is attached to another part of the belt, the possibility of incurring serious injury is increased because the impact will not bend the body in a natural direction.

A second type of attachment may also be valuable to the worker, but it must be properly used. This attachment is similar to that used by a lineman. Two "D" rings are attached to the belt so that they are positioned on either side of the body. The lanyard is then attached to one of the "D" rings, looped around the anchorage, and attached to the opposite "D" ring. This arrangement is advantageous in that the worker can lean against the lanyard to aid in positioning himself to perform his job. The fall distance is also kept to a minimum because only half the length of the lanyard extends to the anchorage point, the other half returns to the belt where it is attached to the second "D" ring.(59)

A problem occurs when the worker must use the lanyard without both ends attached to the safety belt. In this situation, one end of the lanyard is attached to the anchorage and the opposite end is attached to a "D" ring located on the worker's hip. Should the worker fall, the body will be bent sideways, greatly increasing the possibility of serious injury.



Picture 23 - Connectors stand on top of a prestressed concrete beam waiting to attach the double tee wall panel being tipped toward them.



Picture 24 - Three men work to release the rigging, measure, plumb, and attach the top of the panel. They will manuever around each other numerous times during the process. In the narrow area of the beam surface, the use of lifelines and lanyards could cause a significant tripping hazard.

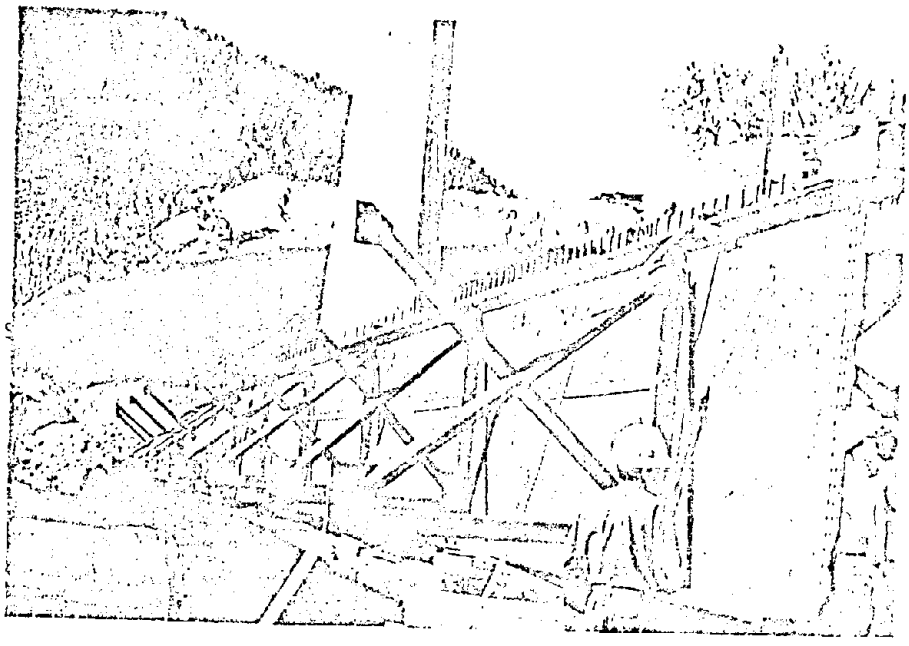
4.3.4 PROBLEMS IN USING A SAFETY BELT WHEN CONNECTING

Several factors make it difficult for a connector to utilize a safety belt for fall protection. As was described in Chapter 3, a connector spends very little time at any one location. The longest stationary period is while the connector is waiting for the next member to be raised. This is also the time when he is least susceptible to a fall, as he can move to the next connection point and remain stationary or can move to an area where a fall hazard does not exist (e.g., move to a solid deck while waiting). During the connection task, however, the connector must move a considerable distance around the structure.

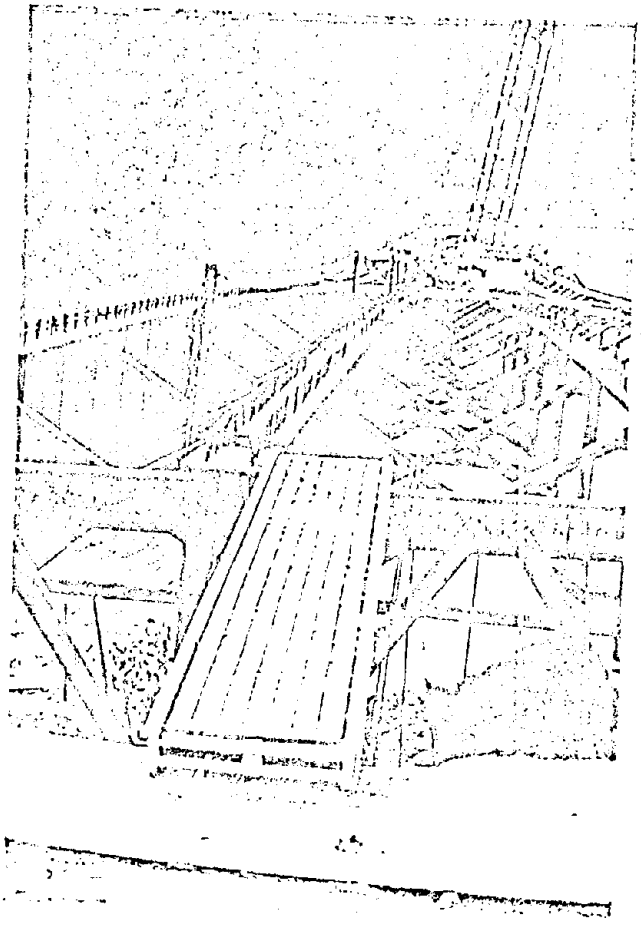
Where two or more people are working in such a way that they are in a confined area or must cross each other, there is danger of tripping over lanyards or becoming tangled in them. This situation was demonstrated during a site visit to a prestressed erection project. Two men were working on an erected concrete beam approximately 2 feet wide. They were to position and secure a wall panel 30 feet in height. The panel was set on a footing at ground level and tipped up so the top could be connected to the beam on which these men were standing. The connectors were responsible for properly leveling the panel and welding it to the beam. In performing this task, the two had to maneuver around each other numerous times as measurements were taken and the position of the panel was adjusted.(60) Had they been tied to the building by lanyards, there would have been considerable trouble in maneuvering so that the lanyards would not have been fouled. The fact that they were at the top of the structure negated the possibility of securing the lanyards overhead. Therefore, both lanyards could only have been attached to a lifting eye cast into the deck of a member already erected. Both lanyards would have been laying on the beam and could have posed a serious tripping hazard.

The problem of connectors moving past one another during various phases of the precast/prestressed erection process is not unusual. New connectors are paired with more experienced connectors for training purposes. Because of this fact, the more experienced of the two must check each measurement and demonstrate a variety of techniques to the other. In the process, they must continuously trade positions as a member is erected. If they are to be attached to lanyards, they will have to contend with tangling and tripping hazards which could cause a fall into the belt. The question then becomes: In this situation, are safety belts and lanyards a safety precaution or a hazard in themselves?

There may be no point to which a lanyard can be attached. Often the holes available in steel cannot be used to attach a lanyard because they are located where the next member will be placed. In tiered buildings, the connector may have the option of tying his lanyard around a column or beam; however, particularly in the lower part of the structure, the column or beam may be quite large. A column 24 inches square would require 8 feet of lanyard to encompass it. It may also require some agility on the part of the connector to get a lanyard around such a large member.



Picture 25 - A girder is readied on the ground with a cantenary cable on both sides running between the stiffner plates and a cable on top approximately three feet from the top of the flange supported by angle iron. Note that the cross bracing, which will be attached between the girders in the bridge, has been attached on the ground to eliminate some of the connection time required in the air.



Picture 26 - Connectors walk along this route to reach the connection point. A cantenary cable is in place which the workers used as a hand rail. Note the sheer ties protruding from the top of the girder flanges, a potential tripping hazard.

In bridge work, the problem is further compounded as a connector might easily stand upright on the bottom flange of the girder without touching the top flange. In the expanse of metal between the flange, there are often no holes or other attachment points for a lanyard.

4.3.5 USE OF CATENARY LINES

Various solutions for the mobility problem have been considered. Some feel that a connector can make use of catenary lines (i.e., a cable strung horizontally between two columns). A lanyard can be attached to the line and slid along it as the connector moves about. Several factors make this solution somewhat questionable, at least where a tiered building is concerned. First, if a connector is to use such a line, it must be installed between two columns. To perform this installation requires a connector to spend as much time on the column as he would to make the beam connection itself.

Second, if such a line is to be installed so that a connector can walk along a beam, it must be overhead or below him. For example, if a connector must walk along a beam 6 inches wide, the presence of a line next to him at waist level, attached directly to the columns, would prevent him from centering his weight over the beam and balancing himself. Installing the line above the connector might be possible on the first level of a two-story column; however, the column extends only a few feet above the beam at the second level. Attaching the line to the web of the beam could be a solution; however, it would require the connector to attach his lanyard below his feet which would most likely extend a fall farther than 6 feet. (If a snap hook at the end of a 6 foot lanyard is attached to a catenary line below foot level, the fall distance would be 6 feet plus the distance from the connector's waist to the line, at least 3 additional feet, making the total fall 9 feet.)

Third, the fall exposure incurred by increasing the time spent at each connection point and the cost of supplying cable to extend between each of the hundreds of columns at each floor level would significantly increase the cost of the project. Yet, each of these lines would provide protection for a connector only for the amount of time necessary to walk across the beam (perhaps a minute or less). The lines might also be used by other workers who bolt up the beams; however, here again, the protection would be used for a short period of time as other attachment points are usually available when these workers are stationary.

Fourth, should lines be strung over every beam, it becomes more and more difficult for the crane operator to lower a member into position without the member becoming fouled. Should the member suddenly swing out of control, it could easily swing into a catenary line, perhaps dislodging it from a column. If a worker is tied to it at the time, a fall could be caused. Catenary lines would no longer be attached and the worker's fall would not be stopped by the safety belt.

However, catenary lines have been used successfully in bridge construction. In the case of the bridges being built during the site visit

in southern Utah, three catenary cables were attached to each bridge girder before it was lifted to the connectors. Special holes were fabricated in each of the stiffener plates placed approximately every 20 feet along the girder. A steel cable was strung through each of these holes. In addition, a cable was supported approximately 3 feet above the top flange by specially installed angle iron supports.

Several things made the catenary cable concept viable for this bridge. First, only seventy-three girder sections were used to place five girder lines 1400 feet across the canyon. Second, as discussed in Chapter 3, connectors spend a great deal more time connecting bridge cross bracing and girders than connectors spend making a connection on a tiered building. Third, the lines attached to the girders were left in place to protect workers who may have to inspect the bridge at a future date. These three factors made the use of catenary lines much more economical than they would be in a different type of structure. It was estimated that the cost of installing the lines was .15 percent of the total cost of the project.

It should be noted that even though these lines were available for use when moving around the structure, connectors seldom tied their lanyards to these lines as they moved from point to point. The lines were used as hand rails by workers as they walked. Lanyards were attached to them only when the workers were relatively stationary. Further, connectors and management alike agreed that the connectors should not attach their lanyards to these lines until a member had been landed and temporarily secured.(61) (In this instance, a net system was devised to protect the connector at the point of erection. More detail concerning this installation is presented in the safety net discussion which follows.)

4.3.6 ATTACHMENT POINTS

Fabrication of special attachment points into steel and precast/prestressed is often possible if sufficient preplanning is done. Any hole or other attachment must be approved by the engineer who designed the member. It is sometimes difficult to convince these people and the fabricators that an extra hole is necessary. However, it can be done, as is evidenced by the holes placed in stiffener plates described above. The most reasonable time to obtain any modifications is before fabrication of the member begins. Anchorages could also be cast into precast/prestressed members if sufficient planning and consideration of the connector's task is done before the members are cast. It is possible that some design restrictions will not allow a member to be weakened by an additional hole; however, it is anticipated that such situations would be the exception, not the rule.

A device known as a connector's toggle allows a lanyard to be securely attached when a hole in the steel is available. It can be obtained commercially. The connector's toggle is spliced to the end of a lanyard. It is made with a movable T-section which can be inserted into a 1¼-inch or larger hole in steel members. When the rope is pulled taut, the locking "T" is formed. The toggle can be released by pulling

the release knob to thread the "T" section back out of the hole. (See Figure 2.) Some companies have begun installing holes in columns above each connection point so that these toggles can be used.

4.3.7 PENDANT LINES

The concept of utilizing a pendant line attached to the top of a column is also being considered and used by various steel erection companies and is specifically mentioned in the Cal-OSHA standards. The line is used principally where the fall distance exceeds 25 feet (i.e., at the perimeter of the structure or when the column is placed next to a shaft).

In one application, the installation includes a 3/4-inch diameter manila rope line which is 26 feet long, with a 5/8-inch diameter eye bolt connection on one end and a knot on the other end. (See Figure 3.) The pendant line is attached to each perimeter column before it is raised. After the column is raised, the connector who will be attaching beams to the column will attach his lanyard to the pendant line by tying a stopper hitch knot around the line. This knot allows the line to be pulled through it in only one direction and locks tight should the man fall. The stopper hitch knot will not slide along the pendant line as the worker climbs. When he reaches the first connection point, it will be necessary for him to pull the pendant line through the stopper hitch until it is above him. In this position, if he fell, he would be stopped within a few feet. However, while the man is climbing, being tied to the pendant line is of limited value.

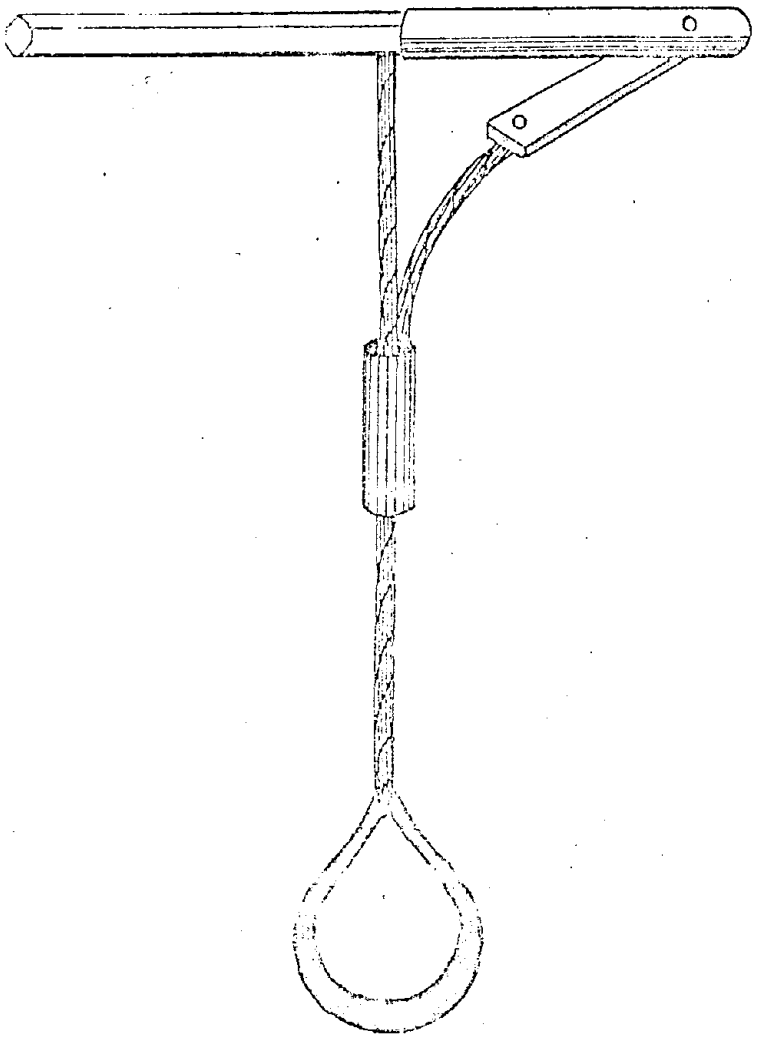
To examine this situation further, assume that the connector protects himself to the greatest degree possible. While standing on the deck, he ties a stopper hitch to the pendant line above his head approximately 7 feet from deck level. Further assume that he does not tie off at the end of his lanyard, but rather ties off using the minimum amount of lanyard possible between his waist and the 7 foot level (approximately 4 feet of lanyard). (See Figure 4) Now as the connector climbs the column, his potential fall distance is less than 6 feet until his waist is at the 9 foot level. At this point his total fall distance is 6 feet (4 feet of lanyard plus 2 feet of pendant line). From the 9-foot level until his waist is at the 15-foot level (i.e, his feet are at the 12-foot level, a standard elevation between floors, see Figure 5) the fall distance extends from 6 feet to 12 feet, that is, the 4 feet of his lanyard plus 8 feet of pendant line. Being stopped by a belt after falling 12 feet can cause serious internal injuries.

Several points must be emphasized concerning the above description. First, a man climbing a column is gripping with his hands and feet as he climbs. He is perhaps not at as great a risk as when he is reaching for an incoming beam (a point at which he would be protected). Second, the time necessary to climb 12 feet up a column is less than a minute. Thus, the time spent between the 9 and 15-foot level is minimal.

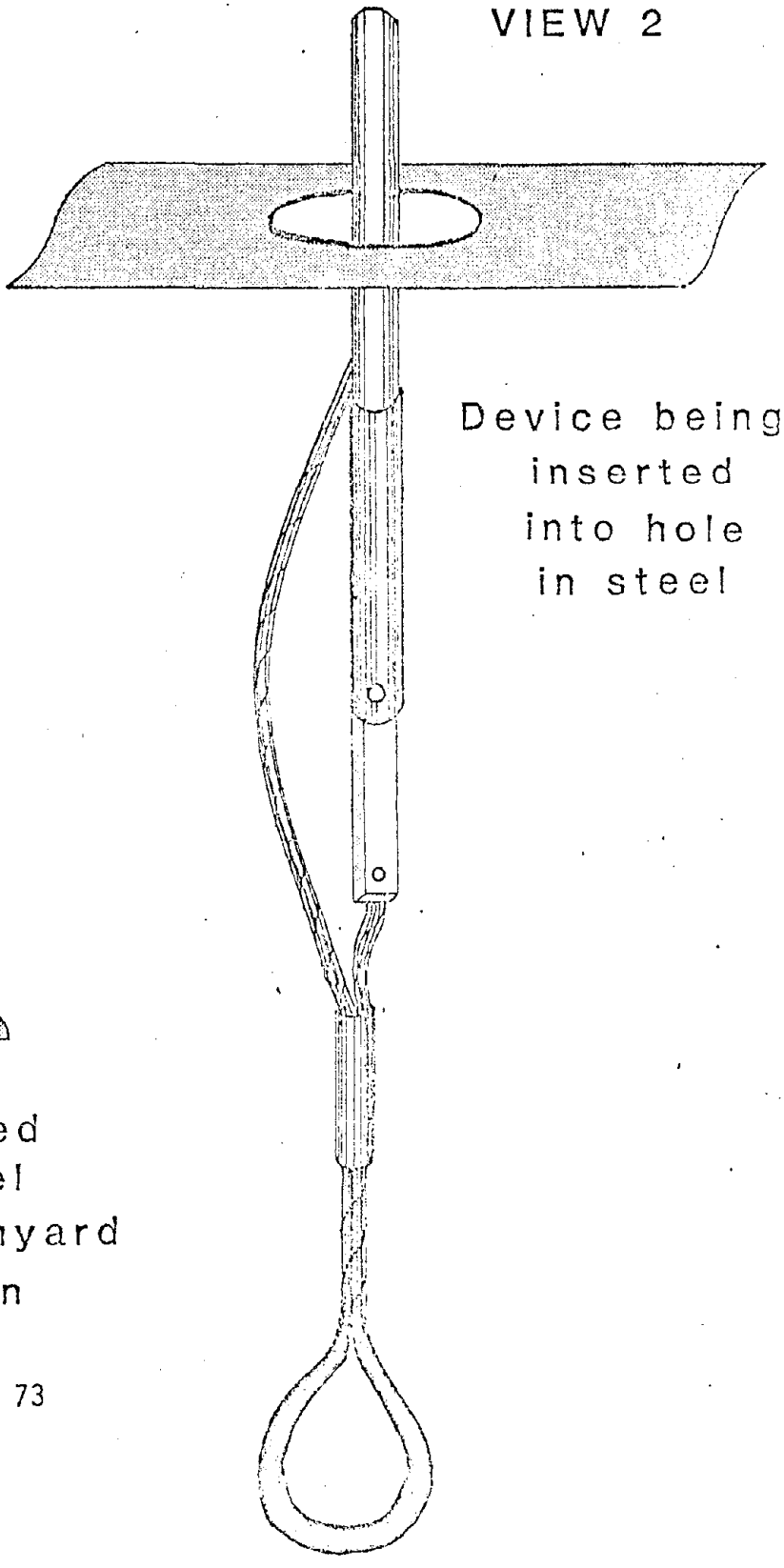
From the opposite position, the example assumes the best possible situation. If the man ties off at the end of his lanyard at a point less

FIGURE 2 - Connector's Toggle Which Allows A Lanyard To Be Securely Attached To A Hole In The Steel

VIEW 1

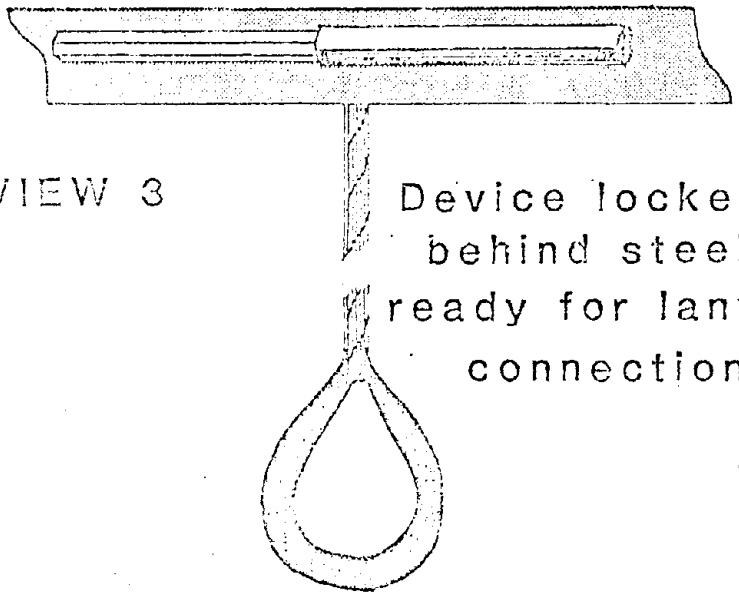


VIEW 2



Device being inserted into hole in steel

VIEW 3



Device locked behind steel ready for lanyard connection

FIGURE 3 - Use Of Pendant Line (Typical Connector Position Before Climbing Column)

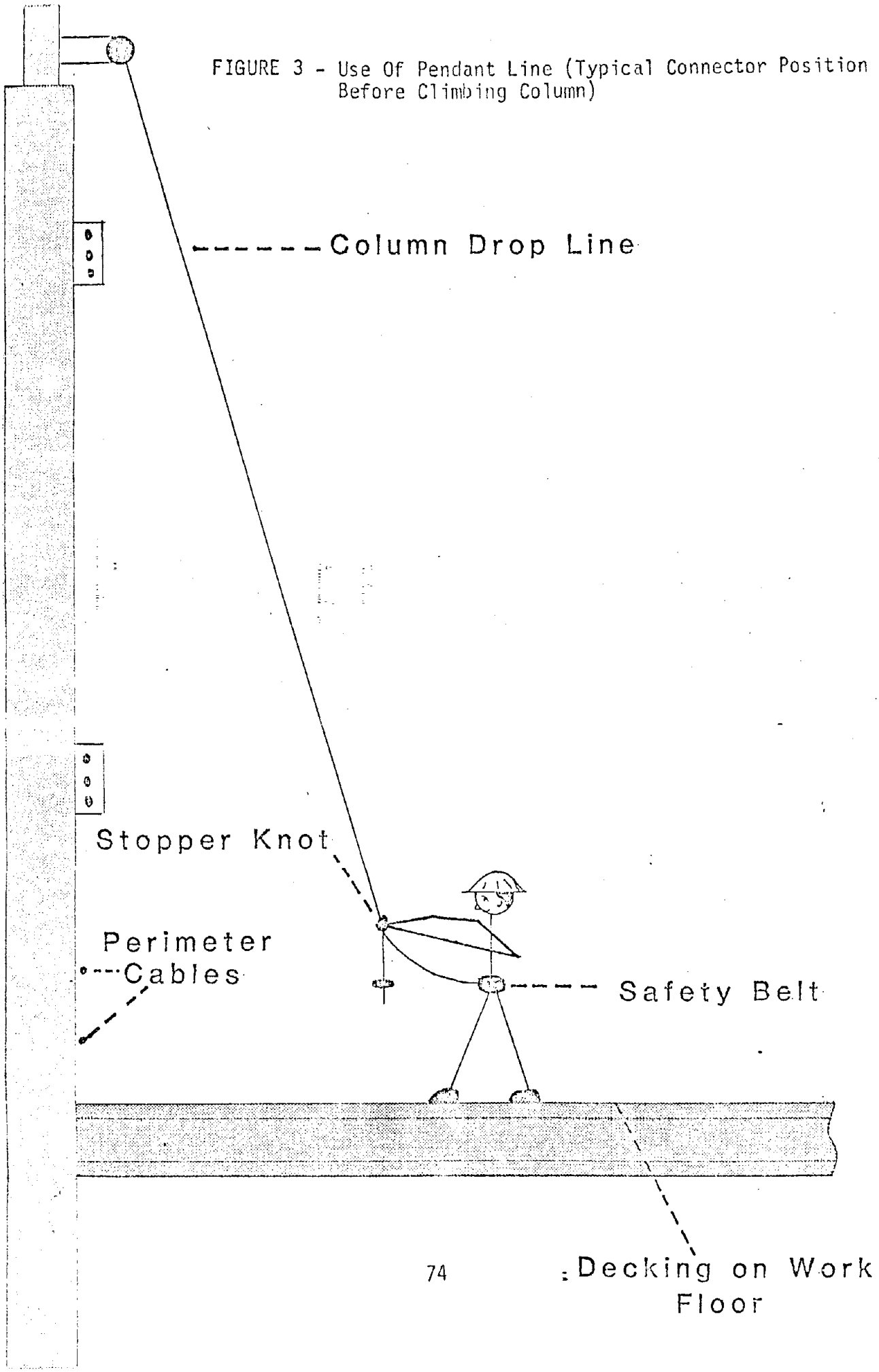


FIGURE 4 - Connector Tied Off Using Minimum Amount of Lanyard

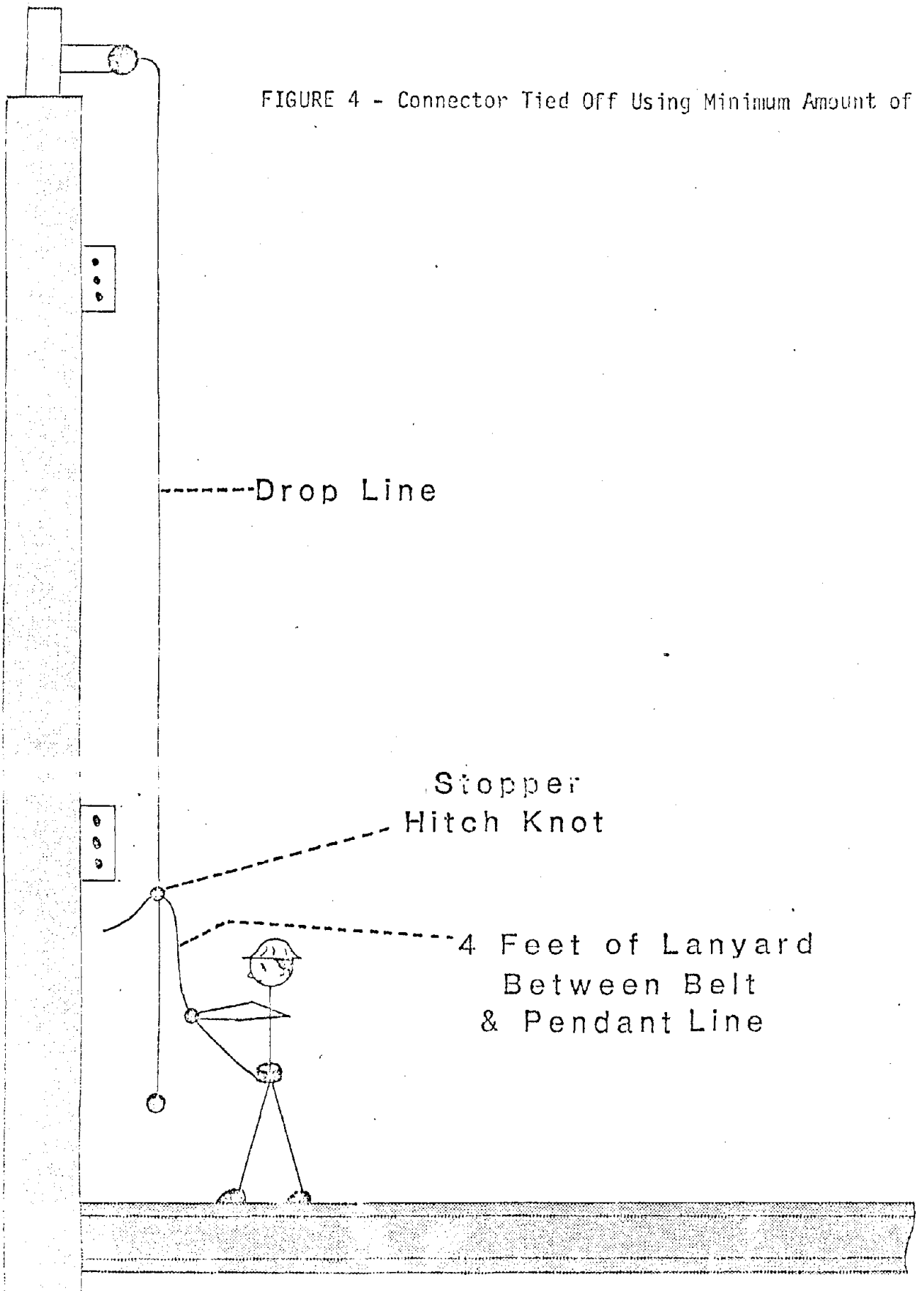
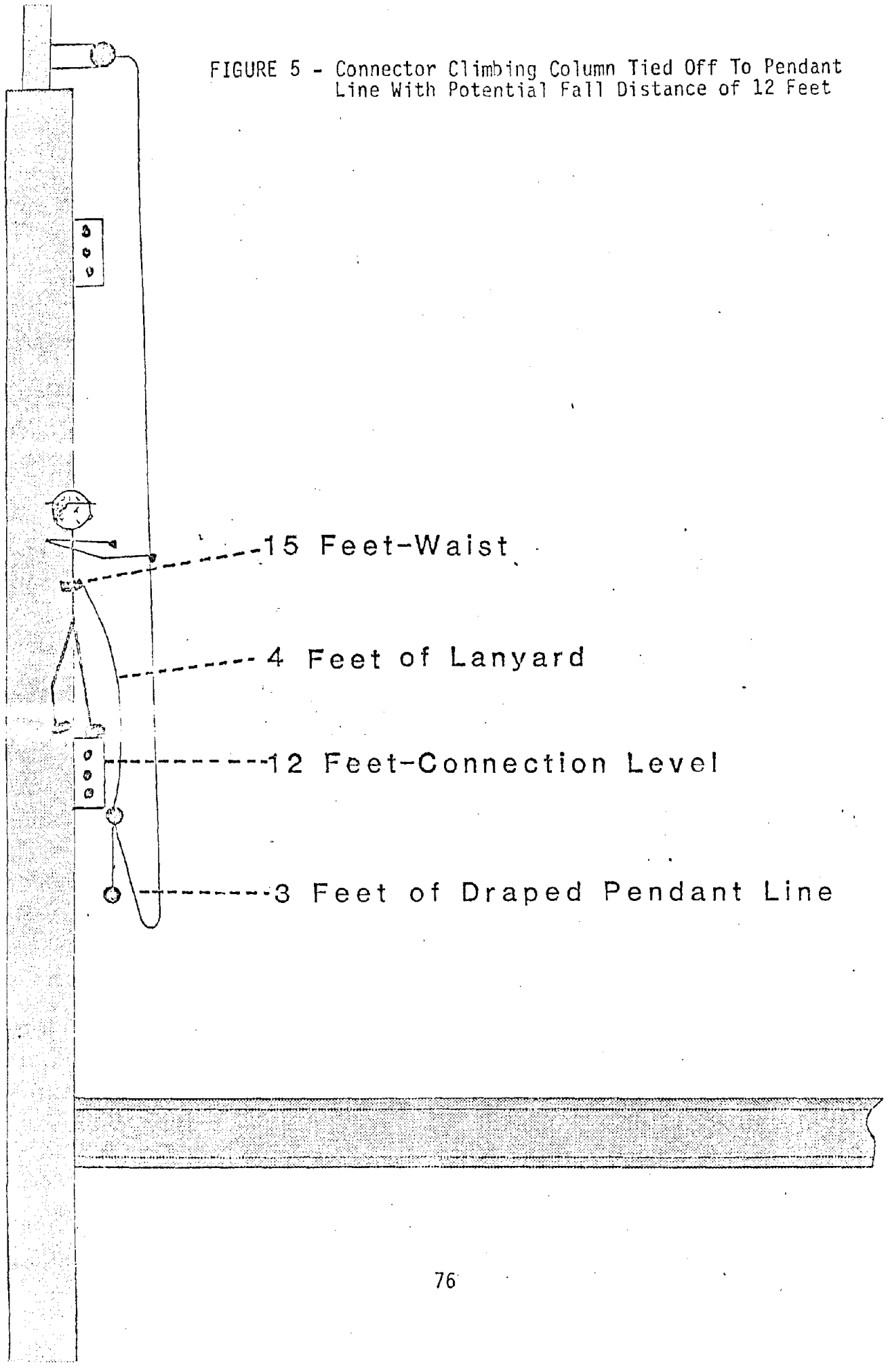


FIGURE 5 - Connector Climbing Column Tied Off To Pendant Line With Potential Fall Distance of 12 Feet



than 7 feet from the deck, he will be exposed to a fall greater than 6 feet for a longer period during his climb, although still less than one minute.

When the connector must walk out on the beam to untie the choker, he will remain tied to the line attached to the column. For example, with a 20 foot bay, he may have to walk 8 to 10 feet out on the beam to release the choker. When he does, he could fall, swinging pendulum-wise and hit the column. Once he makes the first connection, he repeats the procedure and climbs to the next point.(62)

An alternative method would be to attach the pendant line at the bottom of the column as well as at the top. In this way, a mechanical rope grab could be used which would slide up the line as the connector climbs, but would lock, should he fall. Two basic types of rope grabs are available. They are explained in the following discussion excerpted from Best's Safety Directory.

> Manually Operated Grab. The worker moves this device, by hand, up and down the lifeline with relative ease. It is preferably positioned above the work level. The device actuates during a fall by squeezing the rope or tips in such a way as to lock onto the lifeline by friction. The fall is thus halted. An advantage of many of the manually operated grabs is that they can be attached to the lifeline at any point, thus facilitating use in certain applications. A lanyard is needed to provide freedom of movement from the fixed-position, rope-grabbing device. Shock absorption is partly provided by slippage of the device down the rope.
>
> Mobile Grab. This grabbing device is designed to travel freely on the lifeline, helping to provide freedom of movement, but locks automatically should a fall occur. In some systems, the device is actuated by inertial forces generated by a fall. The mechanism contains three balls floating in a cage which are forced, during a fall into a conical wedge, exerting pressure against the rope. The stopping distance is designed to be limited to a few inches. A second cam-operated lock in some models provides a more positive locking feature in dusty locations. A lanyard is not always necessary; the body belt can be attached directly to the grabbing device. An advantage of the mobile grab is that it cannot be removed or lost from the lifeline except at the lower end, and it needs no worker manipulation while ascending, working or descending on the lifeline.(63)

Neither system fully solves all the attendant problems. The manual rope grab could not be used by a connector climbing a column, because it requires a free hand to manipulate the device. However, it can be removed from the line at any point. This is a very desirable feature when a connector must leave the pendant line to work on a beam.

The mobile rope grab would allow the connector to climb up and down using both hands to grip the column. However, this device can only

be removed by slipping it off the end of the pendant line. Rope grabs were available on lines attached to formwork next to ladders during a site visit to the construction of a natural draft cooling tower.(64) These devices were seldom used, because they were usually not in the proper position. In this situation, a connector might use the rope grab to climb to a position where a precast beam was to be connected into the internal structure of the tower. After connecting the beam, the connector would unclip from the rope grab and move out on the beam to release the choker. In the process of the erection, it would be some time before he returned to the first ladder. In the interim, additional beams were connected which caused the connector to climb higher before returning to the ladder. When the connector did return to the ladder, he was perhaps 15 feet above where he had left the rope grab. He would then have to climb down, unprotected, 15 feet to retrieve the rope grab. The inconvenience of the system assured that it was seldom used. A similar problem would be encountered by a steel connector.

4.3.8 CABLE REEL

A potential solution to the maneuverability problem encountered particularly in some precast/prestressed erection situations may be the use of a cable reel. These are self-contained devices holding 15 to 100 feet of lanyard. The device acts to keep the lanyard taut between the worker's belt and the point where the device is anchored. The device could allow the flexibility needed by a precast/prestressed erector to move from one end of an 80-foot long member to another. However, the problem of two workers becoming tangled is not solved. In fact, such a tangle could prevent the cable reel from retracting as the worker moved, thus potentially exposing him to a greater fall than 6 feet.

4.3.9 WHERE SAFETY BELTS ARE USED

Safety belts have been put to practical use in a number of connection situations where a stationary connector is asked to tie off. One such situation involving bridge construction was discussed earlier.

A second situation was encountered during the site visit to the natural draft cooling tower. Employees were involved in erecting the "internals" of the cooling tower at a fossil fuel power plant. At the time of the visit, iron workers were erecting precast beams between 30 and 45 feet from ground level. The situation was somewhat atypical because the beams were relatively light and they were being tied into formwork on either end, where the column would later be poured in place. The formwork provided numerous places where the connectors could easily tie their lanyards.

This was the only project observed where connectors tied off before the member was landed. Their willingness to do so was a result of the determination of the Iron Workers foreman, site management, and the trust given to a very experienced crane operator. In this case, lanyards

were looped around the anchorage and both ends were attached to "D" rings on the safety belt. This allowed the connectors to lean against the lanyard to position themselves to accomplish various tasks. It is important to note, however, that even in this situation, the people exposed to a fall hazard did not tie off when moving from point to point.(65)

The practice of using a safety belt would seem more prevalent when the consequences of a fall are greater. For example, several companies contacted during the course of the project indicated that connectors should tie off when working along the perimeter of a building or on trusses being erected into a high roof. The practice is used more extensively in tower construction where members are narrow and the consequences of a fall are great.

4.3.10 THE CONNECTOR'S VIEWPOINT

The connector's job is to first install pieces of the structure. While this may seem obvious, it means that he is typically working in an area where very little surrounding structure exists. The structure that is available has not been permanently attached. This is done deliberately, not only to speed the connection process, but also to provide enough flexibility in the structure to allow additional members to be fit into position. The support structure also has not yet been installed. For example, a steel column standing alone is not as stable as it will be when the surrounding beams and bracing have been installed. However, to install this bracing, someone must make the connections.

What this means is that while the structure is stable under normal conditions, abnormal situations, such as a gust of wind carrying a member suspended from a crane into the structure, can cause a localized collapse. If a connector is tied to the structure when this occurs, no options are available. The connector would be carried down with the structure.

A steel or precast/prestressed member being raised by a crane can move out of control for several reasons. The crane operator, for example, may inadvertantly misunderstand a signal and move the member inappropriately. Sudden gusts of wind could also cause a member to swing suddenly (this is particularly a problem with the large surface areas of precast/prestressed members). When this happens, a connector may suddenly have to move a considerable distance to avoid injury. If a tied-off safety belt is being used, the connector could be trapped. Based upon such potentials, the connector argues that there is a greater risk of injury if he is attached to the structure.

The frequency of such occurrences is extremely difficult to determine, as no records are generated when a connector avoids an accident because he was able to use his wits and agility. The only judgement which could be made during this project, concerning the validity of these claims, was based upon informal interviews with connectors and contractors during telephone contacts and site visits. Connectors, both union and non-union, working on a wide variety of projects, in geographically

separated areas, with from four to thirty years of experience voiced a nearly unanimous opinion. Connectors should not be required to tie off to the structure, at least until the member being raised by the crane has been successfully placed into position. It must be added that this opinion was also shared by an OSHA compliance officer in Connecticut who had been an iron worker.(66) (The single exception to this statement concerned connectors erecting precast concrete beams inside a cooling tower during the visit to that site. As discussed above, several things about this site were atypical, however.)

Virtually every person who had done connection work could relate one or more instances in his career where serious injury was avoided because he was not tied to the structure. The following two situations were related by connectors to members of the project team. They are included here only for their value in demonstrating the types of situations which might occur.

In the first incident, a connector had just positioned himself atop a column so he was ready to receive a beam. The beam being swung in by the crane was caught by the wind and hit the column. The column began to fall. The connector was able to swing around the column and slide down it as it fell. As a result, the connector was near the bottom of the column where he jumped free as it hit floor level. The connector was only slightly injured. Had he been tied to the column, he would have had no options.

The second incident occurred when single tee prestressed members were being placed in a roof structure. The single tee is a product consisting of an 8-foot wide deck with a single stem in the middle protruding 20 inches below the deck. As the incoming single tee was being maneuvered into position, one end dipped below the erected deck and swung upward. It struck the tee at the leading edge of the roof and broke it free so that it tipped down. As this happened, a second tee was dislodged and the roof tees began collapsing in domino fashion. The connectors standing on top of the previously erected tees recognized the situation and had to turn and run the length of the roof as the deck collapsed behind them. Both were able to reach safety. Again, both would have been seriously injured had they not been able to move rapidly away from the collapse.

It is impossible for any researcher to completely quantify and assess the feelings and experiences of steel and precast/prestressed connectors concerning the use of safety belts. However, one must be struck by the agreement demonstrated in interviews with people whose only commonality was the experience of doing connection work. To some degree, this must carry weight over the observations and postulations of people interested in providing a safer work place who have never worked as a connector. This is not to say that improvements cannot be made nor that new or existing systems might not prove valuable in specific situations. However, it points out a need for careful evaluation of any safety standard which attempts to establish a universal fall protection system for connection work. Many of the systems described above may have potential value; however, it is important that a thorough period

of testing be devised where connectors use the piece of equipment in a job situation, to determine effectiveness. This would allow any shortcomings in a device to be determined and solutions to these shortcomings to be devised. Overall, it would seem the only reasonable means of determining when and where a connector is safer using a safety belt, would be for a decision to be made by an experienced individual. In this way, the specialized operations being performed on a specific project can be taken into account.

4.4 FEASIBILITY OF USING SAFETY NETS

In some cases where the use of safety belts is impractical, safety nets can be installed below the connector. In comparison with safety belts, nets provide a number of advantages.

4.4.1 COMPARISON BETWEEN BELTS AND NETS

A safety belt is only effective when the person wearing it ties it properly to an acceptable anchorage. If the individual does not wish to use the belt, no protection is achieved. In contrast, after a net is in place, it provides protection without requiring the active involvement of the person working above it.

A person who falls into a safety belt will find the experience uncomfortable, at least. Depending upon whether the equipment has been used properly and the position of the person's body when caught by the belt, there is a risk of injury even in a 6-foot fall. A fall into a properly installed safety net should result in no injury to a worker.

In addition, a net provides protection for a worker moving from one point to another. Where a net can be used, it eliminates the problems involved with installing and operating around catenary lines which are provided so a worker can remain tied off while walking. Nets also help to solve the mobility problem caused by belts. A connector walking above a net can move freely to catch an incoming member, work on the connection, or move away from danger.

4.4.2 ADDITIONAL BENEFITS OF SAFETY NETS

Claims have been made that people working over a net are more productive. They can move along the structure faster and can concentrate more upon their work and less upon the consequences of a fall. Various people (who were not connectors) have reported that they had little concern walking along a bridge girder, for example, when a net was in place below them. However, proceeding on the girder over an area where nets had not yet been installed was a completely different matter. On the other hand, some connectors feel a person working over safety nets is apt to be more careless because the consequences of that carelessness are less severe. Both views are interesting; however, no formal studies have been conducted to investigate either point.

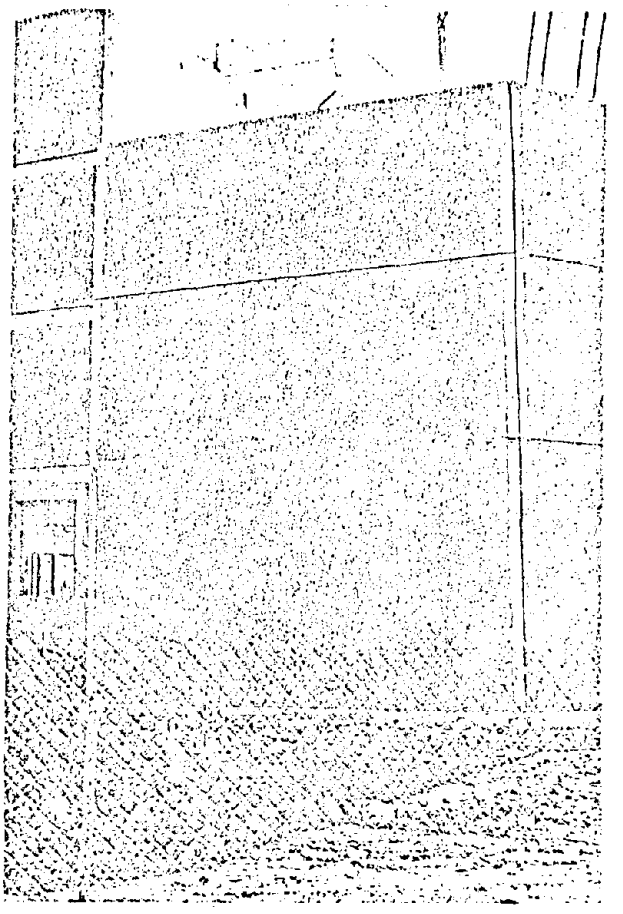
Some companies that use nets have incorporated other features into the design for the net support, which aid in performing the work. For example, one net support structure used on bridges incorporates a work deck in the design. This provides a platform where tools can be kept, supplies can be stored, water containers can be installed, and workers can move freely across several girder spans. Personnel nets combined with finer mesh debris nets also protect people from falling tools or bolts as they work below the connectors.

4.4.3 LIMITATIONS OF SAFETY NETS

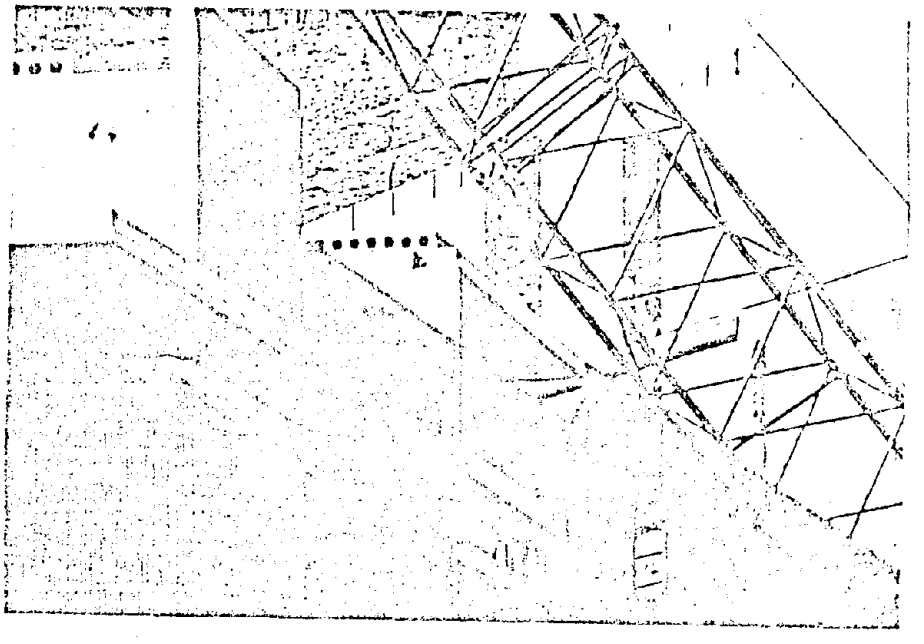
While the use of nets may offer advantages, the installation of them is not always possible. Again, the simple fact that a connector's job is to erect the structure means that there is often no secure anchorage to which nets can be attached. Once a structure is available to support nets, the connectors are finished in that area. For example, when a prefabricated steel building is being erected, the columns are supported only by bolts at the base and by guy wires before beam connections are made. There is some question as to whether these columns can be guyed sufficiently to support the weight of a large net and if they would remain standing when the net is impacted by a falling body.

A second obstacle to the use of nets is the distance that must sometimes be spanned if nets are to be installed. This problem is demonstrated in a situation where a bridge will perhaps extend hundreds of feet across a bay. To install a net to protect connectors could require cables to be strung between the shore lines from pier to pier, so that net sections can be attached to them before the bridge structure is put in place. Performing this task is not easy and can be expensive. However, it can be done in some cases, in part, because of the strength of the supporting structures available. The problem is also encountered where boiler cavities are left inside powerhouse structures. These cavities can be several hundred feet wide and quite high. As columns are connected, they are left flexible enough that they can be moved slightly to aid in fitting beams between them. The columns may not secure enough to hold the large expanse of cables and nets that would be needed to fill the cavity to protect connectors.

There are also situations in which attachment points are not available. In steel, this problem can sometimes be solved if the problem is considered in the design stage, before fabrication, so that the appropriate approvals can be obtained and special holes or connection points can be fabricated. In precast/prestressed erection, the problem can be harder to solve. The surface of precast/prestressed members is often specially prepared with exposed aggregate or a particular finish which will be exposed in the completed structure. Weld plates or other potential attachment points cannot be cast into these surfaces and removed at a later time. When these panels are used to erect the exterior of elevator shafts or stairwells at the perimeter of a multi-story building, there are no openings or potential attachment points for nets on that section of the building wall. To use nets, a separate structure beside the building would be necessary which can be raised periodically so that the nets remain no more than 25 feet below the connection operations.



Picture 27 - Nets are difficult to install on a sheer wall. The problem is particularly difficult when the panel has an exposed aggregate surface which can not be mared.



Picture 28 - To position members into the structure, the crane boom must work very close to the structure. In some cases it would potentially interfer with peremeter nets.

This situation illustrates another point which makes the use of nets difficult. The time necessary to build a separate structure beside a sheer wall, even if scaffolding is used, could easily exceed the time necessary to do the connection work. In addition, the potential fall exposure to the people building this structure would probably equal or exceed the time of exposure necessary to do the connection work. The exposure time for those installing nets must be considered whenever a net installation is contemplated.

The placement of nets also can restrict the type and capacity of the crane being used. Perimeter nets which extend 8 feet horizontally from the edge of a structure require that a ground crane be set back farther from the structure than would otherwise be necessary. It also requires that a greater length of boom be used. In some cases, particularly where heavy precast/prestressed products are involved, a crane with a higher capacity must be used, which is more expensive and often requires more room to maneuver. When the crane must be located inside the perimeter of the structure, as is often the case, the size and ability to maneuver can be critical.

In another situation, in order for nets to protect connectors, they would have to be erected in the same space where the next member is to be placed. This is particularly true in precast/prestressed erection. If one accepts the argument that a connector is in greater danger when erecting precast/prestressed members if he cannot move out of danger, then the use of nets must be considered. In the situation discussed previously where two connectors are helping to install wall panels to a beam 25 feet above the ground, net protection would have to be placed in the same area where the panel must be installed. In the case of placing double tee roof panels, the nets would be located in front of the leading edge. This again is the area where the next double tee panel is to be placed.

The erection of precast/prestressed roof members also illustrates the point that the erection process advances rapidly, with perhaps thirty members being placed in a single day. Therefore, if nets are to be used, they must be rigged so that they can be moved forward rapidly. Where load bearing wall panels are placed on either side of the structure and a roof member is attached between them, the building may advance forward in 8-foot increments, six or more times a day. This would mean the nets would also have to be repositioned six times each day. Since no support structure is in place before the wall panels are erected, a special structure to support the nets would also be necessary.

4.4.4 GENERAL ECONOMIC FACTORS

Several economic factors are evident. Nets must be purchased or rented, a support structure must be built, an attachment point must be fabricated into the structural members, and time must be spent to assemble, disassemble, and move the net system. However, nets can have a greater impact on job economics than simply the cost of material and the man-hours for installation.

The most important consideration in planning an economical erection process is the critical path. Procedures in the critical path are those that require crane time. This crane time is "critical" because the crane is the only means of providing workers with the material they need. Because cranes are expensive to operate, it is extremely important to make efficient use of them.

If crane hook time must be used to move nets, the time used to do this is lost to the erection process. Therefore, there is a multiplying effect. For example, if two days of crane time are needed to move nets, not only does the contractor incur two days of extra crane charges, but potentially he must pay for two more days of the raising crew's time because the crane was unable to supply them during that time.

Another example of this multiplying effect involves the cost of money. If netting a job requires that the contractor spend more time than normal to complete the building, then the contractor must charge more money and the owner spends more money on building cost and on interest. More specifically, if a seventy-one story building costs $250 million, more than $10,000 a day is spent on interest to finance the $250 million. Each extra day of time spent on a job to install nets can have a significant economic impact. For example, if a job ran five days longer because nets were installed, then an extra $50,000 would be spent to cover interest alone. This amount does not include the money spent for renting the nets, for the crane time to move them, or for the labor to install them.

If price considerations are of paramount importance to a building owner, the contractor who includes the cost of perimeter nets in his bid could be at a distinct economic disadvantage to one who did not include this cost.(67)

4.4.5 EXAMPLES OF NET APPLICATIONS

Nets have proven usable in a number of situations. In fact, several contractors have solved some of the problems discussed above. The following discussion will provide several examples of net installations which have been successfully used.

4.4.5.1 Use of Perimeter Nets

Contractors in the State of Connecticut have devised a number of ways to erect perimeter nets on steel tiered buildings. There is an economic impact upon the cost of construction; however, it does not generally effect bid competition because of the position taken by both OSHA and the Iron Workers Union locals, discussed earlier. The Iron Worker Union business agent for Local 424 in New Haven, Connecticut, estimates that perimeter net protection has been used on 150 tiered buildings over three stories in height which have been erected in his local area during the last five years.(68)

One system was designed by a local Connecticut company to be put up and taken down rapidly. This netting system, which can be raised by

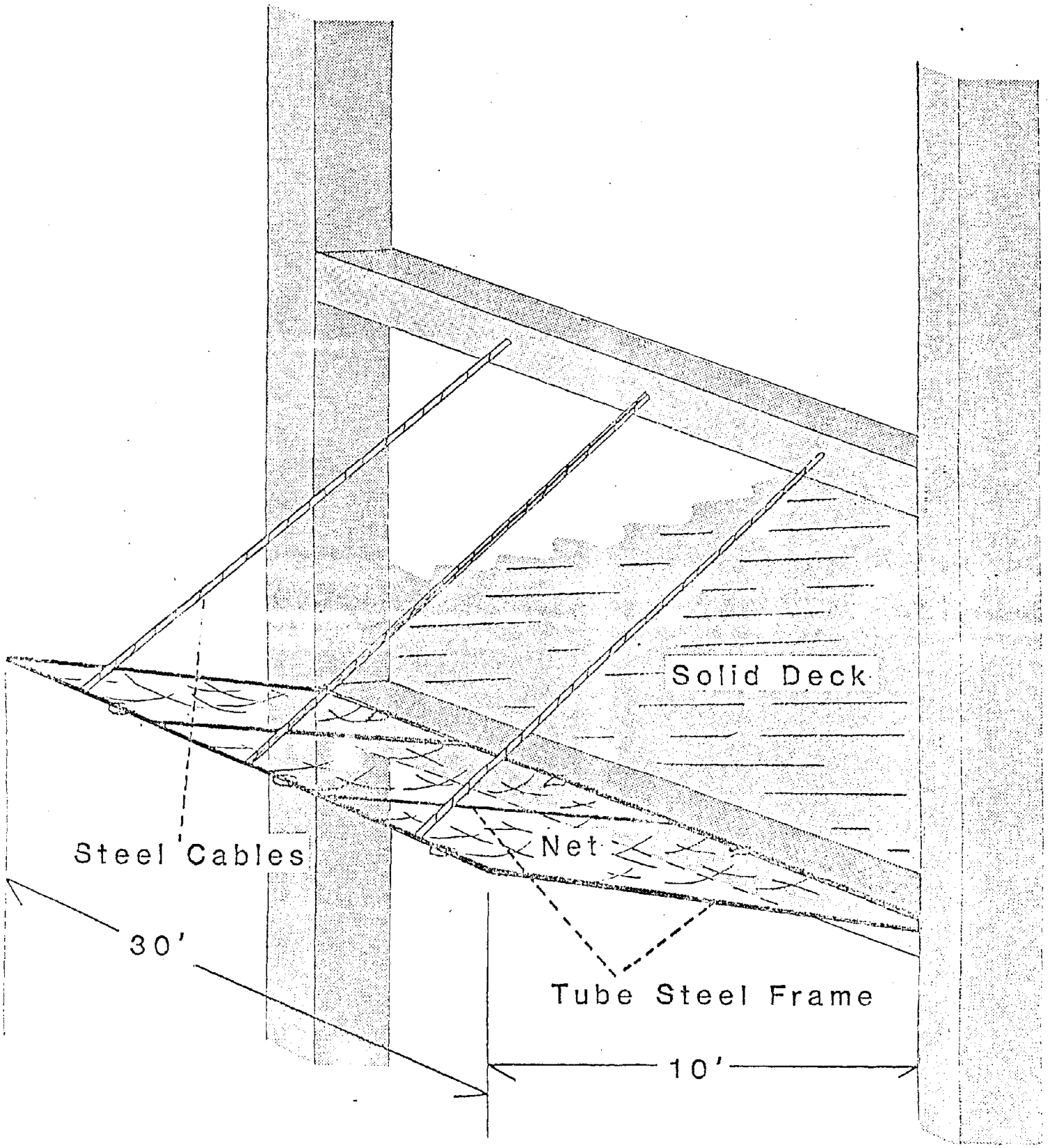


FIGURE 6 - Local Connecticut Company Net System;
Figure Shows One Section

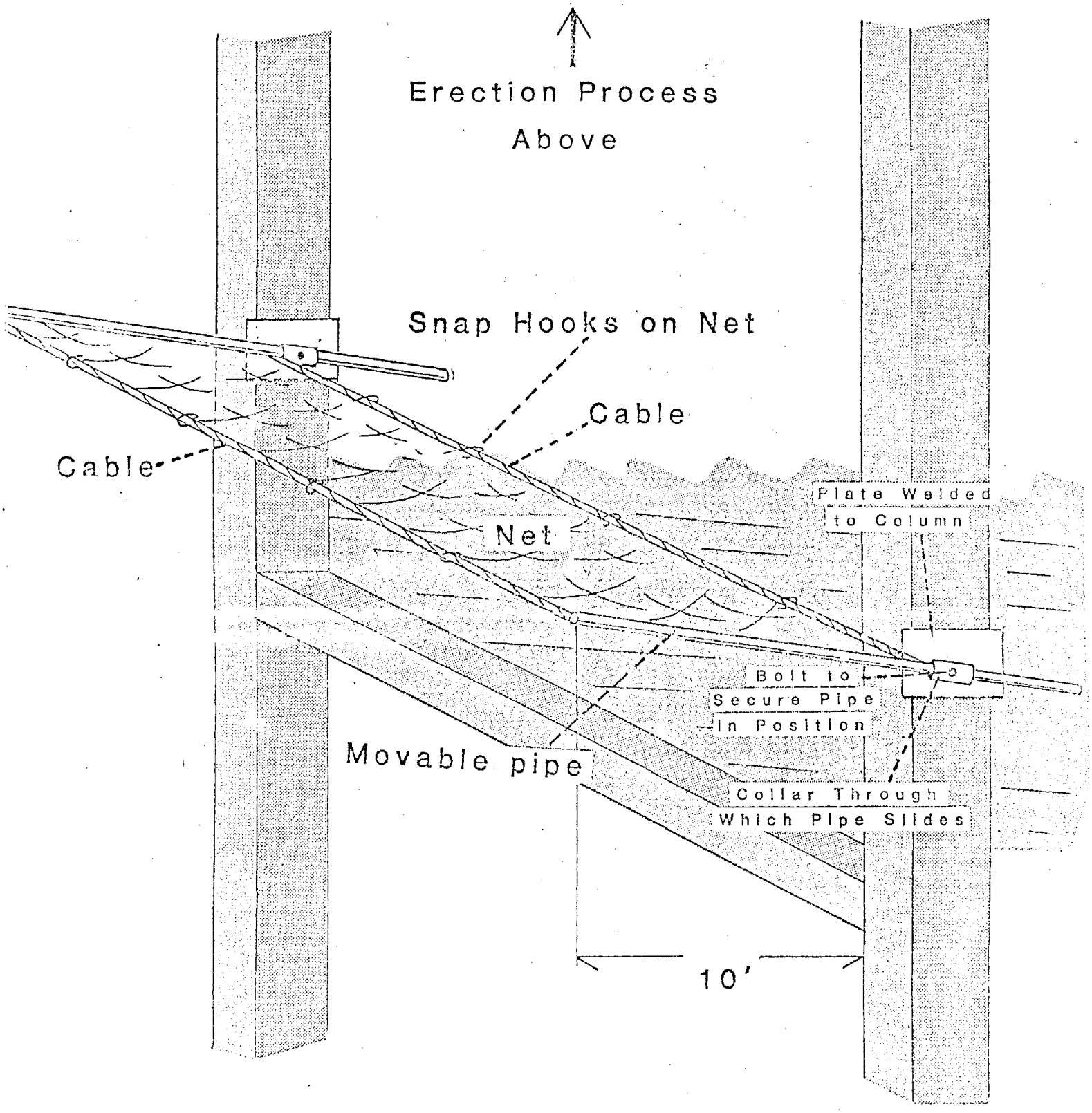


FIGURE 7 - Second Connecticut Net System - Uses Metal Plates and Pipes For Support

a crane, is supported by 2-inch wide tubular steel. The system is attached to the building by connections made through eyes which are welded on perimeter columns or beams in the same position at each level. One section of this netting system is 30 feet by 10 feet and consists of three, 10-foot square bays. A section is lifted by a crane using a two-point connection, to the level where it is to be used. (See Figure 6.) The net section is installed so that the perimeter of the net is higher than the perimeter of the building. If a man falls and bounces in the net, he will be thrown toward the structure, not away from it.

One advantage to this system is that once the tubular steel sections are assembled and the nets are stretched over them, they can be moved up the building and attached to the structure as needed; no other assembly is necessary. Another advantage is that the sections can be taken apart and stored when not in use.

However, this system has two disadvantages. First, it is possible that a man could fall onto the cable suspending the net and be catapulted out from the building. Second, a man could fall on the tubular steel and be injured.

A second system which is being used in Connecticut makes use of metal plates with short lengths of hollow channel welded to them. (See Figure 7.) These plates are either welded to perimeter columns or a second plate is located on the opposite side of the column, and the two are bolted together to clamp the column between them. A pipe is then inserted in the hollow channel. The end of the pipe has eyes attached so that a cable can be strung from one pipe to the next. A second cable is installed along the perimeter columns, 42 inches above the deck where the top perimeter cable would be placed. Net sections are snapped to the cable at the end of the pipe and to the cable attached to the columns. The pipe is then extended approximately 10 feet from the perimeter by sliding it forward through the hollow channel attached to the plate on the column. When in position, the pipe is secured by tightening a bolt against it. The net clipped between the cables unfolds as the pipe is moved out, to provide perimeter fall protection. Again the net is angled, so if a falling person bounces, he is thrown toward the deck in the building.

The poles can easily be slid back into the building, draping the net next to the structure, so that equipment can maneuver close to the structure without becoming fouled in the net system. When the net system is disassembled, the cable attached to the columns is left in place as the perimeter cable.

There are two problems with this system. One is that a worker who falls can hit the supporting pipe, instead of the net, and be injured. Secondly, because the net is not at deck level, if a man on the interior of the building falls onto the metal decking near the perimeter, it is possible that he could bounce underneath the netting and fall even further.

A third perimeter net arrangement was being used during the Bridgeport, Connecticut, site visit. It requires that two "ears" be attached to

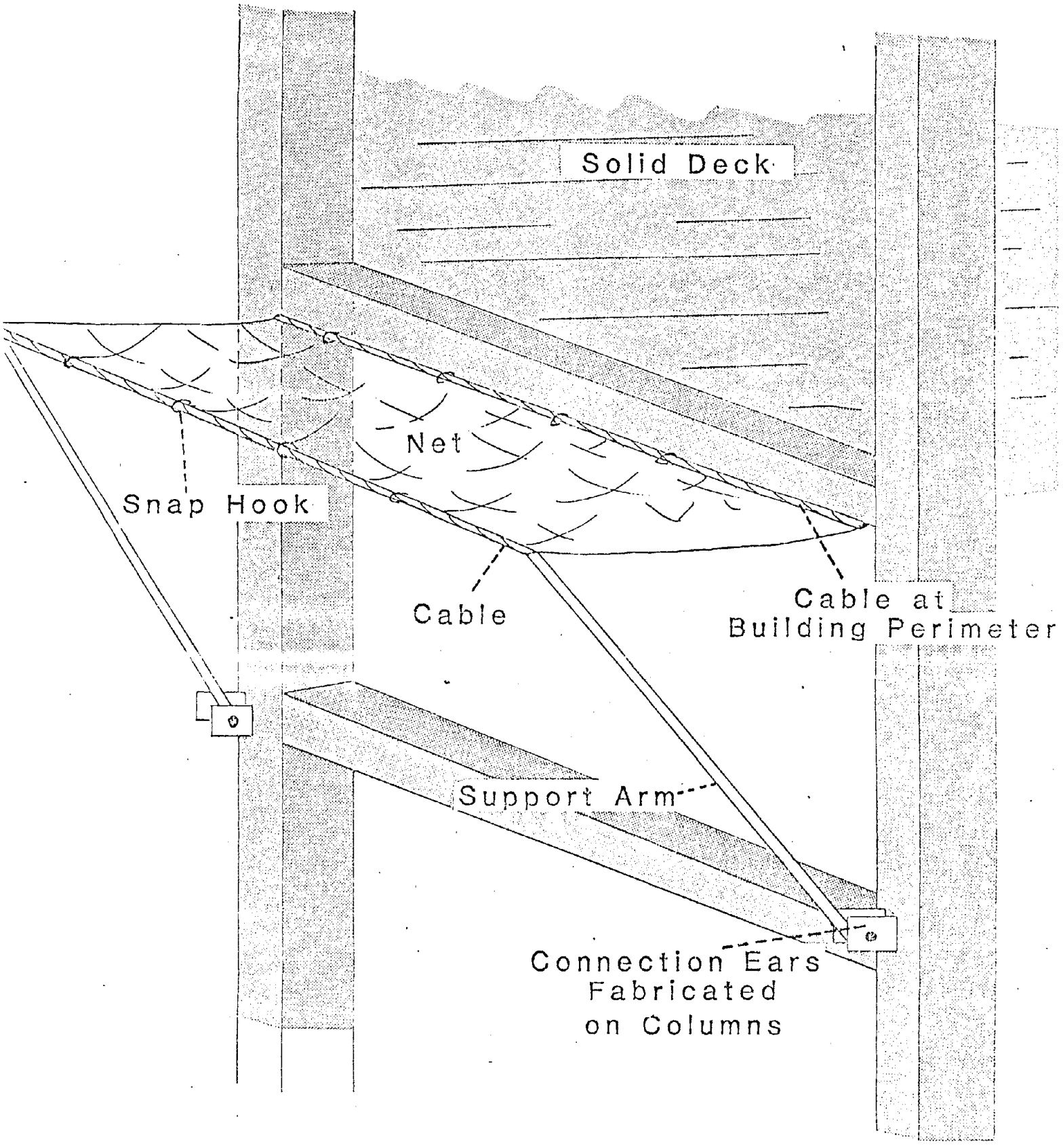
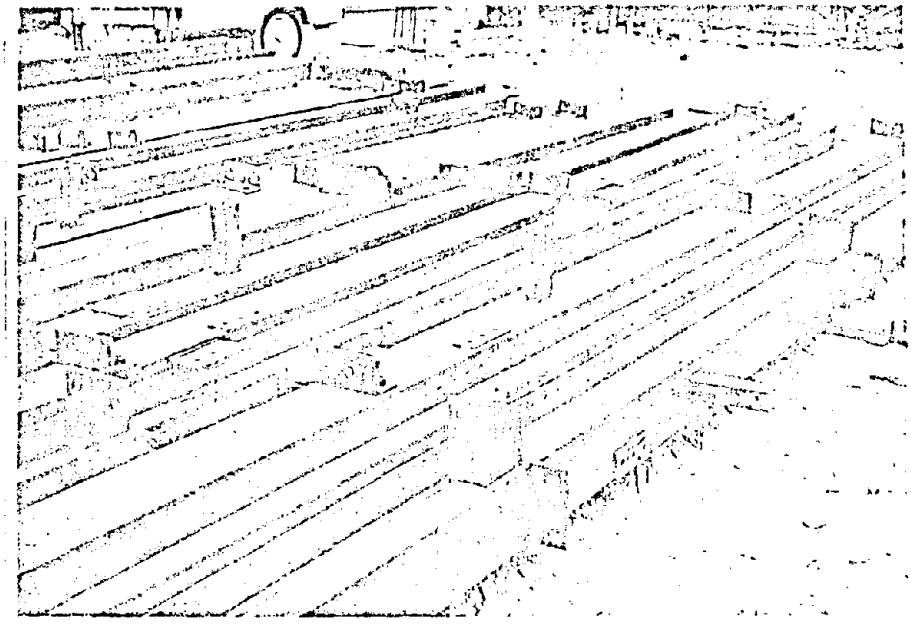
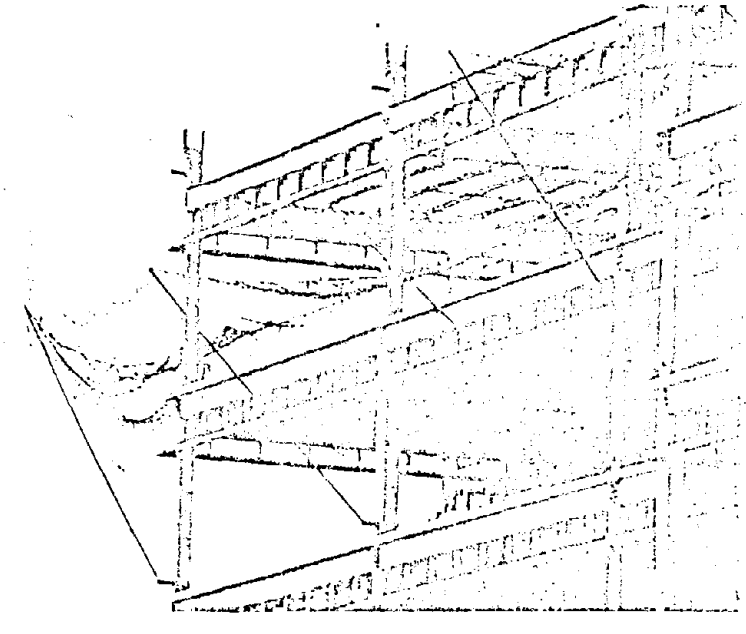


FIGURE 8 - Net System Used On Bridgeport, Connecticut Construction Site

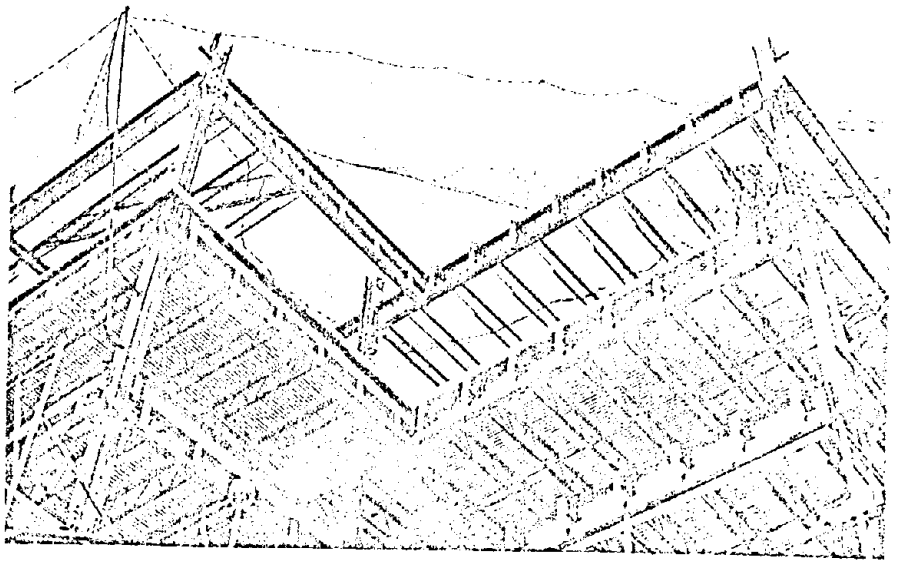


Picture 29 - The "ears" necessary to attach the peremeter net system are pre-fabricated onto the columns when they are delivered to the job site.

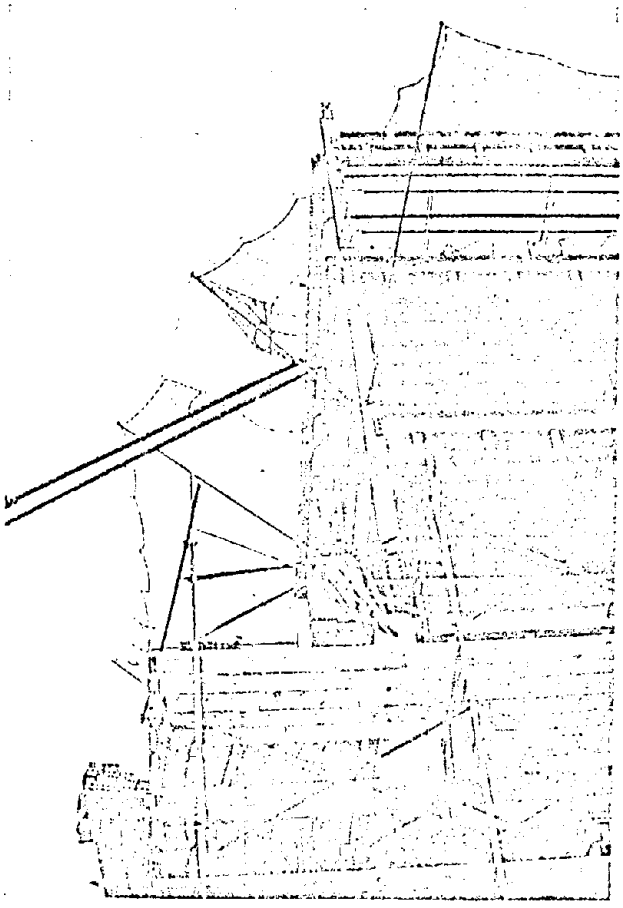


Picture 30 - The peremeter net system makes use of poles attached to "ears" on the columns. The nets are draped between a cable attached along the building perimeter and cable attached to the end of the poles.

Picture 31 - Interior corners are neted using an extra net section attached to the peremeter of the structure and the inside edge of the 10 foot wide peremeter net.



Picture 32 -Perimeter nets can be separated to allow equipment access, as has been done to position the boom of a concrete pump. The nets can also be folded up against the structure when necessary.



each perimeter column, either during fabrication or by a clamp arrangement. (See Figure 8.) The "ears" are two parallel pieces of metal extending out from the column. A pipe is attached to the ears, for example, at the third story level. It is then folded against the building so someone on the fourth level can attach a cable at the end of the pipe. Another cable is attached to the building at deck level and net sections are clipped between them and folded out into position. The net can easily be pulled against the building to avoid entanglement with equipment.

The supporting structure for this system is below the net so that a person falling into the net would not hit one of the pipe supports. There is still a possibility, however, of striking one of the cables extending between the ends of the pipes and the structure.

4.4.5.1.1 Development of Commercial Perimeter Net System

A net manufacturing company has designed a perimeter debris net system which is being modified for use as personnel safety nets. This marks the first time that a commercial company has developed a standardized net support structure which is flexible enough to have wide application on tiered buildings. The system is similar to the one just described, in that the support arms are below the net, it can be folded against the building when necessary, and the net will close around anyone falling into it.

Hinged plates are bolted or welded to perimeter beams. Poles made of schedule 40 reinforced steel, 15 feet in length and 2½ inches in diameter, are slipped into sleeves attached to the hinged plate. The system is designed so that a pole is placed every 20 feet along the perimeter. (See Figures 9 and 10.) A cable is installed at the end of the poles and along the perimeter of the deck through eyes provided in the hinged plates. Net sections are then snapped onto each cable and the pole is folded out from the building at approximately a 45° angle. The entire system is designed to be taken apart in pieces that can be carried by one individual. It is therefore possible that crane time will not be necessary to move the nets to the next level. For example, perhaps a block and tackle arrangement could be used to lift the support poles, cables, and nets to the next level.

The manufacturer is currently redesigning the method of attaching the system to the building to develop a more efficient means of attaching the plates to a steel beam. They are also experimenting with lighter poles which could be more easily handled by employees.(69)

4.4.5.1.2 Cost of Perimeter Net Systems

Cost estimates regarding the perimeter net installation were obtained from the erection foreman during the Bridgeport site visit. The building in which this system was installed was roughly rectangular, covering an area approximately 250 by 70 feet, and was to be ten stories in height.

Figure 9 - Commercially Available Perimeter Net System

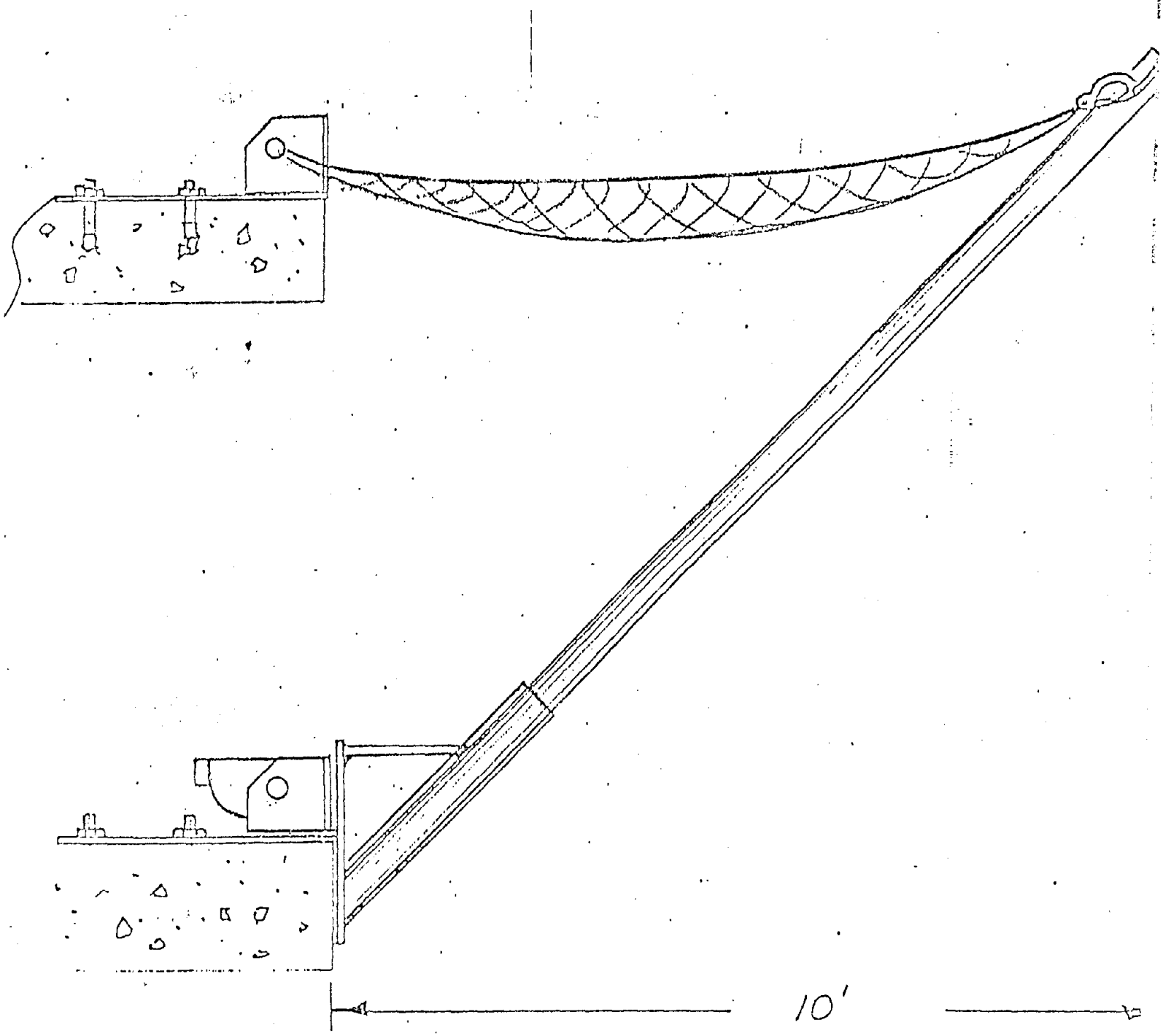
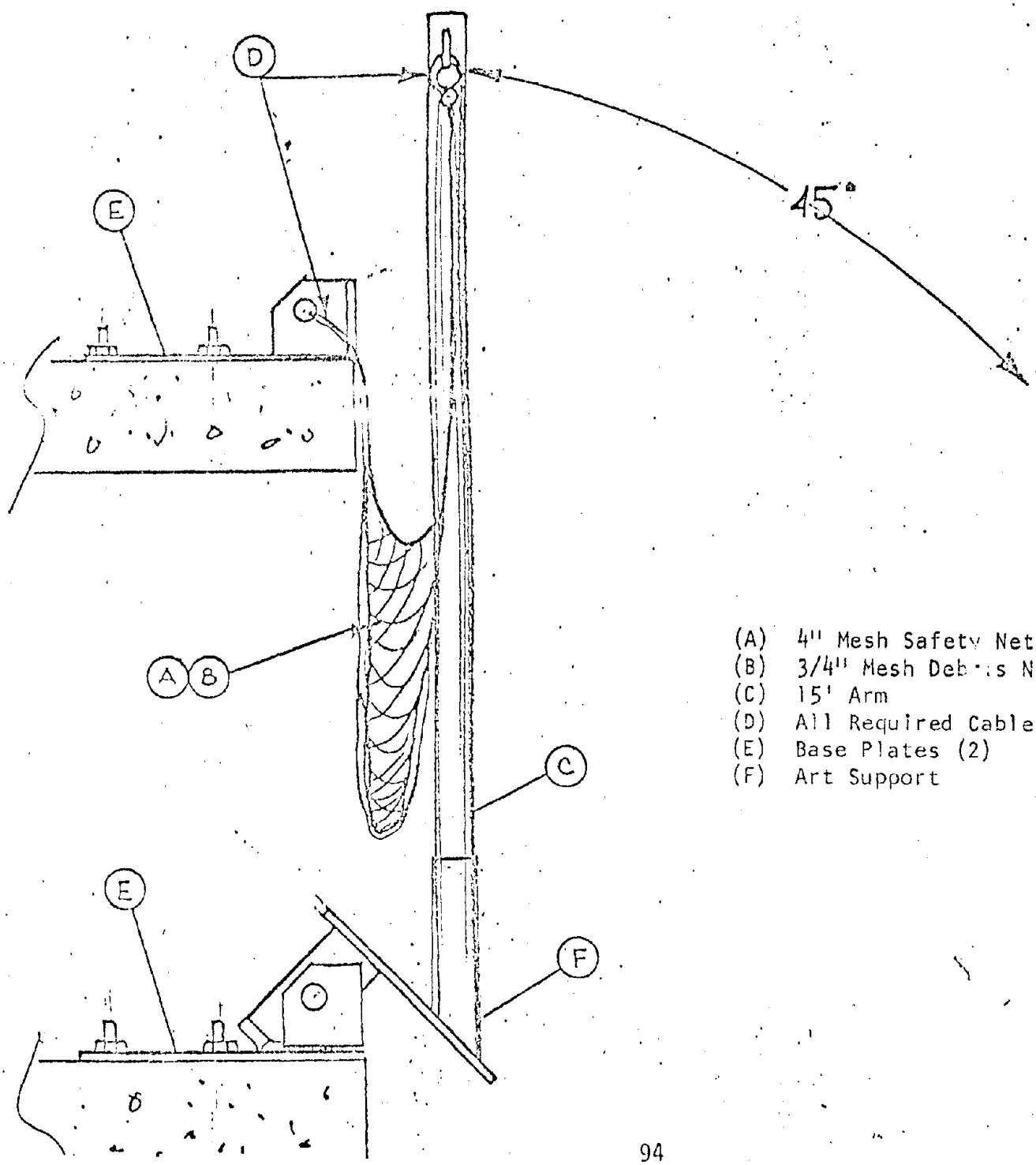


Figure 10 - Commercially Available Perimeter Net System As Folded Against Structure



(A) 4" Mesh Safety Net
(B) 3/4" Mesh Debris Net
(C) 15' Arm
(D) All Required Cable Assemblys
(E) Base Plates (2)
(F) Art Support

The nets used on this job rent for 12 cents a square foot for the first month and 8 cents a square foot for each additional month. Using the dimensions of the building and assuming that net sections 10 feet wide were used, approximately 6400 square feet of net were required. Since the connection work required four months, the nets cost $2300.

Additional costs are incurred for the labor required to install and move the nets. According to the site superintendent, five men could move the nets to the next level in one day. The first time the nets were moved on this job, it took one and a half days because the ears were not prefabricated on the columns and the temporary ears had to be moved.

The average iron worker on this job received a wage of $16.65 per hour. If 35 percent is added to this figure to cover overhead and profit, the cost per man-hour would be $22.48. The nets were installed and taken down four times, so that they remained no more than two stories or 25 feet below the connectors. It therefore took 180 man-hours to move the nets, costing $4,406.40.

The cost of the pipe, extra steel cable (the perimeter cable would have been installed in any case), and fabrication of the "ears" on the columns is estimated to be $12,500. (The pipe and the cable could be reused on other jobs.) No estimates were available concerning crane time or delays to the completion date of the project. Therefore, the total of the costs that could be identified was $18,846.(70)

Cost figures were also available regarding the perimeter net system being developed commercially. There is a six-month minimum rental on this system. One cable and arm system rents for a total of $125.00 for the first six months, $15.00 per month thereafter. Nets are rented for $8.50 per linear foot for the first six months and $1.00 per linear foot for each additional month. According to representatives of the manufacturer, 100 linear feet of net can be moved in eight man-hours.(71)

Using these figures, cost estimates for net use can be made. For example, on the 250 by 70 foot ten-story building discussed in the previous example, 640 linear feet of netting would be required. This means that 34 poles and cable systems, plus 640 feet of net, must be rented at a cost of $9,690 for six months. Additional costs would be required for labor to install and move the nets four times. This would involve 205 man-hours. If iron workers are used to move the nets, at a rate of $22.48 per hour, $4,608.40 would be spent in labor costs to install and move the nets. Therefore, a total of $14,298.40 would be required, exclusive of any multiplying effects caused by crane time requirements and delay in project completion.

It is recognized that few buildings are perfectly rectangular. An additional arm assembly must be used for each external corner and several arms spaced more closely than 20 feet would be needed to install the nets around a circular area. Recessed areas in the structure would require extra cable to be attached around the deck and additional net sections would have to be used to cover these areas.

4.4.5.2 Interior Nets

Interior nets can be installed in a variety of situations when a substantial structure is available beneath the connection operation. Personnel nets generally come in sections which can range in size from 8 by 8 feet to 25 by 50 feet. The sections are attached together either by using snap hooks permanently attached to the edge of the net sections or by splicing them together using a line threaded between the sections. OSHA requires that the mesh in personnel nets not exceed openings of 6 by 6 inches. Some net manufacturers indicate that 4 by 4 inch openings reduce the possibility of a worker injuring a leg or arm in the mesh during a fall.(72)

To install a net section, a cable is run from column to column to encompass the area. Intermediate cables may be used, depending upon the size of the area to be netted, to prevent the nets from sagging. The nets are then clipped to the cable. Alternately, a rigid frame structure is constructed, the nets are stretched over it, and secured. This technique is valuable when the net will be moved. For example, one company constructed a frame which can be secured in the open shafts of a building. When the nets must be moved, the crane is used to raise the entire frame, with the nets attached, up the shaft to the next installation point. These nets are used to protect connectors installing columns and beams at the perimeter of the shafts. This method saves a significant amount of labor.

4.4.5.2.1 Example of Interior Net Installation

Using a tower crane in a tiered structure requires that an open shaft be left in the building where the tower is located. The shaft is often two bays wide, leaving perhaps a 20 by 40-foot void in the building. Often this area does not have to be planked every two stories so that it can be used as a work platform. When this is the case, the area can be netted to protect connectors working to install columns and beams around the shaft.

Nets have also been used occasionally instead of solid decking to provide protection for workers. In this case, the nets are often draped over the open steel skeleton and attached to cables encompassing the area. The amount of protection provided is limited by three factors. First, a person falling could strike the steel structure supporting the net instead of the net. Second, in tiered buildings, a connector working on the second level above the nets has often installed a number of steel beams between himself and the net two levels below. Again, there is a possibility of striking the structure before hitting the net. Third, an impact force could cause the net to be cut by any sharp edges present on the structural steel members on which the net is draped.

Net protection systems have also been devised to protect connectors installing trusses in roof structures more than 25 feet from the ground. In this situation, the truss is at least partially assembled on the ground and is then lifted as a unit. Net support arms are attached

to the lower beam of the truss, at right angles to it. Each of the arms extends 8 feet on either side of the truss. Cables are attached to the end of the arms and the nets are strung between the cables. When everything is in place, the truss is lifted to the connectors in the structure with the nets already in place. In this way, connectors who will work to complete the structure of the truss are protected by the nets below them.

It should be noted that these nets will have to be taken down before the structure is completed. To do this work, someone will have to walk along the lower beams of the trusses. However, at this time, it is more feasible for the workers to use a safety belt as they will not have to contend with the unexpected hazards that can be caused when landing members suspended from a crane.

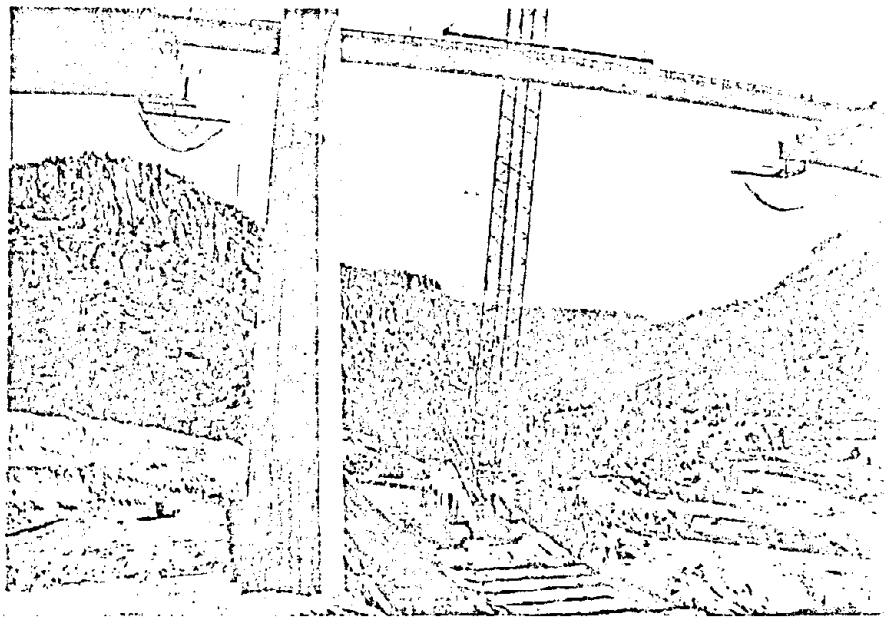
Nets might also be used in some situations when erecting precast/prestressed members. For example, consider a situation where a line of columns and beams has been installed for some distance before the floor or roof members are placed. With proper job preplanning, it would be possible to provide attachment points on the columns so that cables could be strung down each column line. Nets could be clipped between the cables in such a way that lines could be used to pull nets forward from the ground. In this way, a roof member could be set in place over the nets. The nets would then be pulled forward so they again extended in front of the newly installed deck. In this way, the nets could be continually pulled forward as the roof erection progressed without slowing the process.

This system would only be practical when a sufficient area is available for maneuvering the crane and the member being raised. Ideally, the crane could place the members from a position adjacent to the bay where the members are being erected. In this way, there would be no possibility of the crane or member becoming fouled in the nets.

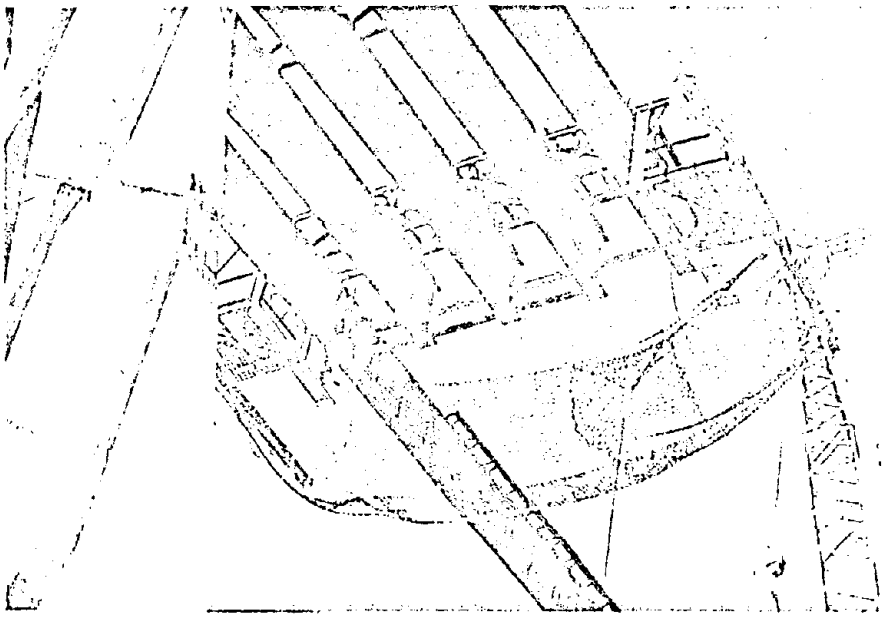
Elaborate net installations have been occasionally used within boiler cavities and in other situations where there are no intermediate floors which can be decked. In these cases, the net installation cannot be completed until the area is ringed with columns and beams which have been stabilized sufficiently to support the nets. However, once this has been done, connectors installing a roof over the area might be protected by nets. In one instance, where a tower crane was being used, the interior area was completely netted except for one corner. The tower crane used the open corner for access to the ground so that additional members and materials could be lifted.

4.4.5.2.2 Economics of Interior Nets

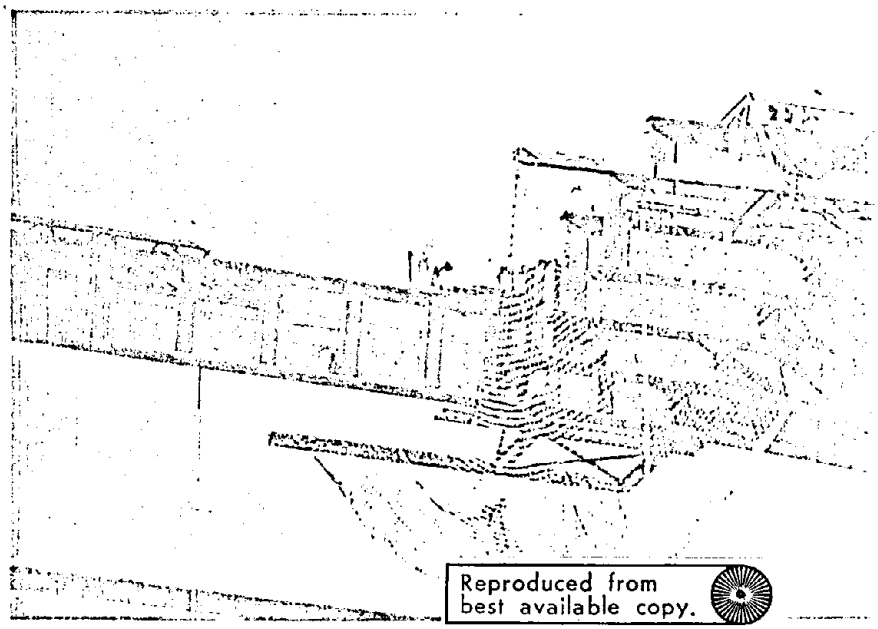
The economics of interior net installations are difficult to generalize, as was done in the perimeter net discussion. Many times unique systems are developed which may never be used by that contractor again. A simple installation using cable strung from column to column around a shaft would be relatively inexpensive. A 20 by 20-foot section of net could be installed in approximately four man-hours at $22.48 per



Picture 33 - The crane has positioned a girder at the connection point. Net systems provide protection for connectors working at each end of the girder being connected.



Picture 34 - The net system is a single unit, which suspends the nets and provides work platforms on either edge of the bridge. The bottom of the work platform on top of the girders can be seen between them. Connectors are working over the net on the left girder.



Picture 35 - The net is draped between two steel beams attached to the net support structure.

hour. The nets would cost $543 to buy or $256 to rent for six months. The 80 feet of cable would cost approximately $160. Therefore, a total of $505.92 would be required for a single installation.

However, where connectors are involved, specialized structures must often be built to support the nets. In this case, cost will depend upon the design being used and upon whether the structure can be designed so that it can be used in several situations rather than only one time.

4.4.5.3 Bridge Net Installations

Safety nets are more commonly used in bridge construction. It is relatively easy to install nets on the bridge structure to protect those installing decking and doing other jobs. This is routinely done by some contractors. However, the problem has been how to provide nets for connectors who are working to install new sections of the bridge. Such protection requires that a special support structure, not related to the bridge, be placed in front of the bridge. This is not always easy to do when the bridge spans a canyon hundreds of feet deep or a deep water bay.

4.4.5.3.1 Examples of Net Installations on Bridges

Where the piers of a bridge have been erected, it is often possible to install cable between them to support the nets before the structure is put in place. The potential for doing this depends upon the location of the bridge and the type of crane or cable way that must be used to lift structural members to the connectors. In some locations the crane must work in the area where this net system would be located.

One way to install this system is to place a beam, which extends at least 8 feet past the perimeter of the bridge on either side, at the foot of each pier. Cables are installed between the ends of the beams. If the span is greater than 100 feet, some provision must be made to prevent the nets from sagging in the middle. The nets are spread on the ground between the cables so they can be attached to the cables. The beam at one end of the pier is then lifted and fastened to the pier. (The connection system used for this should be decided upon in the design stage.) The second beam on the opposite side is then raised and fastened to that pier.

If no access is available between the piers, either because of the terrain or because the bridge is over water, the basic process can be modified. In this case, the beams are placed at the base of the piers (on barges if necessary), or they are installed on each pier. The cables are then attached as before. The net sections are clipped between the cables next to the beam at one of the piers so that all the nets are bunched at one end of the span. A spreader bar is attached to the leading edge of the nets and lines from the spreader bar are carried across to the opposite pier. These lines are then used to pull the nets across the opening.(73)

A second method of providing net protection for bridge connectors was designed by a company for use when building interstate highway bridges in Utah.(74) In this situation, the bridge spanned 6,400 feet over a canyon 200 feet deep. Two bridges each containing five lines of solid web girders were being installed between poured in place concrete piers. A crawler crane was placed on the canyon floor to lift the girders. The net system just described would not have allowed the crane to move close enough to the connection point to erect the girder.

To allow the crane to access the structure, a net support system and work platform were devised which could be attached to the end of the erected girders where the connector must work. This assembly provides a 4-foot wide work platform on top of the bridge which extends entirely across the width of the five girders. This platform is fully decked and has hand rails installed along the rear. Attached to this platform are vertical members which extend downward to a point level with the bottom flange of the girder. At that level, additional 8 by 8-foot work platforms have been built on either side of the bridge. A metal plank is cantilevered out from this structure an additional 5 feet to allow a man to move out to the splice point. The I-beam forming the outer edge of the lower work platform furthest from the bridge is cantilevered out 10 feet from the platform. This beam is used to support a net. The net is draped below the area where the connectors are working. In all, the net covers an area which is 18 feet wide by 61 feet long. The net extends approximately 6 feet beyond the splice point. Thus, men working on the connection of a new girder are able to work from a platform with a net below them. Wooden planks are placed on the flanges of the interior girders to provide work platforms for the connectors. Men working on these planks are also working directly above the net. The entire assembly described above is a single unit and can be lifted and installed in one process.

4.4.5.3.2 Practicality of Net Protection System

According to discussions with personnel at the site, two factors contributed to the practicality of this solution. First is the fact that the unit spanned the entire width of the bridge, which eliminated the need to install and disassemble temporary work platforms beside each of the five girder lines as erection progressed. Thus, by installing the unit once, work platforms and protection were provided for five connections. Previously, work platforms had to be installed and taken down for each of the five connections to be made. The second factor is that each girder connection required that over 200 bolts be placed and tightened before the next connection was made. This meant that the connectors working on the connection were in that position for four to six hours. The extended length of time spent at the erection point made more elaborate protection measures practical.

The job superintendent estimated that no more time and expense was involved in using the new system than was involved in assembling and disassembling work platforms five times using the old system. In short, he found the system to be superior both in protection offered connectors and in the efficiency of the erection process.(75)

This project demonstrates the concept that fall protection should be viewed as a system which combines different elements depending upon the various situations involved. The catenary lines installed on each girder before they were raised were discussed in the earlier section involving safety belts. Using both systems, the site superintendent estimated that connectors could be protected between 95 and 98 percent of the time. It should be noted that even though elaborate plans were made and a good deal of time and money was expended to provide fall protection, the connectors still occasionally had to move into an unanticipated area where the designers had thought protection would not be necessary. This illustrates that in some cases a number of fall protection problems can be solved, but special unexpected situations will occur.

4.4.5.3.3 Cost Estimates for Bridge Net Installation

To provide some indication of the costs associated with bridge netting, the Safety and Occupational Health office of the U.S. Army Corps of Engineers was requested to provide estimates based upon actual projects run by the Corps of Engineers. Table 7 presents a summary of the information provided. As yet, neither the Corps of Engineers nor the contractors involved maintain a separate accounting system for costs associated with safety nets. Therefore, these estimates are generally based upon contractor estimates provided to the Corps of Engineers. Further, the reader will notice that only the costs of the nets and labor are estimated. No estimates were available concerning any design work that may have been necessary or for the cost of hardware or special support structures that may have been used on these projects.

4.5 FEASIBILITY OF USING TRAINING TO PROTECT CONNECTORS

Connection work involves a wide variety of work tasks and the potential that work will have to be done which could not have been anticipated. Due to these and other factors discussed previously, there are situations where a connector cannot be protected by using a safety belt or net. In these situations, the connector must rely upon his own skills and abilities. When a connector is experienced, this safety measure is valuable. This is evidenced by the large number of accident-free hours worked by various connectors at the different sites visited during this project. In one case, ten stories of steel had been connected without mishap, even though connectors were not using safety belts or nets.(76) In another situation, approximately 2300 pieces of prestressed concrete had been erected without incident.(77)

4.5.1 PREDOMINANT MEANS OF TRAINING

If skill and safe work practice can provide significant protection to a connector, how does a connector develop the skill needed to work safely?

TABLE 7 - ESTIMATES OF NET COSTS ON BRIDGES*

TYPE OF CONSTRUCTION	TYPE OF STRUCTURE	TOTAL CONTRACT COST	COST OF NET PURCHASE/RENTAL	NET ASSOCIATED LABOR	TOTAL COST OF NETS**	NET COSTS AS A PERCENTAGE ON CONTRACT
Steel	Bridge	$ 338,000	$4,200	$5,800	$10,000	3%
Steel	Bridge	1,716,000	3,000	1,600	4,600	.3%
Steel	Bridge	6,005,700	5,000	9,000	14,000	.3%
Precast Concrete	Bridge	315,000	5,000	1,500	6,500	2.1%
Precast Girder & Cast in Place Concrete Deck	Bridge	458,000	12,500	3,000	15,500	3.2%

*Source: U.S. Army Corps of Engineers, Safety and Occupational Health Office.

**Note: No allowance has been estimated for the cost of building a net support structure, supplying hardware that was needed, or allowing for delays to project completion.

The predominant means of developing a safe connector involve choosing the right person, allowing him to gain general steel erection experience, and pairing him with an experienced connector. The following general sequence of events was described to members of the project team during several site visits.

It is apparent to an experienced foreman when a new person exhibits behavior which might make him a candidate for connection work. The individual will be in good physical condition, will be agile, and will have a good sense of balance. The new person on a steel erection job will usually begin by making up bolts (i.e., sorting, placing nuts on them, and supplying them to the raising gang and bolt-up crew). As the individual becomes more familiar with the steel erection process, he will make a decision about whether he would feel comfortable doing connection work. The majority of iron workers know that they do not have whatever intangible attributes are necessary to feel totally comfortable doing a connector's job. These people will work in bolt-up gangs, detail gangs, and other skilled structural steel trades.

If the individual wishes to become a connector, he may be placed on a bolt-up crew where he will have to maneuver around on open steel structures, but where protection is available and can be used. The foreman and fellow workers will form an opinion of the person's abilities to work in this situation, and if he seems comfortable doing this work, he may eventually be given the opportunity to try connection work. Often by the time the individual is asked to connect, a considerable amount of instruction in moving around the steel has been provided by fellow workers and foremen.

The new connector is paired with an experienced connector who will quickly evaluate the new person. The new person will be judged on such things as agility, balance, climbing technique, safe use of tools, and the ability to read prints, so he will understand what has to be done next. The safety of each connector is dependent upon the actions of the person manipulating the opposite end of the beam. The experienced connector will usually refuse to work with the new connector if he finds that the new person takes chances and places the experienced connector in danger. During site visits, foremen, union officials, and site superintendents indicated that they would honor a request from a connector for a new partner, if that connector felt unsafe working with a new person.

A similar process is followed in precast/prestressed erection, although fewer people are usually required by such a project. At first, the new person may be running for supplies and perhaps learning welding techniques. Some period of time may then be spent welding the members together. A new connector is placed with a more experienced individual and a natural evaluation process follows which is based upon the new person's ability to avoid placing himself and others in danger. The process may take six months to a year before a new person is tried as a connector.

4.5.2 UNION TRAINING PROGRAMS

Few formal union connector training programs exist. In the Phoenix Iron Workers Union Apprenticeship Program, apprentices actually erect a structure at the training facility. During the process of erection, apprentices do the connection work; however, no formalized training of connectors is done. Several other union locals have attempted to set up a similar facility where apprentices could be trained on an actual structure, but the money and cooperation involved in such an undertaking has not usually been available.

Many apprenticeship facilities have erected columns, beams, and other structural members to provide various types of experience to apprentices. Most will explain the technique involved in climbing a steel column and coach the apprentices as they make their first climbs. The use of safety belts is also an integral part of the curriculum of most apprenticeship programs.

However, in-depth training of connectors is not normally done. As one apprenticeship coordinator explained, perhaps less than 25 percent of the people in the apprenticeship program will occasionally connect structures and only 2 percent will actually become full-time connectors. The realities of the situation are that they must concentrate upon the skills and knowledge which all iron workers (including connectors) will need to perform the job.(78)

The International Association of Bridge, Structural and Ornamental Iron Workers has developed a series of slide/tape presentations, two of which deal with erection of columns and beams. However, these presentations deal mainly with the process involved in the erection. They are not designed to develop connection skills. In addition, training concerning safety devices, such as safety belts and safety nets, is contained in the Structural Manual for Iron Workers, the text used in apprenticeship training. However, the special uses of these items for connector protection is not specifically addressed in these materials.

4.5.3 CONTRACTOR AND ASSOCIATION TRAINING

Contractors generally feel that their training should be directed at familiarizing workers with the rules and procedures used on a particular job. Most would agree that any specialized safety techniques necessary for a particular task should also be taught by the contractor. This is most often done in an informal manner and through the use of periodic safety meetings between a foreman and his crew. Several of the contractors working on sites visited by the project team required new workers to view employee orientation training materials before starting work. Many contractors provide safety handbooks to new employees to inform them of safety rules enforced at the job site.

Specific skill training, other than on-the-job training, is seldom provided by the contractor. It is their feeling that they hire experienced employees to do a specific job. If the employee proves that he cannot do the job, someone else will be found.

The Prestressed Concrete Institute has produced two slide/tape programs dealing with the erection of precast/prestressed products. These are available to any member of the industry; however, relatively few erectors take advantage of them. These programs are geared more toward explaining the process than developing the skills needed to perform connection work safely.

4.5.4 IMPORTANCE OF FOREMEN

Since on-the-job training plays such an important role in preparing a connector to work safely, the influence of the raising gang foremen can be extremely important. Union business agents attempt to place apprentices on jobs where they know the foreman will help to train the apprentices in safe work habits. Foremen who insist that a connector work safely and take time to explain any special procedures that will be needed will have a lasting impression on the work habits used by new connectors. This was demonstrated particularly well during the site visit to the natural draft cooling tower where the Iron Worker foreman insisted that connectors use safety belts.(79)

The foreman is not always experienced at supervision. Contractors hire crews from the local area wherever the project is being built. Therefore, the people who are chosen as foremen may not have a great deal of experience in the supervision of other workers.

Local union business agents know members who have developed as experienced foremen; however, if one of these people is not available, the informal rule is that the first person hired on a crew is designated as the foreman. The contractor, of course, has the right to determine if the foreman does an effective job and to request that another person be designated the foreman if there is a problem. The person who operates as a foreman, however, has no guarantee that he will be chosen as the foreman on the next job where he is employed. One of the other crew members may be designated as foreman on the next job, therefore, reversing their roles. A foreman in this position may be hesitant to take a stance that is unpopular with members of the crew. Thus, all foreman may not be forceful in assuring that connectors follow the safest procedure.(80)

4.5.5 TRAINING OF A CONNECTOR

Since the safety of a connector depends to a great degree upon the procedures used to perform the job, establishing a formal training program should be considered. While the focus of this project has not been on determining the knowledge and skills needed by a connector, a number of skills have been identified. These are provided only to demonstrate the type of training which might be considered for connectors. It must be emphasized that the connector must not only have knowledge of these skills, but should be given ample opportunity to practice them in a controlled environment.

The connector should be able to:

- perform connection tasks in such a way that he remains in a balanced position.
- demonstrate the use of tools to bring an incoming member under under control and secure it to a structure.
- evaluate the risk of the various maneuvers that could be used to perform a task and choose the safest one possible. (For example, if one connector is working at the perimeter of the structure and another is on beams above a solid deck, the second person should move to maneuver the incoming member whenever possible.)
- maneuver around the interior side of the columns when moving along a beam line.
- avoid unnecessary fall exposure. (For example, when removing hooks from a precast/prestressed wall panel, do not walk along the top of the wall panel, unless absolutely necessary. Reposition the ladder whenever possible.)
- straddle the beam and walk along the lower flange whenever possible.
- choose the types of rigging which can be used to allow members to be disconnected from a crane without fall exposure.
- determine how a member should be prepared on the ground, to simplify the connection process before being lifted to the connector.
- decide when to send a member back to the ground so that splice plates, etc., can be repositioned more easily without exposing the connector to a greater fall hazard.
- evaluate the erection sequence to determine the safest sequence to use
- recognize the safest way for the crane to be operated when delivering structural steel or precast/prestressed members.
- evaluate the type of fall protection procedures and/or equipment which should be used in a specific connection situation.

4.6 SUMMARY

Considering the divergence in enforcement, judicial findings, incentives and disincentives, and actual situations encountered by connectors, it is relatively easy to simply say the problems cannot be solved.

It must be taken into account, however, that some unique and innovative solutions to these problems have been found in some situations. Information gathered during the Utah and Connecticut site visits makes it evident that these unique and innovative solutions can be found, provided the time and money are available. Since there is such a divergence, decisions regarding the use of safety belts or safety nets need to be made by experienced personnel on a project by project basis.

CHAPTER 5. IDENTIFICATION OF GAPS AND VOIDS IN THE STANDARDS

Two broad questions are considered in this chapter. The first deals with specifications which might make the standards in question more reasonable to enforce. Second, if one accepts the premise that there are some situations where a connector cannot be protected by either a belt or a net, what additional safeguards should be provided?

The Occupational Safety and Health Administration (OSHA), the California Occupational Health and Safety Administration (Cal/OSHA), the U.S. Army Corps of Engineers, the American National Standards Institute (ANSI), and the Ontario Occupational Health and Safety Division all have written standards which apply to connector work in construction. (See Appendices A,G,H,I, and J for full texts of each.) Although there are many similarities among the standards, there are also many dissimilarities, especially regarding when and exactly how a worker must be protected. A comparison of these standards is provided prior to the discussion of each OSHA standard.

5.1 SAFETY TRAINING STANDARD

5.1.1 REVIEW OF SIMILAR STANDARDS

OSHA, Cal/OSHA, the Corps of Engineers, and Ontario all have a training standard as part of their construction standards. None of the standards is very specific. Cal/OSHA requires that new employees be instructed regarding unsafe conditions and hazards relating to their work environment. The Corps of Engineers also requires new employees to be trained and requires continued training so an employee can work safely. Ontario's training standard, however, mentions only that an employee be instructed in the care and use of any protective clothing, equipment, or device that he is required to wear or use.

5.1.2 OSHA TRAINING STANDARD

The OSHA training standard (29 CFR 1926.21(b)(2)) requires an employer to instruct an employee so that he can recognize and avoid unsafe conditions. No specific recommendations are made concerning what type of training shall be done, when it is to be done, or how the effectiveness of the training is to be judged. It provides neither the employer nor a compliance officer with sufficient information to determine what should be done or the priorities which might be used to determine the

most important type of training. Based only upon the language of the standard, a compliance officer could cite it in any situation where an accident occurred, unless the employer could specifically show that the people involved had been trained to avoid that type of accident. The compliance officer would also have difficulty determining if the training had been sufficient. For example, if the safety booklet given to a new employee stated that a safety belt should be worn when working at heights, has the worker been sufficiently trained about when to wear a safety belt?

It would appear that there are situations in connection work where the only practical safety measures available involve the skill of the individual doing the work. Yet a compliance officer would have difficulty determining by what criteria the training of a connector should be judged. Therefore, it may be necessary to further define how a connector should be trained and perhaps some proof of that training should be provided.

It is outside the scope of this study to define specifically what a connector should know to work safely. To establish this would require an in-depth review of the connector's task on various structures by a variety of highly experienced connectors. The resulting volume of information would be far greater than would be appropriate for a standard. Furthermore, a compliance officer would have to be well-trained concerning connector safety to be able to observe a connector and judge from his actions whether he had been properly trained.

It may be more reasonable to modify the standard in such a way that it would specifically state that a connector must receive safety training. It may also be appropriate to require that some proof of successful completion of a basic connector safety course be available for review by a compliance officer at the job site where a connector is employed. For already experienced connectors, this proof might be obtained by having two connectors, with proper credentials, observe the actions of the "experienced" connector on the job and determine if safe procedures are being followed. If they are not, the connector would be required to take the training course. If they are being followed, the connector could be certified by the two observers.

A great deal of training must take place in an actual job situation if the connector is to have the opportunity to actually experience various situations and learn to deal with them. A trainee category should be established which could allow a less experienced individual to do connection work for a certain period of time when paired with a properly certified connector.

5.2 SAFETY BELTS, LIFELINES, AND LANYARDS

5.2.1 REVIEW OF SIMILAR STANDARDS

There are several differences in the provisions between the various construction standards for belts. Table 8 summarizes the major points

TABLE 8 - COMPARISON OF SAFETY BELTS STANDARDS*

	OSHA (29 CFR 1926.104)	Cal/OSHA (Article 24-1669 1670,1672)	ANSI (A10.14-1975	Army Corps (07.A.13-07.A.21)	Ontario (Part II-Section 35)
Potential Fall Distance Where Safety Belt Required	not specified	15 feet or one story	not specified	6 feet	9.8 feet (3 meters)
Maximum Fall Distance Allowed	6 feet	6 feet	as short as possible (6 feet implied)	6 feet	5 feet (1.5 meters)
Peak Arrest Force Allowed	not specified	not specified	10X gravity	not specified	8 kilonewtons
Lanyard Specifications	½-inch nylon or equivalent	nylon rope	anything satisfactory for application	½-nylon or equivalent	.64-inch (16 mm) nylon
Location of Lifeline Anchorage	above operation	at waist level or at feet level, if controlled	to fixed anchorage	above operation	to any fixed support
Provision for Pendant and Secondary Lifeline at Perimeter	not specified	specified	specified for drop lines (pendant lines)	specified for drop lines (pendant lines)	not specified
Allowance of Exception to Standard	none	if supervised	with equal protection	none	when moving between work positions or connecting structural members
Lifeline	3/4-inch manila	nylon rope	½-inch wire rope	3/4-inch manila	.64 inch (16 mm)
Lifeline Limited to One Worker	not specified	not specified	specified for drop line (pendant line)	not specified	specified

*The full text of each standard can be found in the appendices.

of agreement and disagreement. The Cal/OSHA, Corps of Engineers, and Ontario standards each provide an indication concerning the height at which a belt shall be used (i.e., Cal/OSHA - 15 feet, Corps of Engineers - 6 feet, and Ontario - 9.8 feet). The OSHA and Corps of Engineers standards require that a worker tie off above the point of operation. All standards, except OSHA and the Corps of Engineers, recognize that a belt may not be practical to use in some circumstances. Ontario goes furtherest in this regard by actually exempting people moving from one point to another on skeletal steel and those working as connectors.

A major point of agreement between all five standards is that the fall distance be limited to either 5 or 6 feet. It would seem that none would agree with the statements of the British Standards Institute which would prefer a 2-foot limit for a fall into a safety belt. The 6-foot fall would be allowed only if the worker were wearing a full body harness.(81) The 6-foot fall is qualified, however, by the ANSI and Ontario standards so that a force of no more than 10 times gravity (ANSI) or 9 kilonewtons (Ontario) is allowed. In some situations, this aspect may effectively shorten the distance allowed by these standards. It is difficult to determine how a contractor could adequately assess the force which would be exerted against a falling body when caught by a safety belt. Therefore, while these standards are more specific, there is a question concerning whether this specification is valuable to those seeking to comply with the standard.

The Cal/OSHA steel erection standards also provide for the use of safety belts. They state that when connecting beams at the perimeter of the structure where there is a fall distance greater than 25 feet, employees should be tied off by safety belts or lifelines to columns, pendant lines on peripheral columns, catenary lines, or other anchorage points. The OSHA standards make no specific mention of tying off when connecting, but only to tying off when gathering and stacking floor planking and when working on floating scaffolds to bolt up. Furthermore, the OSHA general construction standard for safety belts (29 CFR 1926.104) makes no mention of the possible use of pendant lines, as does the Cal/OSHA standard. The Cal/OSHA steel erection standards also stipulate a requirement to coon peripheral beams. However, there is no mention of whether or not a iron worker should be tied off while doing so.

5.2.2 OSHA STANDARD

The OSHA standard involving safety belts (29 CFR 1926.104) principally deals with the design of a belt, lifeline, and lanyard and how they should be used to prevent a fall. However, the standard does not indicate when a safety belt should be used. Both the OSHA Review Commission and the courts have stated that the belt standard alone is not sufficient to uphold a citation issued because people were working at a height without wearing safety belts. In reality, only the personal protective standard (29 CFR 1926.28(a)) seems to provide this authority. However, the OSHA Review Commission and the courts are at odds concerning whether this standard is written so broadly that it is unenforceably vague.

The employer and the compliance officer are left with the dilemma that neither knows exactly when a belt must be worn. Many steel erectors, for example, feel that a belt is not required when working over a solidly planked surface no more than two stories or 25 feet below. Individual compliance officers may or may not agree, depending on the circumstances.

There is considerable controversy over what potential fall distance is appropriate for requiring a belt to be used. The Corps of Engineers specify 6 feet, the Ontario standards specify 9.8 feet, and the Cal/OSHA standards specify 15 feet, except at the periphery of tiered buildings where 25 feet is allowed. This study was not designed to establish this distance; however, it is clear that specifying such a distance in the safety belt standard would aid in judging and enforcing compliance.

5.2.2.1 Location of Anchorage

The requirement that a lifeline be secured above the point of operation is not always practical when dealing with a connector, as there is often no structure above the connection operation. It would appear that the major reason for this requirement is to aid in limiting the fall distance and prevent a tripping hazard caused by having lanyards and lifelines laying on the deck.

The ANSI, Cal/OSHA and Ontario standards do not specify that an anchorage must be above the point of operation. ANSI and Ontario only require a fixed anchorage. Cal/OSHA specifies a waist level anchorage unless that is found to be impractical. Then a foot level anchorage can be used, if proper precautions are taken.

The problem with attaching a 6-foot lanyard below waist level is that the fall distance may be extended beyond 6 feet. Therefore, the Cal/OSHA standard would appear to take the best tact in requiring an anchorage at waist level and one lower if proper precautions are taken. This, in combination with the limitation of a fall to no more than 6 feet, already specified by the OSHA standard, should effectively limit the fall and save the life.

5.2.2.2 Composition of Lanyard

The OSHA standard currently states that ½-inch nylon or equivalent material should be used for a lanyard. No mention is made concerning how an equivalent lanyard material should be judged. One of the most important factors in lanyard design is the cushioning effect provided by the elongation of a nylon rope when a fall is arrested. If a steel rope lanyard is used, there is no cushioning effect to break the fall.

As discussed before, there are good reasons for using something other than a nylon rope lanyard (such as where welding is being done). However, it is important that some shock absorbing feature be a criteria for choosing an alternate type of lanyard material. For example, a

wire rope lanyard may be perfectly acceptable if a commercially available shock absorber is attached between the rope and either the anchorage or the belt.

5.2.2.3 Resistance to Cutting

The OSHA standards specify that lifelines subject to cutting or abrasion shall be 7/8-inch wire core manila rope. However, no specification is made for a lanyard. The National Bureau of Standards study, discussed earlier, stated that at least two of the thirty-five cases where safety belts were properly used resulted in fatalities because the lanyard was cut by sharp edges on the structure to which which it was attached. Structural steel can have sharp edges and the rough surface of concrete members can abrade rope. Therefore, some provision should be included in the standard to assure that lanyards are made of material which will not be damaged by attaching them to structural products.

5.2.2.4 Training in Use of Belt

The National Bureau of Standards study also stated that in over half of the fall cases which could be located, the safety belt, lanyard, and lifeline failed to prevent serious injury because the equipment was not being properly used. The safety belt, if it is improperly used, is an item which could result in greater injury to the worker than would a fall.

The OSHA standard makes no specific mention that a worker should be trained in how the belt is used. The training standard (29 CFR 1926.21(b)(2)) implies that such training shall be done; however, it is not specific regarding training for the proper use of personal protective equipment.

It would be advisable to specify that training, regarding the manufacturer's recommendations for belt use, be provided. It is important that a single lanyard attachment to the belt is at the small of the back. If a double attachment belt is being used, it is important that both ends of the lanyard are consistently attached to the belt itself. It is also important that a worker is trained to tie the proper type of knot when anchoring the lanyard and that the worker be capable of inspecting the belt, lanyard, and lifelines to detect flaws or excessive wear. None of these things are mentioned in the standard.

5.2.2.5 Recognition of Exceptions

The OSHA standards do not recognize any circumstances where the use of a safety belt or other form of safety device is not possible. Such recognition is a part of the Cal/OSHA, ANSI, and Ontario standards. The Ontario standard specifically exempts a worker who "is proceeding to or from his work position" and who "is engaged in connecting structural members of a skeleton structure". The Cal/OSHA standard specifies that adequate supervision will be required, and ANSI requires equal

protection. Both the OSHA Review Commission and the courts have ruled that there are specific isolated circumstances where belts and/or nets cannot be practically used.

The inclusion of verbage which allows an exclusion to the standard under specific circumstances (e.g., where the worker would be placed in greater danger by the limitation of mobility) and specifies what should be done in lieu of the standard (e.g., only fully trained connectors under close supervision are allowed to work in these situations) could aid in establishing guidelines for more uniform enforcement of this standard for connectors. However, a good deal of knowledge is needed by a compliance officer to be able to make such a determination adequately.

5.3 SAFETY NET STANDARDS

5.3.1 COMPARISON OF SIMILAR STANDARDS

To allow the various standards involving safety nets to be compared, the major parts of each standard have been summarized in Table 9. Of interest is the fact that the OSHA and Cal/OSHA standards indicate a preference for safety belts instead of safety nets. Also, while all standards require the net installation to be tested, only the Corps of Engineers and ANSI standards specify a procedure to be used. The standards generally agree that at least 8 feet of net protection should be provided around the work area and that safety nets should be required when a fall distance of 25 feet is exceeded. The Cal/OSHA standard is the only one to specifically mention the requirement to provide perimeter netting on tiered structures.

The OSHA, Cal/OSHA, and Corps of Engineers standards include specific standards for steel erection. All require that nets be used on buildings or structures not adaptable to temporary flooring or where scaffolds are not used.

The Cal/OSHA steel erection standards go on to say that nets should be used to protect connectors when tying off is not possible. Clearly, safety belts are preferred over nets. Where nets are used, they cannot be installed lower than 25 feet below the work surface, as opposed to the 10-foot requirement in the general Cal/OSHA net standard.

The Cal/OSHA steel erection standards also require that an erection plan and procedure prepared by a registered civil engineer be provided by the employer to serve as an erection guide for trusses and beams over 25 feet long. No mention of an erection plan and procedure is made in the OSHA standards.

5.3.2 OSHA SAFETY NET STANDARDS

The requirement to provide net protection is stated in the general construction standards (29 CFR 1926.105 Safety Nets) and in the Subpart

TABLE 9 - COMPARISON OF SAFETY NET STANDARDS*

	OSHA (29 CFR 1926.105)	Cal/OSHA (Article 24- 1669, 1671, 1672)	ANSI (A10.11 1971)	Army Corps of Engineers (07.0)
Height of Workplace where Safety Net Required	25 feet	25 feet	25 feet	25 feet
Preferred Safety Devices	safety belts	safety belts	no preference	unclear
When Nets Must be Tested	before used	on-the-job	after installation, major repair and six months use	after installation, relocation major repair, and six months use
Test Procedure Contained in	not specified	as specified by net manufacturer	specified	specified
Number of Feet Net Must Extend Beyond Edge of Work Surface	8 feet	8 feet	10 feet	8 feet
Maximum Allowable Distance Between Work Surface and Net	25 feet	10 feet (25 feet on steel erection)	30 feet	25 feet
Allowance of Exception to Standard	none	if supervised	with equipment safeguards	none
Number of Levels Needed on Bridges	one	one	one	one
When Inspection is Required	not specified	not specified	once per week, after repair, impact loading, and welding operations	daily
Frequency of Debris Removal	not specified	not specified	daily and before hot work	daily and before hot work
Requirement to Use Perimeter Net on Tiered Structure When Belt Impractical	not specified	specified	not specified	not specified

*The full text of each standard can be found in the appendices. (The Ontario, Canada, standards do not include a specific standard for nets.)

R steel erection standard (29 CFR 1926.750(b)(1)(ii) Temporary Flooring). These two standards provide similar requirements concerning when a net must be used and the clearance required beneath a net. The general construction standard is much more specific than the one contained within the steel erection standards.

There has been a general controversy regarding which standards are to govern the erection of a steel tiered building. The courts have generally found that the Subpart R steel erection standards supersede the same or similar general construction standards. However, standards such as the one requiring safety belts also apply.

5.3.2.1 Design of Net Installation

The general construction standard for safety nets specifies that a net will extend at least 8 feet beyond the work surface, will be no more than 25 feet below, and will be hung with sufficient clearance to prevent the user's contact with structures below. However, there is no specification for the manner in which the net should be rigged, the force it will withstand, or the strength of any specially built supporting structure. For example, if a perimeter net is to be erected, there are no guidelines concerning the strength of the supporting arms or the attachments to the building.

Further, there is no requirement to arrange a safety net in such a way that a person rebounding from it will not be thrown over the edge and subjected to a further fall. The need for this specification was demonstrated by one of the fatality cases, summarized in Appendix B, where a man fell into a net but rebounded and was thrown over the perimeter. The man fell an additional 80 feet to his death, even though the net was in basic compliance with the net requirement in the standard.

5.3.2.2 Impact Testing

The standard states that the net will be impact load tested before operations are undertaken. However, no specifications are provided to determine how this test should be accomplished. A similar test procedure is provided in both the ANSI and Corps of Engineers standards. The ANSI standard states:

> The test shall consist of dropping a 400-pound bag of sand not more than 30 inches (± 2 inches) in diameter of the net. There shall be no broken strands nor significant distortion of the net pattern or the suspension system.

5.3.2.3 Perimeter Nets

The OSHA standard states that nets will extend 8 feet beyond the edge of the work surface. This would require the use of perimeter nets on

tiered buildings, even though perimeter nets per se are not mentioned. Standards are not provided regarding how perimeter nets should be installed. For example, the exterior edge of a perimeter net should be higher than the interior edge so that a person rebounding from the net would be thrown to the interior instead of over the edge.

The standard also states the net should be placed as close as practical beneath the work surface. Literally interpreted, the net should be placed 2 or 3 feet below the work location whenever possible. However, no deck area would be available next to a perimeter net attached in this manner. If a worker fell and rebounded from the net toward the interior of the building, he could fall still further to the uppermost solid floor.

The standard should perhaps state that a perimeter net installation should be at the level of and next to the uppermost solidly decked floor. This would insure that a person rebounding from the net would be thrown toward a solid surface. It would also insure that a person falling on the interior of the structure near the perimeter would not rebound from the flooring and fall between the edge of the net and the floor level, as was possible with some of the perimeter net systems discussed earlier.

5.3.2.4 Inspection and Debris Removal

The OSHA standards do not specify when or how often nets will be inspected or what will signify that a net should be replaced. Specifications are provided for a new net; however, many factors such as sunlight, salt air, welding operations, corrosive chemicals, sharp edges, etc., can cause a net to wear significantly. It is therefore important to periodically assure the net is in good condition. ANSI specifies that a net shall be inspected by a qualified person once per week, after each repair, after impact loading, and following welding operations. The Corps of Engineers require a daily inspection.

Debris can also damage a net or can cause a person falling into a net to be injured unnecessarily. It is also important to assure periodic removal of debris from the nets. OSHA standards do not specify when or if this should occur.

5.4 FALL HAZARDS NOT ADDRESSED BY THE STANDARDS

In addition to a lack of specificity in some standards, there are other connector fall hazards which are not addressed by the standards. When the connector cannot be protected by normal means, it is particularly important that other hazards be eliminated to reduce the risk of falling. Several such precautions are included in Subpart R of the standards. For example, two bolts are required in each end of a beam before it is released from the crane. The hazards created by other practices should also be recognized and considered.

5.4.1 DOUBLE CONNECTIONS

A double connection occurs when two beams must be attached to the web of a column on opposite sides. The procedure used is for the connectors

to place the beam on one side of the column and secure two bolts through the column web. One connector will then sit astride the beam near the column and reach around the column to catch the next beam and maneuver it into position. The connector may then place the end of his spud wrench through the holes in the new beam, into the holes in the column.

The two bolts attaching the beam he is sitting upon must now be loosened and drawn back so that the new beam can be put into the final position. The two bolts are then pressed through the holes in the first beam, through the column, and into the holes in the new beam so that a nut can be attached.

While the connector is drawing the bolts back far enough to allow the new beam to be positioned, the only secure attachment for the beam on which he sits is at the opposite end. If the incoming beam should hit the column, it can shake the bolts from the hole and release the end of the beam on which the connector sits. A great deal of skill and experience is needed to perform this operation sucessfully.

The problem can be eliminated by one of two methods. First, a seat lug (i.e., an inverted metal "L" bracket) can be fabricated to one side of the column, below the connection point. When the first beam is placed, two bolts are inserted downward into the seat lug. This leaves the other side of the column web clear so the new beam can be positioned without disconnecting the beam on which the connector sits.

A second procedure requires that the connection plate on the end of the first beam be enlarged so that two additional holes can be placed just below the double connection point. Bolts can be placed in these holes to secure the column. Even though these two bolts go through the web of the column, they are below the area where the second beam must be aligned. Again the first beam does not have to be disconnected to allow the second beam to be positioned.

5.4.2 SHEER TIES ON BRIDGE GIRDERS

A concrete deck is often poured on top of bridge decks to provide a strong surface for traffic. To tie the concrete layer to the steel structure below, sheer ties (resembling bolt heads sticking 1 or 2 inches above the surface of the beam) are attached to the top flange of the girder. These sheer ties make it difficult to walk along the top of a bridge girder without tripping. They represent a significant hazard to a connector who will walk along the top flange of the girder numerous times in the course of his duties.

Many bridge erection companies install sheer ties in the field to eliminate the tripping hazard the ties create. The sheer ties are attached after the connection operation is completed and the decking connecting the girders has been placed. In this way, people can work from the decking to install the sheer ties. However, this practice is not universal and bridge connectors still must deal with this problem.

5.4.3 RIGGING RELEASED FROM GROUND LEVEL

After a member has been bolted or welded temporarily to the structure, a connector must climb it or move out on it to release the crane rigging. Several rigging devices have been designed which allow a column to be released from the crane without requiring a man to climb to the top of the column. These devices often make use of a pin which can be slid through holes in plates attached to the rigging and aligned with holes at the top of the column. The pin is secured in place by a spring clip placed through the larger pin so that cannot retract through the holes. A line extends from both the spring clip and from the pin which can be reached from the ground or a solid deck. Both the pin and the clip are also attached, by rope, to the rigging so that when they are pulled free, they do not fall to the ground but remain hanging from the rigging. (Refer to Figure 1 in Chapter 3.)

After the column is secured in place, the connector pulls the spring clip free and pulls the pin out of the holes. This releases the rigging from the column. Such an arrangement is cost effective, as it makes the operation faster and safer. It may be possible to design devices, of a similar nature, for precast/prestressed columns and for precast/prestressed and steel beams.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

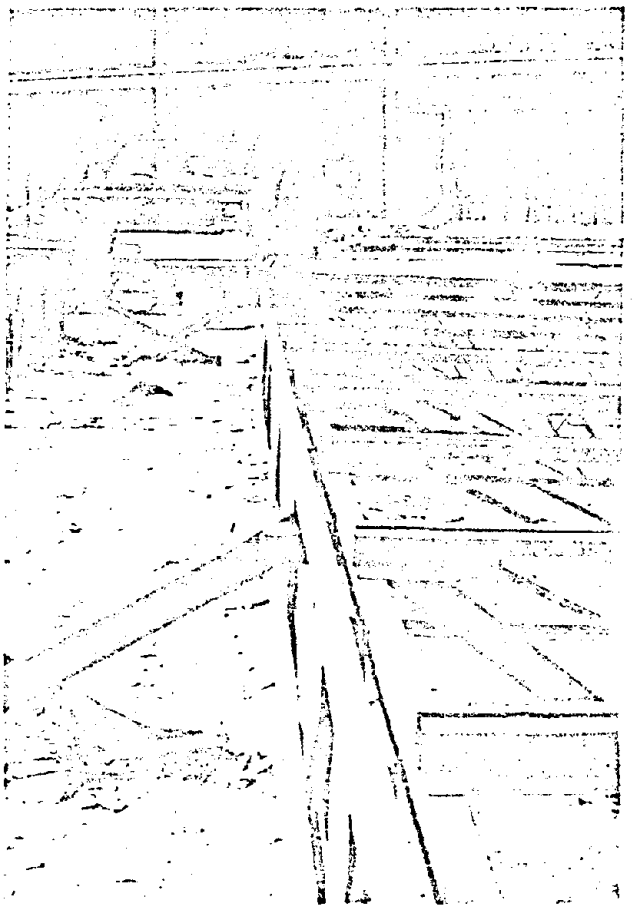
The various discussions presented in earlier sections have shown that the issue of protecting steel and precast/prestressed connectors from falls while working at the point of erection is quite complex. Generalized solutions superimposed over complex issues usually do more harm than good. It is important that OSHA, contractors, and workers be educated concerning what types of protection are possible and what is reasonable for a contractor to accomplish. To be certain, the most effective form of protection, which will not severely disadvantage the contractor from obtaining work and remaining in business, should be sought. Unfortunately, the form this protection takes changes not only on different projects, but also in different areas of the same project.

6.1 SAFETY AT THE DESIGN STAGE

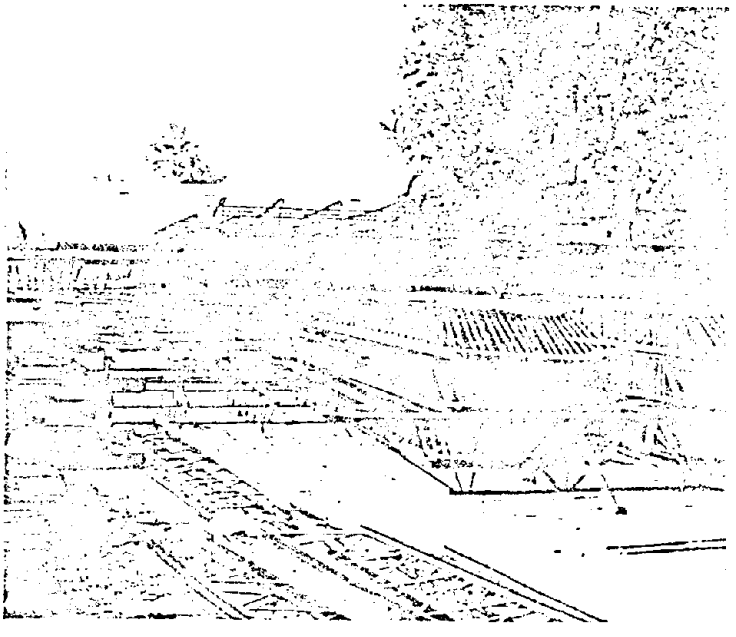
It is perhaps most reasonable to consider fall protection in a generic way when planning safety for a project. As has been shown, connector safety is not limited only to whether or not a safety belt or net is used. It involves a wide variety of items, including the paint on the member, the skill and experience of the crane operator, the type of rigging used, the sequence by which the erection progresses, the experience of the connector, the use of a two-bolt connection in beams, etc. It also includes the possibility of utilizing other types of safety precautions when possible. These include mechanized platforms, rolling scaffolds, ladders, crane supported skip boxes, and specially designed catch platforms.

The most important advancement that can be made in improving connection safety is the consideration of safety at the design stage of the project—in short, where, when and how the connector erects each piece in the structure. In this way, basic decisions, such as the type, size, and capacity of the crane needed to work with a specific net system, can be made. Determining, in the design stage, where and when nets will be used would allow columns to be prefabricated so that net support systems can be quickly and easily attached. Engineers and architects are not educated in the complexities of connection tasks. They do not view their design in terms of the degree of risk a connector may face when erecting the actual structure.

This is not to say that contractors and designers do not take safety into account when planning a project. The erection process is planned



Picture 36 - Bar joists are set out on a jig installed at ground level. Bridging is then welded between the joists to form a square section which can be lifted as a single unit. This proceedure eliminates the need to "shake out' bar joists while walking on beams in the structure.



Picture 37 - Square bar joist sections are stacked in storage before they are lifted to the proper location in the structure.

in great detail to assure that the equipment that is needed is ordered and available. They also consider whether netting should be used. However, many do not know of the variety of protection techniques which could be utilized. It is also apparent from some of the practices still in use (e.g., the use of double connections and sheer ties) that many hazards are not recognized by designers because they do not fully understand how a connector must work or what is hazardous to him.

Many companies who have thoroughly considered how connectors can be protected have developed ways of solving problems. On the bridge project visited in Utah for example, a workable system of protection for connectors was devised. Not only was protection provided, but work efficiency was improved. A second example, used by a contractor in Bridgeport, Connecticut, was the assembly of sections of bar joists before raising them to a connector. Normally a bundle of bar joists are raised to the connector at one time. The connector must then separate the bar joists, carry them to their proper location, and bolt or weld them into position. All of this is done on the open steel.

One contractor has adopted a method which allows the assembly of bar joists sections before they are raised to the connector. The contractor carefully determines where each section of bar joists must be placed and specifies how they are to be assembled. In one application, a jig was layed out at ground level. The bar joists were placed on the jig, as they would be in the structure, and the bridging between them was welded in place. Each section was then marked to identify its location in the structure, and it was stacked in storage.

When the column and beam structure was erected, the bar joist sections were raised to the connectors and set into the building. This eliminated the need for the connectors to shake out the joists on the steel and provided a stable structure as soon as the sections were in place. The connectors then only had to bolt or weld the ends to the supporting beams. Such solutions need to be communicated widely, complete with design considerations and cost experience.

Other design problems should be considered, such as assuring that seat lugs are provided when double connections are made. Consideration can be given to such things as three-story columns which make it difficult for a crane to maneuver beams down into a structure. Three-story precast/prestressed wall panels cause problems for connectors when the panel must be unhooked from the crane. Erection sequence can also have an effect on safety. Precast/prestressed concrete erected in stairstep fashion reduces the fall exposure dramatically.

A project which would work with connectors and designers to determine what a designer can do to help assure the connector's safety would assemble a valuable reference document. The resulting volume would allow designers and erection planners to view a project from the connector's viewpoint and consider whether certain designs should be used. No such information is currently available.

6.2 RESEARCH NEEDED

When steel is to be exposed in the final structure, and particularly when this steel will be placed in a relatively inaccessible area, it is painted or primed during fabrication. In this way, a painter will not be required to gain access to the steel after it is erected.

During the course of this study, many connectors complained that much of this paint is quite slick and does not provide good footing. When a connector must walk a beam or climb a column, a slick surface on the steel can seriously hamper the security of his footing.

It has been suggested by some connectors that a light grit could be mixed into the paint before it is sprayed onto the steel. This would allow the steel to be painted during fabrication and would provide more positive footing for the connector who must erect it. It would be necessary to study this problem further to determine what type of grit would not affect the properties of the paint and would not be loosened by the connector's movements.

6.3 OSHA ENFORCEMENT

It is clear that many protective systems, primarily those involving nets, can be quite expensive. The decision regarding their use is often not a safety decision, so much as it is a competitive decision. If contractors could be assured that bids would not be won or lost based upon the costs associated with the protection system, more protection would be provided.

To solve this problem, a balanced and informed system of OSHA enforcement is needed which is uniform throughout the country. The key factor in developing effective enforcement is to train compliance officers concerning the connection task, inform them of the types of protection which have proven feasible, and educate them so they determine where physical protection should be provided and where the experience and training of the connector must be utilized.

In providing this training to compliance officers, OSHA should provide basic instruction which will allow compliance officers in all parts of the country to make uniform decisions. To do this, criteria must be established which will provide compliance officers with a specific procedure by which connector safety can be judged. For example, this procedure might include the following types of criteria:

- Consider the connector's need for movement in performing his job.
- Determine the experience of the crane operator and observe crane operations to assure that connector's signals are being followed.
- Consider the degree of hazard potential. For example, a light member being raised a short distance by a small crane is more

easily controlled than a heavier member being dropped into place by a crane four stories above the connector's location.

- Consider the type of structure involved and the unique aspects of the connector's job on that structure.

- Consider the degree of fall exposure in regard to protective measures being used. For example, is more care taken at the perimeter of the structure than when the fall exposure is perhaps less than 10 feet?

- Determine the experience of the connectors. If a new connector is working, is he paired with an experienced connector?

- Observe the connectors to determine if they utilize procedures that reduce the fall hazard. (For example, move around columns on the interior side, coon when possible, limit movement on perimeter beams, etc.)

- Is the erection sequence well-planned and executed? For example, in precast/prestressed erection, are deck members installed whenever possible to provide a more extensive work platform before column splices are made or wall panels are positioned at the perimeter?

- Are tag-lines used to control members and are rigging systems, which do not require employee fall exposure, in use where possible?

Ideally, properly informed OSHA Compliance Officers will be able to inform contractors of protection measures they should consider and then monitor the project to assure that adequate protection is provided.

6.4 CHANGES IN WRITTEN STANDARDS

In addition to better informed compliance officers, standards should be examined to assure they contain sufficient detail to allow critical factors to be controlled. The standards should also be written in such a way that a contractor is provided with clear guidelines by which compliance will be judged.

If exceptions to the standards are to be allowed, alternative measures to be used in lieu of the standard should be specifically stated. In this way, both the contractor and compliance officer will be able to judge whether the alternative measures are acceptable.

Specific recommendations regarding changes in the written standards are discussed in the preceeding chapter. The following is a summary of these suggestions:

Training

- If a connector must work without physical protection, he should be trained in accordance with specific criteria.
- A connector should be able to produce proof of successful completion of an approved connector safety training course.
- A connector in training should be paired with a trained connector.

Safety Belts

- Specifications should be established concerning when a safety belt must be used.
- Lanyards and/or lifelines should be attached to a secure anchorage at or above waist level or lower if proper precautions are followed.
- A criteria for judging equivalent lanyard material should be established which assures that the strength and shock absorbing characteristics of the lanyard are appropriate.
- Lanyards subject to cutting or abrasion should be made of a material which will not be damaged should a fall occur.
- Criteria should be established to assure that employees are properly trained in the use, inspection, and care of safety belts, lanyards, and lifelines.
- Specific guidelines should be provided so employers and compliance officers can determine when an exception to the standard can be considered and what alternative measures must be used in lieu of those required in the standard.

Safety Nets

- Guidelines should be provided so an employer will know whether a project is subject to the Subpart R steel erection net standards or that in the general construction net standards.
- Design criteria should be adopted to determine if a net installation is safely designed and constructed.
- A standardized procedure should be specified for impact testing an installed net system.
- Specifications should be developed to allow the installation of a perimeter net system to be correctly evaluated.
- Specific information should be provided to establish how often debris should be removed from a net and when inspections should take place.

Consideration of Additional Standards

- A seat lug or other means of securing a beam should be required for all double connections in steel erection.
- Sheer ties should be installed on bridge girders in the field after connection operations have been completed.
- Rigging which can be released without exposing a connector to a fall hazard should be used whenever possible.

6.5 CONNECTOR TRAINING

Unions and associations should be encouraged to establish training programs for connectors. There is little doubt that connectors must be well trained to safely do their work, whether or not safety belts and nets are used. There is currently no well-defined way of providing such training for connectors. Attitudes concerning the use of safety belts and other protective devices are formed in large part by the first experiences of a connector. It seems apparent that some care should be taken to assure that these first experiences contribute to a safe attitude.

Iron Workers Union members already receive a good deal of apprenticeship training. It would seem possible for union officials to establish course work for training connectors. While it has been estimated that only about two percent of union members will become full-time connectors, a much larger population will be called upon at various times to perform connection work. These people may be at greater risk because of their relative inexperience. It may therefore be wise to assure that some aspects of connector training be provided to all apprentices.

Industry associations can also provide a good deal of training. This is particularly important for non-union workers. The unfortunate situation of many associations, however, is that financial resources may not be available to finance the time and effort necessary to develop a truly effective training program. Federal assistance should be considered to assure that effective training can be developed, not only through associations, but also through union organizations.

6.6 FEDERAL SPECIFICATIONS

If connector fall protection is to be required and competitive bid disadvantages are to be alleviated, it would seem that federal and state building projects should consider following the example of the U.S. Army Corps of Engineers. In short, connector fall protection should be included in bid specifications. Such a move would help to assure protection for connectors on federally financed projects and would demonstrate the determination of federal authorities regarding this issue.

6.7 CONNECTOR FALL PROTECTION NEEDS ANALYSIS

Performing a comprehensive needs analysis, which would formulate the basic objectives to be accomplished by connector training, would be difficult for any one organization within the industry to accomplish. Such an analysis should seek to contact a wide range of experienced connectors to assemble a definitive set of skills needed by a connector to work safely at the point of erection. A consensus concerning what a connector could be taught should be sought from all parties involved in this issue. In addition, means which have been devised to protect connection workers from falls should be documented and new connectors should be made aware of what they are and how they might be used.

Performing such a study at the federal level would accomplish two major objectives. First, the results of such a study would provide a comprehensive basis from which training could be designed for OSHA compliance personnel who will be inspecting steel and precast/prestressed erection sites. Second, the results of the study would establish a national consensus of what and how a connector should be expected to work to prevent falls. This could then be provided to unions, associations, and contractors as guidelines which should be followed in implementing training programs. If the study is performed properly, all three parties should feel that their impact and point of view has been expressed. Each organization could then customize the objectives for their own use, but each would start from a uniform, mutually agreeable set of objectives.

This approach would allow a much more thorough study to be made of what should be taught to a connector, than would be possible if each organization attempted to perform a similar study using limited time and financial resources. It would also eliminate a good deal of duplication of effort.

6.8 EFFECTIVENESS OF THE STANDARDS IN QUESTION

A scientific study to determine if the subject standards are effective at protecting steel and precast/prestressed erectors from a fall hazard would allow many of the issues identified in this document to be resolved. Very few studies of this nature have been accomplished and a wide range of problems must be considered when designing such a project. A detailed discussion of a proposed research protocol is contained in Appendix K.

GLOSSARY

Anchorage - a secure point of attachment to which is attached a lifeline or lanyard

Bar Joists - open web, trussed steel joists used extensively for floor and roof construction (They are, in effect, small trusses.)

Barrel Pin - a tapered pin used to align two or more plys of steel

Bay - the distance or space between two beams or between two lines of columns

Beam - a horizontal building member which supports a load

Beam Line - a line of erected columns with beams attached between them

Bearing Wall - a wall carrying the weight of another wall above it

Body Belt - a simple or compound strap with means for securing it about the waist and with means for securing a lanyard or snaphooks to it; the part that secures the worker to each fall-safety system

Bolt-Up Crew - a group of iron workers whose primary task is to plumb and level structural steel which has been put into position by connectors and to insert and tighten all bolts necessary to secure the connection

Catenary line - a line installed horizontally between substantial upright structures, to which a safety belt lanyard can be attached

Choker - a piece of crane rigging consisting of a length of steel cable with a spliced eye at each end. The cable is passed around an object to be lifted by the crane, the end is threaded through one of the eyes, and the opposite eye is placed on the crane hook. The piece to be lifted is, in effect, "choked" by the noose formed by the steel cable.

Column - a compression member or a vertical support taking most of its load on its axis

Connector - a person primarily working to first attach steel or precast/prestressed members into a structure

Coon - a process used to move along a steel beam, whereby the connector straddles the beam and walks along the lower flange

Detail Gang - a group of iron workers responsible for attaching miscellaneous pieces of steel to a structure, such as stairways, small beams, and perimeter cables

Erection - the rigging of hoisting or lifting equipment, raising of members to their proper places in the structure, plumbing and aligning the structure, and making the finished connections between members

Fall Distance - free "fall distance" exclusive of lanyard elongation

Flange - in rolled shapes, that part perpendicular to the web

Flashing - sheets of tin, copper, or other material placed over the juncture of other pieces to prevent leaking and provide a finished look

Girder - a word commonly used to describe any extra heavy beam; a beam acting as a main structural member and supporting other intermediate beams, receiving the major part of its load from the smaller beam it supports

Guy Line - a line that steadies a mast or structure by pulling against an off-center load

High Roof Structure - a roof structure being constructed more than 25 feet above a solid surface with no intervening floors

Hollow Core Product - a prestressed concrete product which is dry cast in such a way that voids resembling pipes are left inside the member; used as decking, typically 4 feet wide

I beam - a rolled structural shape which has the cross sectional shape of the letter I

Jig - a device used to maintain mechanically the correct positional relationship between a piece of work and the tool or between parts of work during assembly

Joist - a horizontal member, wood or steel, used as a primary floor or roof framing member

Lanyard - a short length of flexible line or strap webbing which is used to secure a safety belt or body harness to a lifeline or to a fixed anchorage

Lifeline - a line from a fixed anchorage or between two fixed anchorages, independent of walking and working surfaces, to which a lanyard is secured

Load Bearing - term applied to an exterior wall supporting the roof and upper floors; also, interior walls with joists tied directly to them

Member - one part of a unit of a structure

Metal Deck - any of the various ribbed metal sheets used to floor or as roof decking

Pendant line - a line, usually attached to the top of a column, extending vertically along the length of a column to which a safety belt lanyard can be attached

Pipe Shore - a piece of steel pipe, which is usually adjustable in length, used to brace columns and precast/prestressed wall panels before they are permanently secured to a structure

Plumb - vertical; straight up and down

Point of Erection - that place where initial placement and connection of structural members occurs and where employees performing the initial connection are exposed within the swing radius of the member being erected

Precast - a concrete member that is poured and allowed to set up in a location other than in which it is used, then placed in position later

Prestressed Concrete Product - a concrete member manufactured by a process whereby a tendon is elongated, anchored while the concrete in the member is cast, and released when the concrete is strong enough to receive the stress from the tendon through bond

Purlin - horizontal structural members which directly support the roof of a structure

Raising Gang - a group of iron workers responsible for sorting, lifting, and attaching steel and/or precast/prestressed members to a structure

Rigging - an assortment of cables, chains, ropes, and other devices used to attach an object to the crane hook

Rope Grab (safety clamp) - a device, used to couple a body belt or lanyard to a dropline, which, upon impaction, will actuate to arrest a fall within a short distance

Safety Belt - conventionally used in a generic sense to describe all fall-arrest restraint systems and/or their components

Safety Line - a horizontal lifeline

Seat Lug - an inverted "L" shaped steel bracket attached to columns to allow a beam to be secured during double connection operations

Shackle - a device used in crane rigging consisting of a C-shaped metal piece with a pin closing across the open end

Sliver Bar - also known as a connecting bar; one end is pointed, the other has a 15^{0} chisel end used to provide leverage to align or pry steel

Snaphook - a self-closing hook with a keeper latch or similar arrangement which will automatically close and remain closed until manually opened

Span - the distance a bridge extends between two supports

Spreader Bar - a metal bar sometimes attached to the leading edge of a net section to allow the net to be pulled forward as a single unit

Spud Wrench - a wrench with one end which tapers to a point which is used to help align holes in structural steel

Tag Line - a rope attached to a member being lifted by a crane to allow the member to be maneuvered by men on the ground or another solid surface

Tee Product - a prestressed concrete member usually consisting of a deck 8 to 10 feet in width supported by one or more stems beneath the deck

Tiered Building - multi-story building

Toe Plate - a plate placed a few inches above the floor of a platform or catwalk and fastened to the hand rail posts

Truss - a framework placed together to form triangles; used in roofs and bridges

Web - the part of a channel, I beam, or girder between the flanges

FOOTNOTES

[1]International Association of Bridge, Structural and Ornamental Iron Workers, Structural Manual for Iron Workers (Washington, D.C.: International Association of Bridge, Structural and Ornamental Iron Workers, 1979), pp. 1-78.

[2]Letter from Tom A. Thomas, Jr., Thomas Concrete Products, to All PCI Members, Oklahoma City, Oklahoma, October 12, 1976.

[3]Letter from John A. Lishamer, Production Programs Manager, Prestressed Concrete Institute, to PCI Safety Committee, Chicago, Illinois, April 25, 1977.

[4]Interview with Robert E.P. Cooney, International Association of Bridge, Structural and Ornamental Iron Workers, Washington, D.C., March 24, 1981.

[5]Letter from John Mullins, Chairman NEA Safety Committee, to All NEA Active Erector Members, Arlington, Virginia, December 17, 1975.

[6]Interview with Steve Cooper, Institute for the Iron Working Industry, Washington, D.C., October 27, 1981.

[7]Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report - High-Rise Apartment Building, Bridgeport, Connecticut, Western Institute for Research and Education and National Institute for Occupational Safety and Health, Denver, Colorado, November, 1981, pp. 3-5.

[8]Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report - Bandag Warehouse, Chino, California, Western Institute for Research and Education and National Institute for Occupational Safety and Health, Denver, Colorado, November, 1981, pp. 1-5.

[9]Interview with officials from the National Erectors Association, Arlington, Virginia, December 2, 1981.

[10]Interview with Steve Cooper.

[11]Interview with Dennis O'Brien, Local Apprenticeship Coordinator, International Association of Bridge, Structural and Ornamental Iron Workers Joint Apprenticeship and Training Committee, Denver, Colorado, September 17, 1981.

[12]Accident Analysis Information For Various Types of Construction, Liberty Mutual Insurance Co., Loss Prevention Department, Boston, Massachusetts, 1975.

[13]Technical Guides, Employers Insurance of Wausau, Wausau, Wisconsin, 1973-1975.

[14]Letter from John Mullins.

[15]Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point Of Erection: Site Visit Report - Dravo Building, Pittsburgh, Pennsylvania, Western Institute for Research and Education and National Institute for Occupational Safety and Health, Denver, Colorado, November, 1981, p. 10.

[16]International Association of Bridge, Structural and Ornamental Iron Workers, Structural Manual for Iron Workers (Manual V - Vol. 2) (Washington, D.C.: International Association of Bridge, Structural and Ornamental Iron Workers, 1979), pp. 562-568.

[17]Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report - Shingle Creek Bridges, Southern Utah, Western Institute for Research and Education and National Institute for Occupational Safety and Health, Denver, Colorado, July, 1981, pp. 1-3.

[18]Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report - Steel Warehouse Building, Pearland, Texas, Western Institute for Research and Education and National Institute for Occupational Safety and Health, Denver, Colorado, November, 1981, pp. 1-9.

[19]Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report - Communication Tower, Idledale, Colorado, Western Institute for Research and Education and National Institute for Occupational Safety and Health, Denver, Colorado, November, 1981, pp. 1-7.

[20]Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report - Hershey Foods Corporation Plant, Stuarts Draft, Virginia, Western Institute for Research and Education and National Institute for Occupational Safety and Health, Denver, Colorado, June 1981, pp. 2-4.

[21]Secretary of Labor v. Skyline Crane Services, Inc., OSHRC Docket No. 80-1622 and 80-3694 (Consolidated) (1981).

[22]Ibid.

[23]Data Obtained from OSHA Office of Management Data Systems, Washington, D.C.

[24]Interview with officials from the Hartford Area OSHA Office, Hartford, Connecticut, September 29, 1981.

[25]Occupational Safety and Health Cases. (Vols. 1-7; Washington, D.C.: The Bureau of National Affairs, 1974-1980).

[26]B and B Insulation, Inc. v. OSAHRC and Marshall, 6 OSHC 2062 (1978).

[27]S and H Riggers and Erectors, Inc. v. OSAHRC and Standard Roofing and Sheet Metal, Inc. v. OSAHRC (5th Cir. 1981).

[28]Hoffman Construction Company, 2 OSHC 1523 (1975).

[29]H. B. Zachery (sic) Company, 3 OSHC 1705 (1975).

[30]Secretary of Labor v. Spancrete Northeast, Inc., OSHRC Docket No. 79-3431 and 79-4223 (1981).

[31]Brown and Root, Inc., 7 OSHC 2200 (1979) and Combustion Engineering, Inc., 7 OSHC 1675 (1979).

[32]Brown and Root, Inc., 5 OSHC 1538 (1977).

[33]S and H Riggers, 1981.

[34]C. F. Braun and Company, 7 OSHC 1139 (1978).

[35]Crawford Steel Construction Company, 4 OSHC 1891 (1976).

[36]Fishman and Sons, 7 OSHC 1699 (1979).

[37]Sec. of Labor v. Spancrete, 1981.

[38]Taylor Building Associates, 5 OSHC 1083 (1977).

[39]Cleveland Consolidated, Inc., 7 OSHC 1870 (1979).

[40]Sec. of Labor v. Skyline, 1981.

[41]Bristol Steel and Iron Works, Inc. v. OSAHRC, 7 OSHC 1462 (1979).

[42]Taylor Building Associates, 1977.

[43]Letter from Donald A Pittinger, Chief, Safety Engineering Team, Safety and Occupational Health Office of the U.S. Army Corps of Engineers, Washington, D.C., December 4, 1981.

[44]Site Visit Report - Shingle Creek Bridges, Southern Utah, p. 3.

[45]Analysis of Worker's Compensation Laws (Washington, D.C.: The Chamber of Commerce of the United States, 1981), p. 1.

[46]Ibid., p. viii.

[47]"OSHA Communique: OSHA's new inspection targeting plan," Occupational Hazards, 43, November, 1981, p. 31.

[48]International Association of Bridge, Structural and Ornamental Iron Workers, Agreement Between International Association of Bridge, Structural and Ornamental Iron Workers Local No. 424, New Haven, Connecticut; Local No. 15, Hartford, Connecticut; and Labor Relations Division, The Associated General Contractors of Connecticut, Inc. - June 30, 1980-June 24, 1983 (Connecticut, 1980), p. 16.

[49]Interview with John Sullivan, Union Business Agent, International Association of Bridge, Structural and Ornamental Iron Workers, Local #424, New Haven, Connecticut, September 29, 1981.

[50]Ibid.

[51]Interviews with various OSHA and Iron Workers officials.

[52]Interview with officials from the Safety and Occupational Health Office of the Army Corps of Engineers.

[53]British Standards Institute, Code of Practice for Use of Safety Nets on Construction Works (CP 93) (1972).

[54]Best's Safety Directory (Oldwick, New Jersey: A. M. Best Company, 1981).

[55]Ontario, Canada, The Occupational Health and Safety Act, 1978 and Regulations for Construction Projects (1978), Part II, p. 78.

[56]Harold L. Steinberg, A Study of Personal Fall - Safety Equipment (Washington, D.C.: U. S. Department of Commerce, National Bureau of Standards, June, 1977), p. 21.

[57]Occupational Safety and Health Reporter, Reference File 1 (Construction Safety Standards) (Washington, D.C.: The Bureau of National Affairs, 1979), p. 31: 3119.

[58]Steinberg, p. 20.

[59]Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report - Natural Draft Cooling Tower, Newark, Arkansas, Western Institute for Research and Education and National Institute for Occupational Safety and Health, Denver, Colorado, November, 1981, p. 7.

[60]Site Visit Report - Hershey Foods Corporation Plant, Stuarts Draft, Virginia, p. 5.

[61]Site Visit Report - Shingle Creek Bridges, Southern Utah, p. 3.

[62]Site Visit Report - Dravo Building, Pittsburgh, Pennsylvania, p. 3.

[63]Best's Safety Directory, 1981.

[64]Site Visit Report - Natural Draft Cooling Tower, Newark, Arkansas, p. 6.

[65]Ibid., pp. 7-8, 10-11.

[66]Interview with Tony Fuschillo, Compliance Officer, Hartford Area OSHA Office, Hartford, Connecticut, September 29, 1981.

[67]Site Visit Report - Dravo Building, Pittsburgh, Pennsylvania, p. 5.

[68]Site Visit Report - High-Rise Apartment Building, Bridgeport, Connecticut, p. 5.

[69]Ibid., p.11.

[70]Ibid., pp. 6-7.

[71]Ibid., p. 11.

[72]"Safety Net Result: Money Spent, Lives Saved," Engineering News Record, July 8, 1976, p. 21.

[73]SINCO Products Incorporated, The Fall-Protection Handbook (East Hampton, Connecticut, 1980).

[74]Site Visit Report - Shingle Creek Bridges, Southern Utah, pp. 1-4.

[75]Ibid., p. 5.

[76]Site Visit Report - Dravo Building, Pittsburgh, Pennsylvania, p. 7.

[77]Site Visit Report - Hershey Foods Corporation Plant, Stuarts Draft, Virginia, p. 7.

[78]Interview with Dennis O'Brien.

[79]Site Visit Report - Natural Draft Cooling Tower, Newark, Arkansas, p. 16.

[80]Ibid, pp. 16-17.

[81]British Standards Institute, 1972.

BIBLIOGRAPHY

Accident Facts. 1980 ed. Chicago: National Safety Council, 1980.

Accident Facts. 1981 ed. Chicago: National Safety Council, 1981.

Accident Prevention Manual for Industrial Operations. 7th ed. Chicago: National Safety Council, 1974.

American National Standards Institute, Minimum Requirements for Safety Nets (A10.11-1976), New York, 1976.

American National Standards Institute, Requirements for Safety Belts, Harnesses, Lanyards, Lifelines, and Drop Lines for Construction and Industrial Use (A10.14-1975), New York, 1976.

American National Standards Institute, Safety Requirements for Steel Erection (A10.3-1976), New York, 1976.

Analysis of Workers' Compensation Laws. 1981 ed. Washington, D.C.: The Chamber of Commerce of the United States, 1981.

Appleton Area OSHA Office. Appleton, Wisconsin. Investigatory Record Regarding Edward Kraemer and Sons, Inc., June-July, 1979.

Atlanta Area OSHA Office. Atlanta, Georgia. Investigatory Record Regarding Capital Construction Co., August-October, 1980.

Atlanta Area OSHA Office. Atlanta, Georgia. Investigatory Record Regarding Carrie/Cavaness, November-December, 1980.

Atlanta Area OSHA Office. Atlanta, Georgia. Investigatory Record Regarding Heaton Erecting, Inc., July, 1980.

Bendix Corporation, OSHA Safety and Health Training Guidelines for Construction (PB-239 312), Cocoa Beach, Florida, 1972.

Best's Safety Directory. 20th ed. Oldwick, New Jersey: A.M. Best Company, 1980.

Best's Safety Directory. 21st ed. Oldwick, New Jersey: A.M. Best Company, 1981.

British Standards Institute, Code of Practice for Use of Safety Nets on Construction Works (CP 93), 1972.

California Division of Labor Statistics and Research. Work Injuries and Illnesses in California - Quarterly. Work Injuries and Illnesses-First Three Months, 1976 Falls From Elevation in Construction in California, Quarterly Statistical Summary, January-March 1976. San Francisco: California Division of Labor Statistics and Research, November, 1977.

California. Administrative Code, Title 8 - Industrial Relations (1980).

Cooney, Robert E.P. International Association of Bridge, Structural and Ornamental Iron Workers, Washington, D.C. Interview, March 24, 1981.

Cooper, Steve. Institute for the Iron Working Industry, Washington, D.C. Interview, October 27, 1981.

Department of Health and Human Services, Public Health Office, Center for Disease Control, National Institute for Occupational Safety and Health, Contract #210-81-3008. Rockville, Maryland, January 28, 1981.

Dickie, D.E. (ed.). Crane Handbook. Toronto: Construction Safety Association of Ontario, October, 1975.

Dickie, D.E. (ed.). Rigging Manual. Toronto: Construction Safety Association of Ontario, October, 1975.

Dickie, D.E. Manager, Research and Development Department of the Construction Safety Association of Ontario. Toronto, Ontario, May 6, 1981.

Employer's Insurance of Wausau. Wausau, Wisconsin. Technical Guides, 1973-1975.

Fuschillo, Tony. Compliance Officer, Hartford Area OSHA Office, Hartford, Connecticut. Interview, September 29, 1981.

Hartford Area OSHA Office Officials. Hartford Area Office, Hartford, Connecticut. Interview, September 29, 1981.

International Association of Bridge, Structural and Ornamental Iron Workers. Agreement Between International Association of Bridge, Structural and Ornamental Iron Workers Local No. 424, New Haven, Connecticut; Local No. 15, Hartford, Connecticut; and Labor Relations Division, The Associated General Contractors of Connecticut, Inc. - June 30, 1980-June 24, 1983, Connecticut, 1980.

International Association of Bridge, Structural and Ornamental Iron Workers. Orientation Manual for Iron Workers. Washington, D.C.: International Association of Bridge, Structural and Ornamental Iron Workers, 1974.

International Association of Bridge, Structural and Ornamental Iron Workers. Rigging Manual for Iron Workers (Manual III). Washington, D.C.: International Association of Bridge, Structural and Ornamental Iron Workers, 1976.

International Association of Bridge, Structural and Ornamental Iron Workers. Safety Manual for Iron Workers, Journeymen, and Apprentices (Manual IV). Washington D.C.: International Association of Bridge, Structural and Ornamental Iron Workers, 1975.

International Association of Bridge, Structural and Ornamental Iron Workers. Structural Manual for Iron Workers (Manual V-Vol. 1). Washington, D.C.: International Association of Bridge, Structural and Ornamental Iron Workers, 1979.

International Association of Bridge, Structural and Ornamental Iron Workers. Structural Manual for Iron Workers (Manual V-Vol. 2). Washington, D.C.: International Association of Bridge, Structural and Ornamental Iron Workers, 1979.

International Association of Bridge, Structural and Ornamental Iron Workers. Workbook-Structural Manual for Iron Workers. Washington, D.C.: International Association of Bridge, Structural and Ornamental Iron Workers, 1979.

Knab, Lawrence I., "Numerical Aid to Reduce Construction Injury Losses," Journal of the Construction Division (ASCE), 104, December, 1978, pp. 437-445.

Knab, Lawrence I. and Sadoff, Captain Lawrence. Development of Loss Prevention Guide to More Effectively Reduce Construction Injury Loss. Report for ILIR Project #A91D-04-045, August, 1976.

Liberty Mutual Insurance Company, Loss Prevention Department. Boston, Massachusetts. Accident Analysis Information for Various Types of Construction, 1975.

Lishamar, John A. Production Programs Manager, Prestressed Concrete Institute to PCI Safety Committee. Chicago, Illinois, April 25, 1977.

Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products. Chicago: Prestressed Concrete Institute, 1980.

Mine Safety Appliances Company, Industrial Belts and Harnesses (Bulletin No. 1302-15), Pittsburgh.

Mobile Area Office. Mobile, Alabama. Investigatory Record Regarding Brown and Root, Inc., August 20, 1980.

Mullins, John. Chairman National Erectors Association Safety Committee to All NEA Active Erector Members. Arlington, Virginia, December 17, 1975.

National Erectors Association Officials. National Erectors Association, Arlington, Virginia. Interview, December 2, 1981.

National Safety Council, Lift-Slab Concrete Construction (Data Sheet 514), Chicago, 1974.

National Safety Council, Safety Nets for Construction Projects (Data Sheet 608), Chicago, 1974.

National Safety Council, Tilt-Up Concrete Construction (Data Sheet I-513-78), Chicago, 1978.

O'Brien, Dennis. Local Apprenticeship Coordinator, International Association of Bridge, Structural and Ornamental Iron Workers, Joint Apprenticeship and Training Committee, Denver, Colorado. Interview September 17, 1981.

Occupational Safety and Health Cases. Vol. 1. Washington, D.C.: The Bureau of National Affairs, 1974.

Occupational Safety and Health Cases. Vol. 2. Washington, D.C.: The Bureau of National Affairs, 1975.

Occupational Safety and Health Cases. Vol. 3. Washington, D.C.: The Bureau of National Affairs, 1976.

Occupational Safety and Health Cases. Vol. 4. Washington, D.C.: The Bureau of National Affairs, 1977.

Occupational Safety and Health Cases. Vol. 5. Washington, D.C.: The Bureau of National Affairs, 1978.

Occupational Safety and Health Cases. Vol. 6. Washington, D.C.: The Bureau of National Affairs, 1979.

Occupational Safety and Health Cases. Vol. 7. Washington, D.C.: The Bureau of National Affairs, 1980.

Occupational Safety and Health Reporter, Reference File 1. Washington, D.C.: The Bureau of National Affairs, 1979.

Ontario, Canada. The Occupational Health and Safety Act, 1978 and Regulations for Construction Projects (1978).

"OSHA Communique: OSHA's new inspection targeting plan," Occupational Hazards, 43, November, 1981, p. 31.

PCI Design Handbook: Precast and Prestressed Concrete. Chicago: Prestressed Concrete Institute, 1971.

PCI Safety Committee. PCI Safety and Loss Prevention Manual. Chicago: Prestressed Concrete Institute, 1976.

Peter Barnard Consulting Engineer Limited. Injuries in the Erection Industry. Toronto: Construction Safety Association of Ontario, April 28, 1970.

Petersen, Dan. Techniques of Safety Management. New York: McGraw-Hill Book Company, 1971.

Pittinger, Donald A. Chief, Safety Engineering Team, Safety and Occupational Health Office of the U.S. Army Corps of Engineers. Washington, D.C., December 4, 1981.

Prestressed Concrete Institute, PCI Variance Request, Chicago, 1977.

S and H Riggers and Erectors, Inc. v. OSAHRC and Standard Roofing and Sheet Metal, Inc. v. OSAHRC, U.S. Court of Appeals Fifth Circuit Docket Nos. 79-2358, 79-3319, and 80-7297 (October, 26, 1981).

"Safety Net Result: Money Spent, Lives Saved." Engineering News Record, July 8, 1976, pp. 16-21.

Secretary of Labor v. Skyline Crane Services, Inc., OSHRC Docket No. 80-1622 and 80-3694 (1981).

Secretary of Labor v. Spancrete Northeast, Inc., OSHRC Docket No. 79-3431 and 79-4223 (1981).

Shipley, Karl L. "Protection System Prevents Falls From Metal Roof Decks," National Safety Council Construction Newsletter, May-June, 1981, p. 5.

SINCO Products Incorporated, The Fall-Protection Handbook, 3rd ed., East Hampton, Connecticut, 1980.

Steinberg, Harold L. A Study of Personal Fall-Safety Equipment. Washington, D.C.: U.S. Department of Commerce, National Bureau of Standards, June, 1977.

Sullivan, John. Union Business Agent, International Association of Bridge, Structural and Ornamental Iron Workers, Local #424, New Haven, Connecticut. Interview, September 29, 1981.

Thomas, Tom A., Jr. Thomas Concrete Products to All PCI Members. Oklahoma City, Oklahoma, October 12, 1976.

U.S. Army Corps of Engineers. Safety and Health Requirements Manual. Washington, D.C.: U.S. Government Printing Office, April, 1981.

"Was Fall Protection Feasible?" Occupational Hazards, 43, January, 1981, pp. 45-46.

Western Institute for Research and Education and National Institute for Occupational Safety and Health. Denver, Colorado. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report—Bandag Warehouse, Chino, California, November, 1981.

Western Institute for Research and Education and National Institute for Occupational Safety and Health. Denver, Colorado. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report—Communication Tower, Idledale, Colorado, November, 1981.

Western Institute for Research and Education and National Institute for Occupational Safety and Health. Denver, Colorado. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report—Condominium Structure, Copper Mountain, Colorado, November, 1981.

Western Institute for Research and Education and National Institute for Occupational Safety and Health. Denver, Colorado. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report—Dravo Building, Pittsburgh, Pennsylvania, November, 1981.

Western Institute for Research and Education and National Institute for Occupational Safety and Health. Denver, Colorado. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report—Hershey Foods Corporation Plant, Stuarts Draft, Virginia, June, 1981.

Western Institute for Research and Education and National Institute for Occupational Safety and Health. Denver, Colorado. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report—High-Rise Apartment Building, Bridgeport, Connecticut, November, 1981.

Western Institute for Research and Education and National Institute for Occupational Safety and Health. Denver, Colorado. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report—Natural Draft Cooling Tower, Newark, Arkansas, November, 1981.

Western Institute for Research and Education and National Institute for Occupational Safety and Health. Denver, Colorado. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report—Shingle Creek Bridges, Southern Utah, July, 1981.

Western Institute for Research and Education and National Institute for Occupational Safety and Health. Denver, Colorado. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection: Site Visit Report—Steel Warehouse Building, Pearland, Texas, November, 1981.

APPENDIX A - TEXT OF SUBJECT OSHA STANDARDS*

General Construction Standards

- 29 CFR 1926.21 (b)(2) Safety training and education-employer responsibility:

  The employer shall instruct each employee in the recognition and avoidance of unsafe conditions and the regulations applicable to his work environment to control or eliminate any hazards or other exposure to illness or injury.

- 29 CFR 1926.28(a) Personal protective equipment:

  The employer is responsible for requiring the wearing of appropriate personal protective equipment in all operations where there is an exposure to hazardous conditions or where this part indicates the need for using such equipment to reduce the hazards to the employees.

- 29 CFR 1926.104 Safety belts, lifelines and lanyards:

  (a) Lifelines, safety belts, and lanyards shall be used only for employee safeguarding. Any lifeline, safety belt, or lanyard actually subjected to inservice loading, as distinguished from static load testing, shall be immediately removed from service and shall not be used again for employee safeguarding.
  (b) Lifelines shall be secured above the point of operation to an anchorage or structural member capable of supporting a minimum dead weight of 5,400 pounds.
  (c) Lifelines used on rock-scaling operations, or in areas where the lifeline may be subjected to cutting or abrasion, shall be a minimum of 7/8-inch wire core manila rope. For all other lifeline applications, a minimum of 3/4-inch manila or equivalent, with a minimum breaking strength of 5,400 pounds, shall be used.
  (d) Safety belt lanyard shall be a minimum of 1/2-inch nylon, or equivalent, with a maximum length to provide for a fall of no greater than 6 feet. The rope shall have a nominal breaking strength of 5,400 pounds.
  (e) All safety belt and lanyard hardware shall be drop forged or pressed steel, cadmium plated in accordance with type 1, Class B plating specified in Federal Specification QQ-P-416. Surface shall be smooth and free of sharp edges.

- 29 CFR 1926.105 Safety Nets:

  (a) Safety nets shall be provided when workplaces are more than 25 feet above the ground or water surface, or other surfaces where the use of ladders, scaffolds, catch platforms, temporary floors, safety lines, or safety belts is impractical.
  (b) Where safety net protection is required by this part, operations shall not be undertaken until the net is in place and has been tested.
  (c)(1) Nets shall extend 8 feet beyond the edge of the work surface where employees are exposed and shall be installed as close under the work surface as practical but in no case more than 25 feet below such work surface. Nets shall be hung with sufficient clearance to prevent user's contact with the surfaces or structures below. Such clearances shall be determined by impact load testing.
  (2) It is intended that only one level of nets be required for bridge construction.
  (d)The mesh size of nets shall not exceed 6 inches by 6 inches. All new nets shall meet accepted performance standards of 17,500 foot-pounds minimum impact resistance as determined and certified by the manufacturers, and shall bear a label of proof test. Edge ropes shall provide a minimum breaking strength of 5,000 pounds.
  (e) Forged steel safety hooks or shackles shall be used to fasten the net to its supports.
  (f) Connections between net panels shall develop the full strength of the net.

Steel Erection Standards

- 29 CFR 1926.750 (b)(i)(ii) Temporary flooring skeleton steel construction in tiered buildings - requiring nets:

  On buildings or structures not adaptable to temporary floors, and where scaffolds are not used, safety nets shall be installed and maintained whenever the potential fall distance exceeds two stories or 25 feet. The nets shall be hung with sufficient clearance to prevent contacts with the surface of structures below.

*Source - Occupational Safety and Health Reporter (Reference File 1), Washington, D.C.: The Bureau of National Affairs, 1979.

APPENDIX B - REVIEW OF CONNECTOR FALL CASES

FATALITY CASES

Case 1:
Edward Kraemer and Sons, Inc.
Bridge erection project
Green Bay, Wisconsin

Inspection Dates: June 26, 1979 to July 10, 1979

Standard Cited: 29 CFR 1926.105(a)

The employee was working approximately 120 feet from the ground on a steel bridge. He was standing on a plank connecting a 3 by 3-inch angle iron, 8 feet 8½ inches long, with a C-clamp to form a cross brace. The employee was not protected by either a tied off safety belt or a safety net. He fell to the ground.

Source: Investigatory Record Regarding Edward Kraemer and Sons, Inc., Appleton Area OSHA Office, Appleton, Wisconsin, June-July 1979.

Case 2:
Brown and Root, Inc.
Erection of a high roof in a cement plant
Houston, Texas

Inspection Dates: April 17, 1980 to April 18, 1980

Standard Cited: 29 CFR 1926.750(b)(1)

The accident occurred at 4:30 P.M. when workers were leaving the skeleton steel structure of a roof 89 feet from the ground. Witnesses reported that the man involved was seen "with his tool bag in one hand and safety belt disconnected." The man was walking along a beam toward a ladder where he would have descended to the floor. The man slipped and fell. No nets or catch platforms were in place below the beam.

Source: Investigatory Record Regarding Brown and Root, Inc., Mobile Area OSHA Office, Mobile, Alabama, August 20, 1980.

Case 3:
Capital Construction Company
Replacement of a roof structure
Atlanta, Georgia

Inspection Date: August 19, 1980

Standard Cited: 29 CFR 1926.105(d)

The company was in the process of replacing a wooden truss roof 60 feet over a railroad diesel shop. The workers were removing the roof and the wood trusses beneath, one bay at a time. The trusses were being replaced by a steel structure. Two men were in the process of removing one of the longitudinal stringers from the old wood structure. The worker in question went for a wrench while his partner went to arrange with the crane operator to remove the stringer. When the worker walked back to the opening he "stepped across the cap member of the old wooden truss to put his foot on the top of the new steel truss." The worker either slipped or lost his footing and fell into a net strung from the bottom of the truss structure approximately 6 feet below. He rebounded from the net, was thrown over the edge of the net and fell 83 feet to the floor.

Source: Investigatory Record Regarding Capital Construction Company, Atlanta Area OSHA Office, Atlanta, Georgia, August-October, 1980.

NON-FATALITY CASES

Case 1:
Carrie/Cavaness
Erection of an airline cargo building
Atlanta, Georgia

Inspection Date: November 30, 1979

The foremen involved were working on a single story structure approximately 25 feet from the ground installing and shaking out bar joists. Columns and beam lines had been erected, but there was no bracing of the structural steel framing in the area where the accident occurred. A 23 mph wind was blowing with sustained gusts of 31 mph. The structure fell in domino fashion from the northwest moving to the southeast. Four employees were carried down with the structure. Two of the men received minor injuries. The second two workers were hospitalized, one with a fractured vertebra and the other with fractured left ankle.

Source: Investigatory Record Regarding Carrie/Cavaness, Atlanta Area OSHA Office, Atlanta, Georgia, November-December, 1979.

It should be noted that 29 CFR 1926.751(c)(1) Structural Steel Assembly states: "In steel framing, where bar joists are utilized, and columns are not framed in at least two directions with structural steel members, a bar joist shall be field bolted at columns to provide lateral stability during construction."

Case 2:
Heaton Erecting Inc.
Skeleton steel erection site
Atlanta, Georgia

Inspection Dates: July 25, 1980 to July 31, 1980

Two connectors had just bolted a beam, 4 feet 6 inches long, in place. It did not fit properly. Each man thought that the other had put two bolts in his end of the beam. In reality only one bolt had been placed in each end. The sling was disconnected and the man stepped onto the beam. It rolled under his weight causing him to fall 22 feet to a concrete pier.

Source: Investigatory Record Regarding Heaton Erecting, Inc., Atlanta Area OSHA Office, Atlanta, Georgia, July, 1980.

It should be noted that 29 CFR 1926.751(a) Structural Steel Assembly states: "During the final placing of solid web structural members, the load shall not be released from the hoisting line until the members are secured with not less than two bolts, or the equivalent at each connection and drawn up wrench tight."

APPENDIX C - LOST TIME INJURIES FOR IRON WORKERS IN ONTARIO DURING 1979 and 1980

IRONWORKERS AND IRONWORKER APPRENTICES
1979 LOST TIME INJURIES *

A. Total number of lost time injuries in construction in the Province of Ontario -- 14,522.

B. 1,924 of these injuries involved falls to a different level.

C. 58 of the 1,924 injuries were sustained by ironworkers and ironworker apprentices.

D. 5 of these were connecting at the time of the accident (specific reports follow in point F).

E. The total number of ironworkers and ironworker apprentices injured in 1979 due to all causes -- 358.

F. Specific accidents (ironworkers connecting):

1. A 25 year old ironworker was doing steel erection work at a high-rise residential building. He was connecting a metal beam while standing on snow covered structural steel when he fell 10 feet. The worker sustained a sprained heel.

2. A 31 year old ironworker was doing steel erection work at a heavy industrial site. He was connecting a metal beam while standing on structural steel when he fell 10 feet. He sustained infection in his arm and leg.

3. A 35 year old ironworker was doing steel erection work at a light industrial site. He was connecting a metal beam while standing on structural steel when he fell 20 feet. He sustained a sprained back.

4. An ironworker was connecting a metal beam while standing on structural steel when he fell 10 feet. The worker injured his foot. He lost his footing while connecting.

5. A 28 year old ironworker was doing steel erection work at a light industrial site. He was connecting a metal beam while standing on wet structural steel. He was struck by a beam and then he fell 9 feet. He sustained a fractured hip and a fractured wrist.

* Source - Construction Safety Association of Ontario

IRONWORKERS AND IRONWORKER APPRENTICES
1980 LOST TIME INJURIES *

A. Total number of lost time injuries in construction in the Province of Ontario -- 14,441.

B. 1,759 of these injuries involved falls to a different level.

C. 54 of the 1,759 injuries were to ironworkers and ironworker apprentices.

D. 7 of these were connecting at the time of the accident (specific reports follow in point F).

E. The total number of ironworkers and ironworker apprentices injured in 1980 due to all causes -- 370.

F. Specific accidents (ironworkers connecting):

1. A 55 year old ironworker was doing steel erection work at a high-rise commercial building. He was connecting a metal beam while standing on structural steel when he fell 20 feet. He sustained a fractured back and a fractured rib.

2. A 28 year old ironworker was doing steel erection work at an industrial site. He was connecting a metal beam while standing on structural steel when he fell 15 feet. He sustained a fractured hip.

3. A 28 year old ironworker was doing steel erection work at a heavy industrial site. He was connecting structural steel while standing on a platform when he fell to a different level.

4. A 52 year old ironworker was doing steel erection work at a heavy industrial site. He was connecting a metal beam while standing on a ladder when he fell 9 feet. He sustained a fractured skull and various bruises on his body. The worker had lost his footing while connecting.

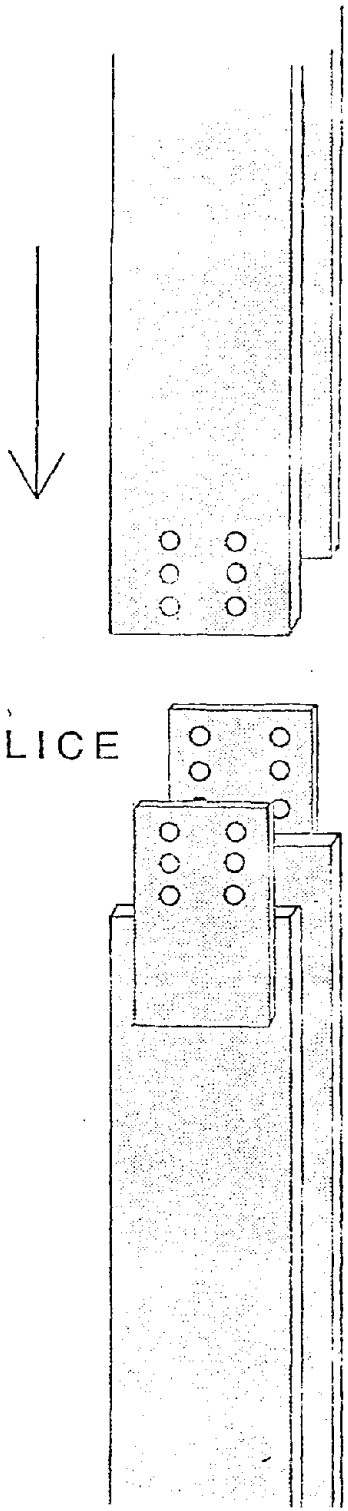
5. A 38 year old ironworker was doing steel erection work. He was connecting structural steel while standing on structural steel when he fell 16 feet. He sustained a fractured back and a fractured heel. The worker lost his footing while connecting.

6. A 41 year old ironworker was doing steel erection work at a low-rise commercial building. He was connecting a metal beam while standing on a ladder when he fell to a different level. He injured his ankle.

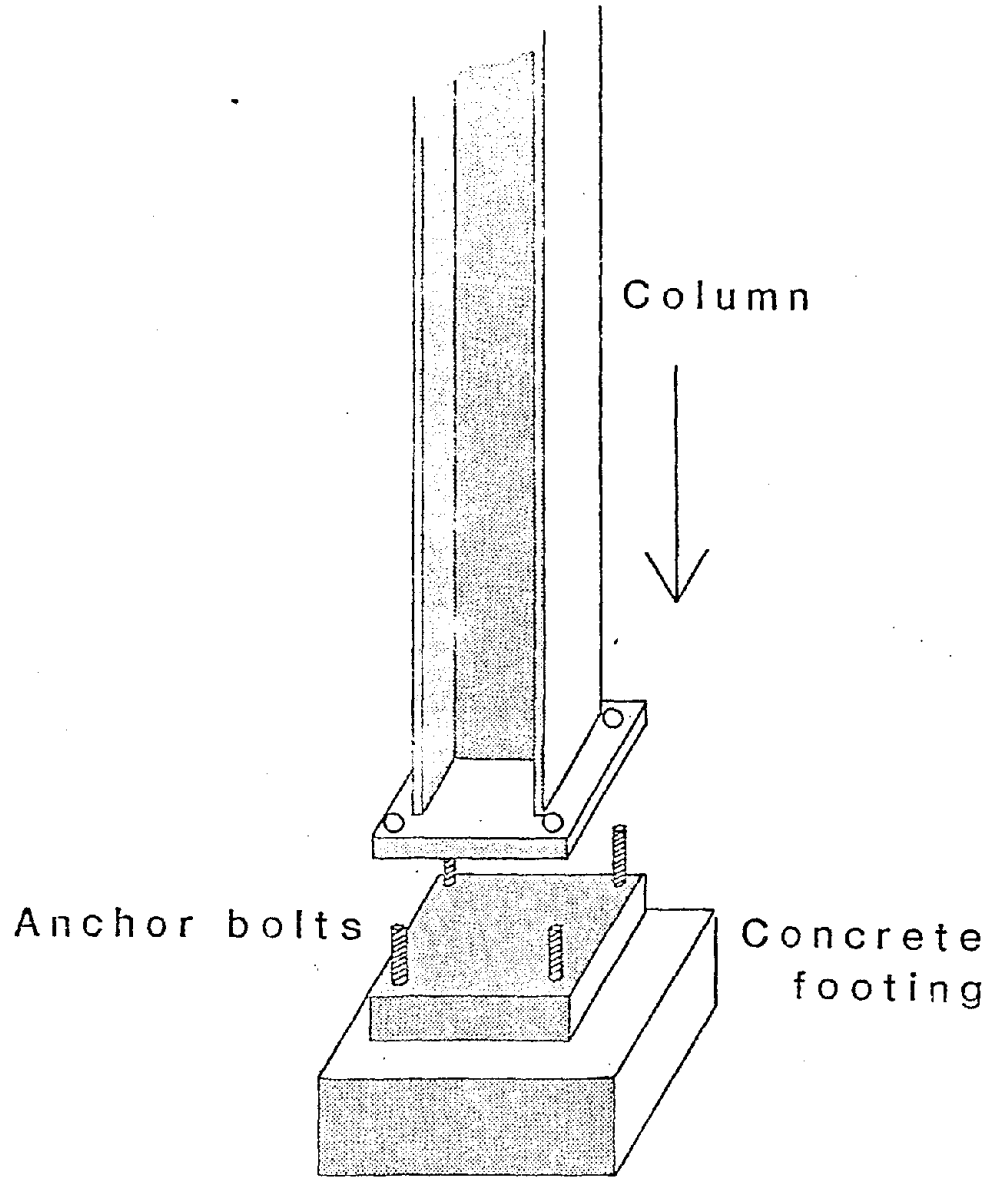
7. An ironworker was doing steel erection work at an institution. He was connecting a metal beam while standing on wet structural steel when he fell 11 feet. The worker sustained a fractured heel.

Source - Construction Safety Association of Ontario

APPENDIX D - TYPICAL STEEL CONNECTIONS



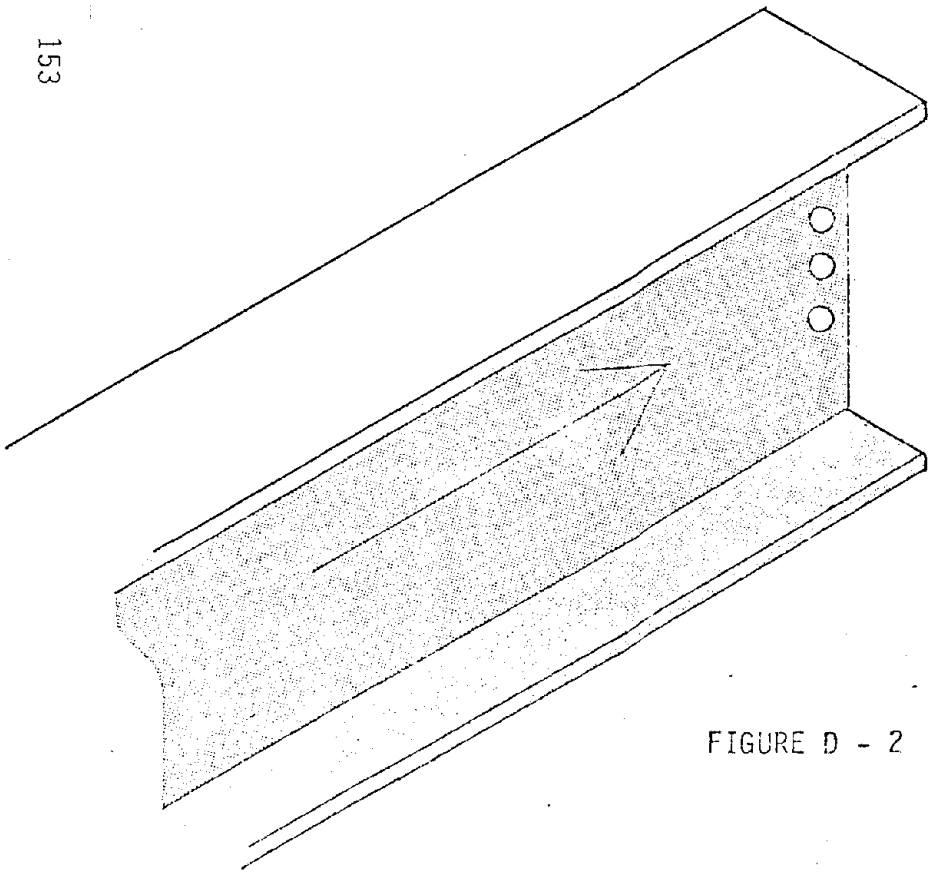
COLUMN SPLICE



GROUND LEVEL
COLUMN CONNECTION

FIGURE D - 1

COLUMN AND BEAM CONNECTION



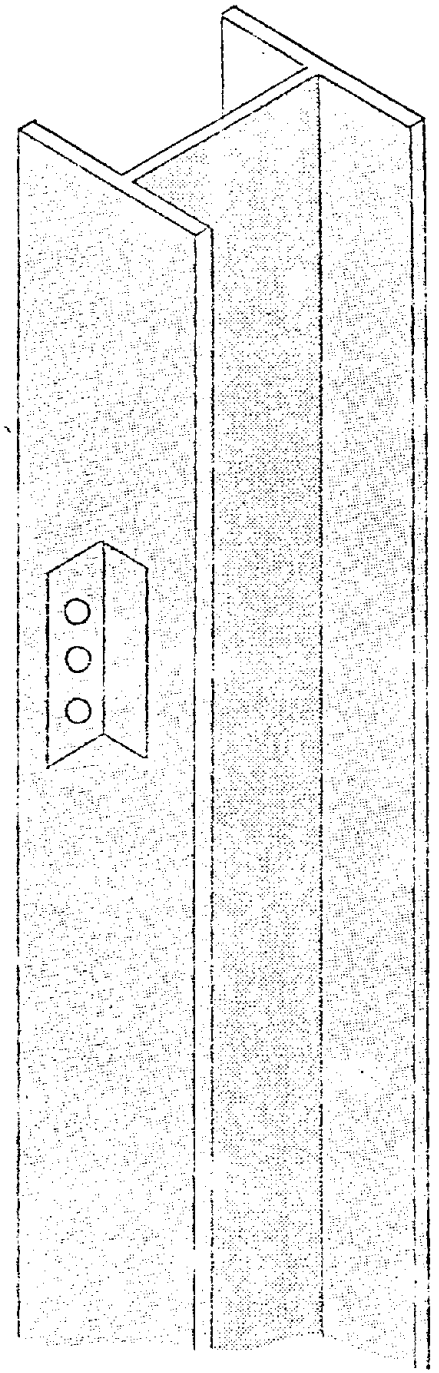
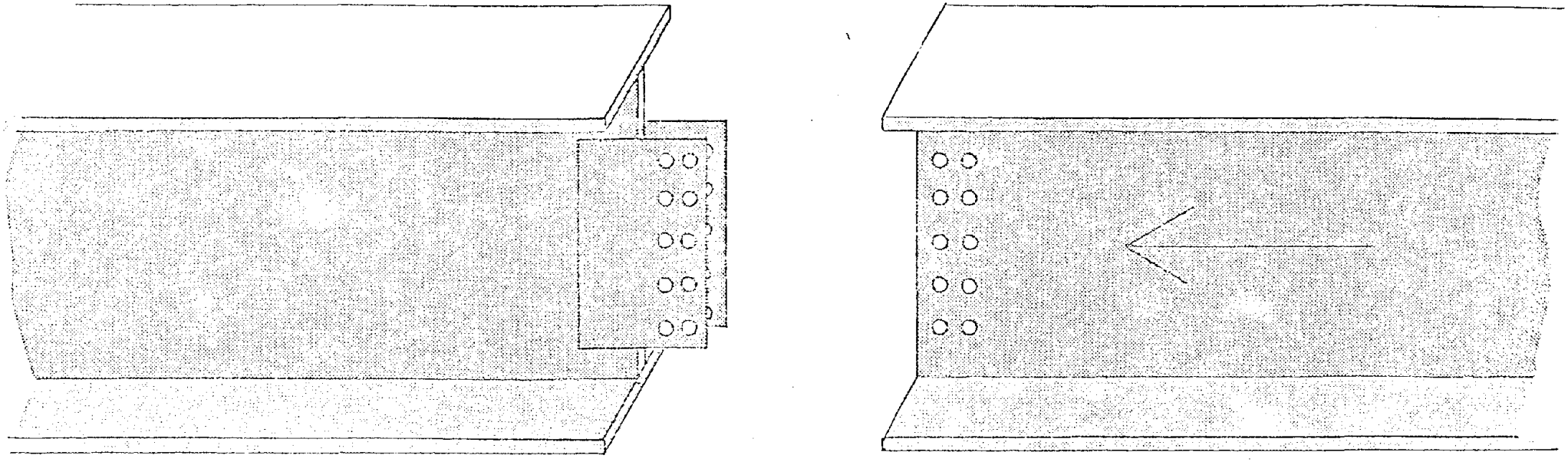


FIGURE D - 2



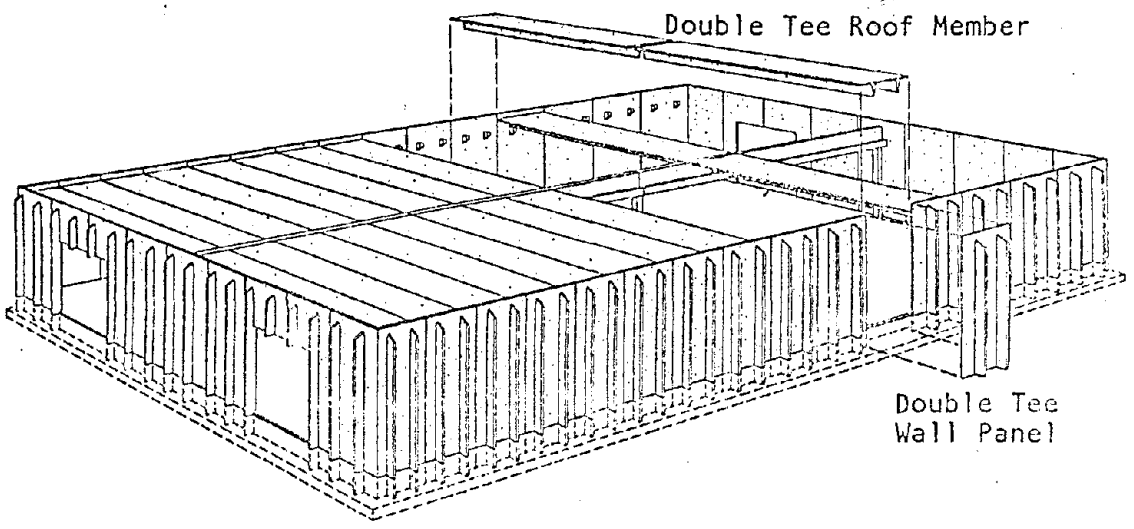
GIRDER SPLICE

FIGURE D - 3

APPENDIX E - VARIOUS PRECAST/PRESTRESSED CONCRETE PRODUCTS AND CONNECTION DETAILS*

Source - PCI Design Handbook: Precast and Prestressed Concrete. Chicago: Prestressed Concrete Institute, 1971.

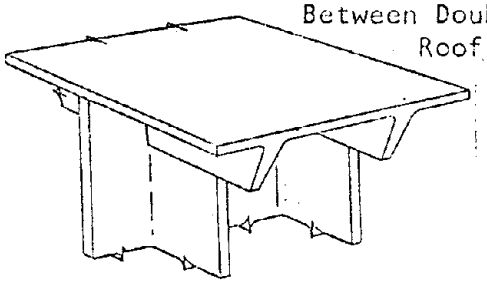
SINGLE STORY CONSTRUCTION
Wall Bearing



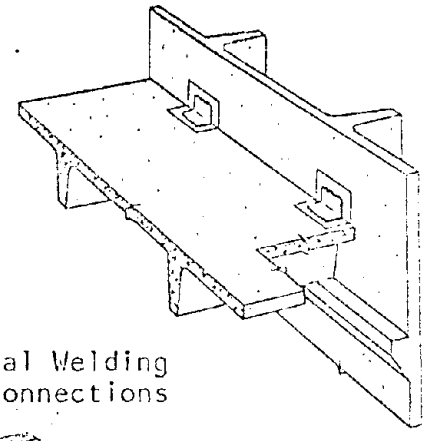
The use of precast prestressed concrete for bearing walls can provide economies by eliminating the need for a structural frame at the perimeter of a building. This economy is most apparent in buildings with a larger ratio of wall to floor area.

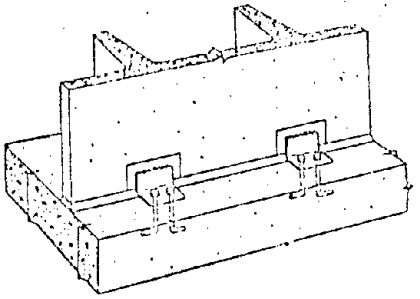
The connection between the roof framing member and the wall member can be handled by either bearing the roof member on a haunch cast into the back face of the panel, or by bearing directly on the top of the wall panel. The former method allows the wall panel to extend above the roof forming a parapet, and the latter method allows the roof members to project beyond the walls forming an overhang.

The wall panels themselves can be selected from a variety of standard sections or flat panels, and specially formed architectural precast shapes depending on the intended use, location, and budget for the building. Any of the standard precast deck units can be used for roofs of single-story buildings.



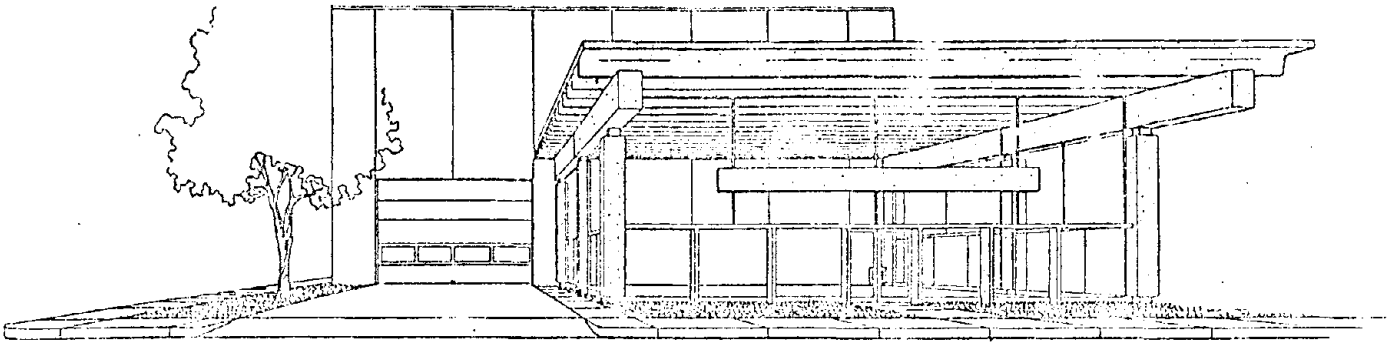
Typical Connection Between Double Tee Roof Member and Double Tee Wall Panel



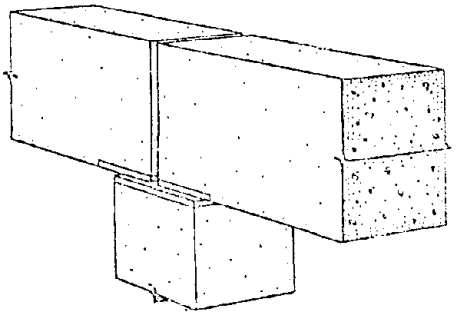


Typical Welding Connections

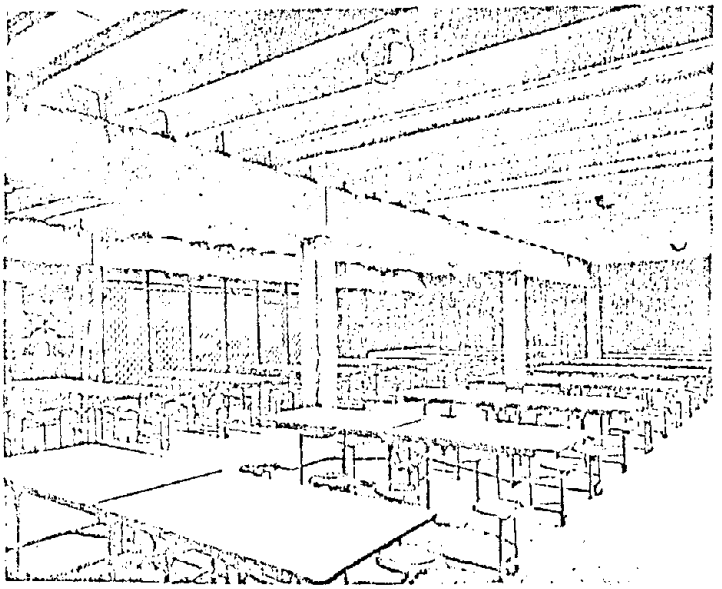
SINGLE STORY CONSTRUCTION
Beam-Column Framing



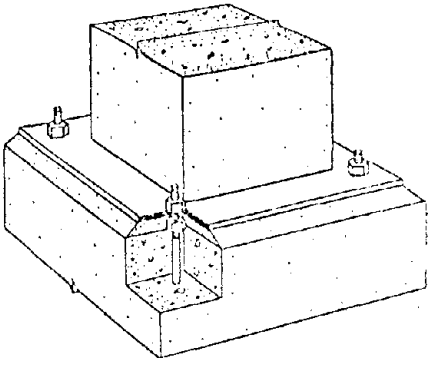
All of the standard precast beam and column shapes shown in Part 3 can be used for single story structures. Selection of the type of beam to be used depends on engineering considerations such as span length and superimposed loads, and architectural considerations such as depth and ceiling construction, if any. Details and design methods for connections are shown in Part 6.



Typical Column and Beam Connection

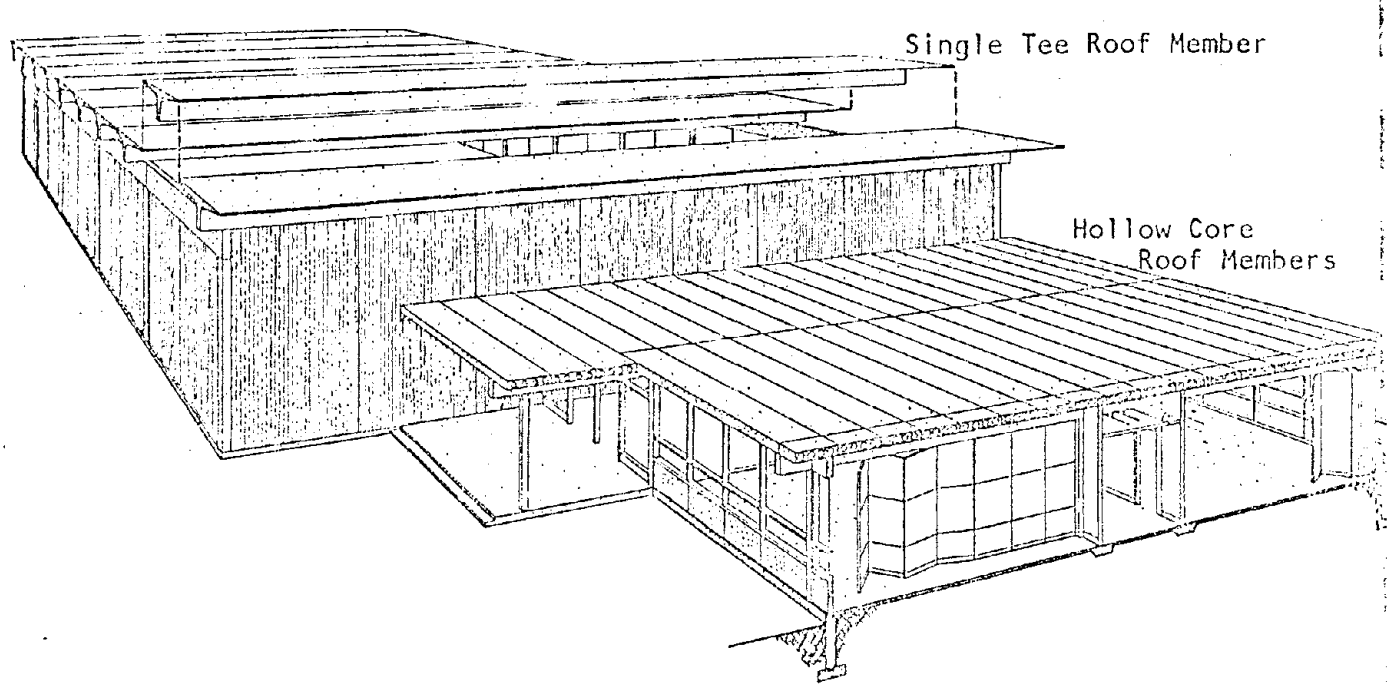


Design simplicity was achieved by supporting double tees on precast rectangular beams resting on square columns.

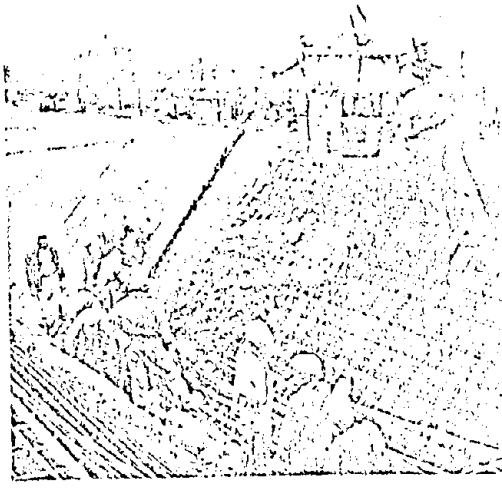


Typical Connection of Column to Concrete Footing

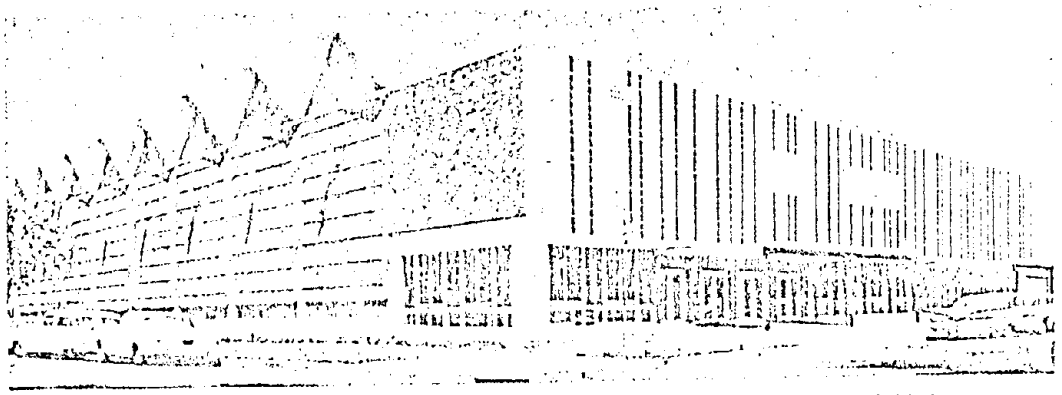
SINGLE STORY CONSTRUCTION
Long Span



Standard precast prestressed sections that will span 100 feet or more are available in most parts of the United States and Canada. Even longer spans can be achieved by combining post-tensioning with precast or cast-in-place concrete. Special consideration must be given to camber and deflection when designing structures of this type.



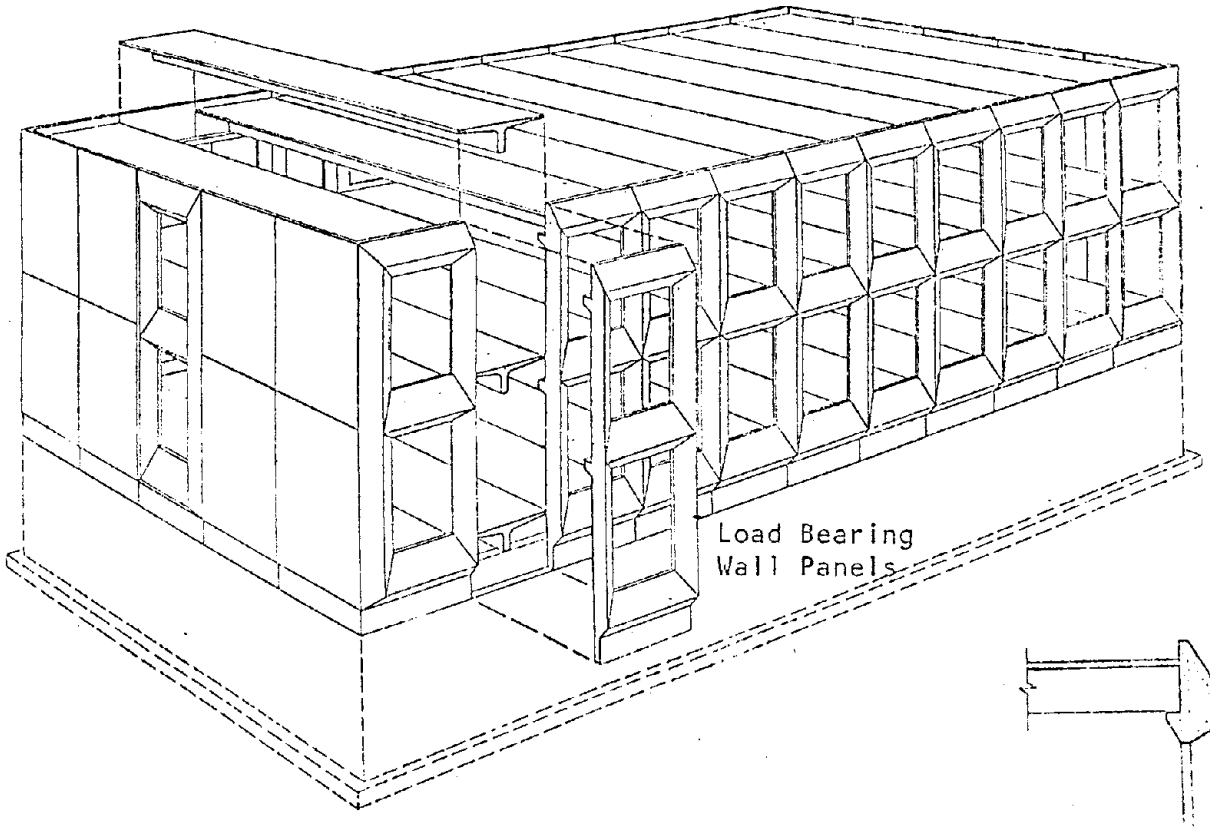
Casting concrete in a long span post-tensioned fol plate.



Long spans can be achieved by folded plate construction. These column-supported folded plates were cast-in-place and prestressed by post-tensioning.

MULTI-STORY CONSTRUCTION
Wall Bearing -Low Rise

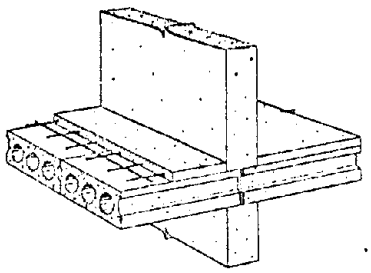
Single Tee
Roof Member



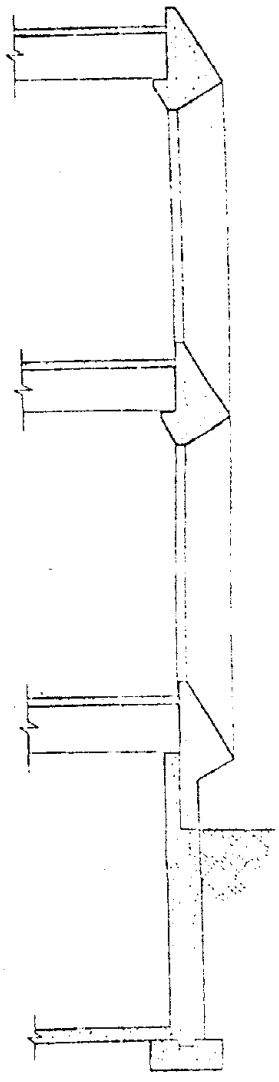
The use of precast concrete bearing walls can provide economies in the construction of multi-story structures. Precast bearing wall units can be cast in one to four-story high sections as shown in the accompanying sketches and photographs. The bearing wall units can rest directly on the basement wall or foundation.

In some cases, the bearing wall units will start at the second floor level with the first floor framed of precast beams and columns allowing a more open space on the first level.

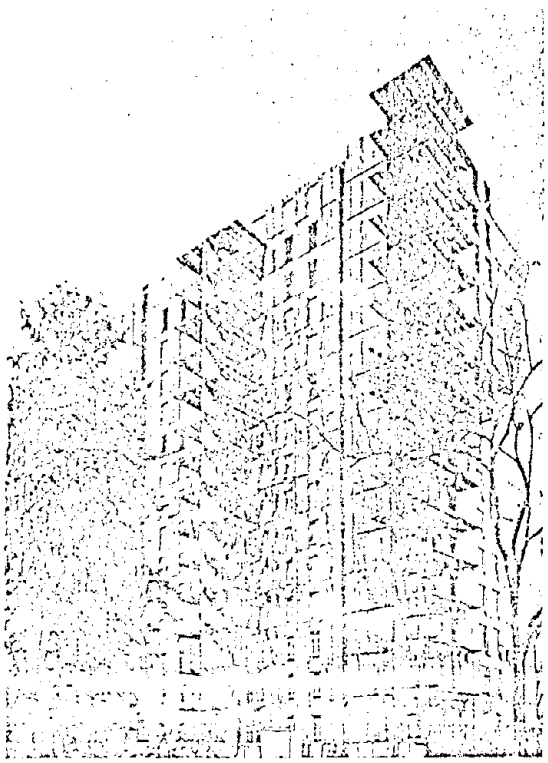
Bearing walls can be any of the standard sections (see Part 3) or can be provided in a variety of architectural shapes. Interior bearing walls, particularly in multi-family residential structures, are usually plain concrete panels cast either horizontally in fixed forms or on tilt tables, or cast vertically in battery molds.



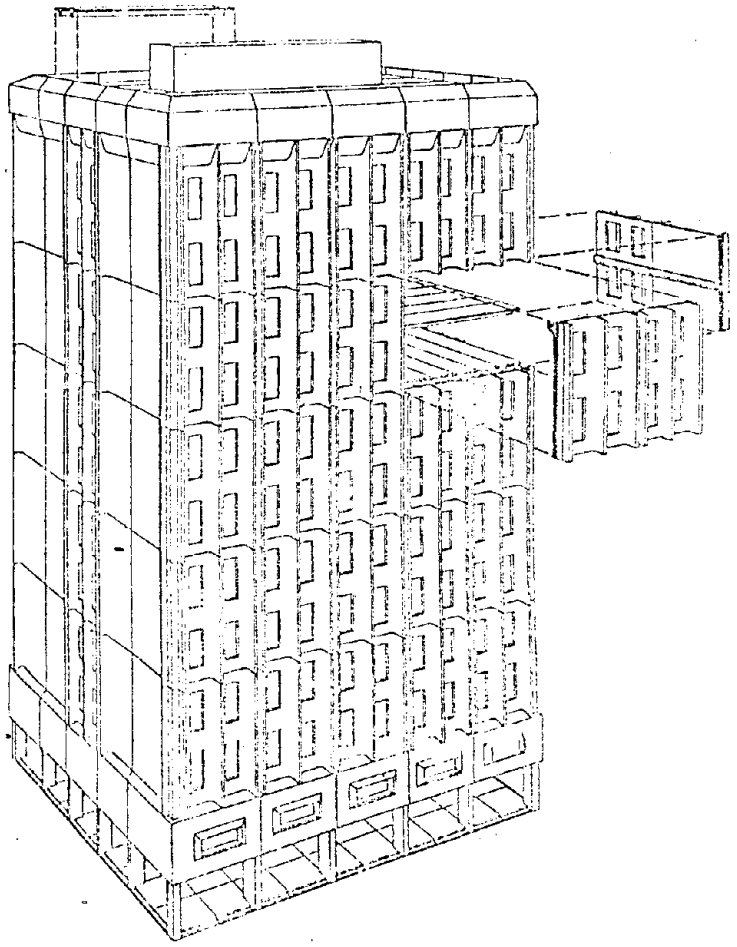
Interior bearing wall.



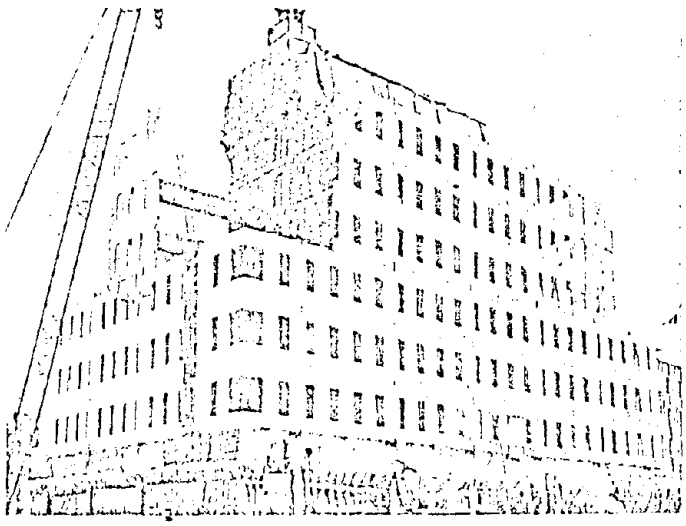
MULTI-STORY CONSTRUCTION
Wall Bearing - High Rise



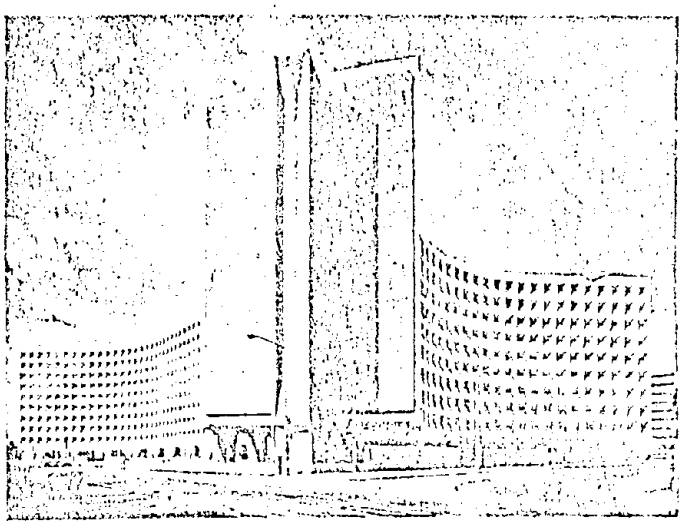
Single-story load bearing exterior walls support 8-ft double-tee floors which serve as diaphragms to distribute lateral loads to shear walls.



A variety of high-rise facades and floor layouts can be achieved with wall bearing construction. Here, perimeter walls and a central core support the floors and roof for column-free interior space.

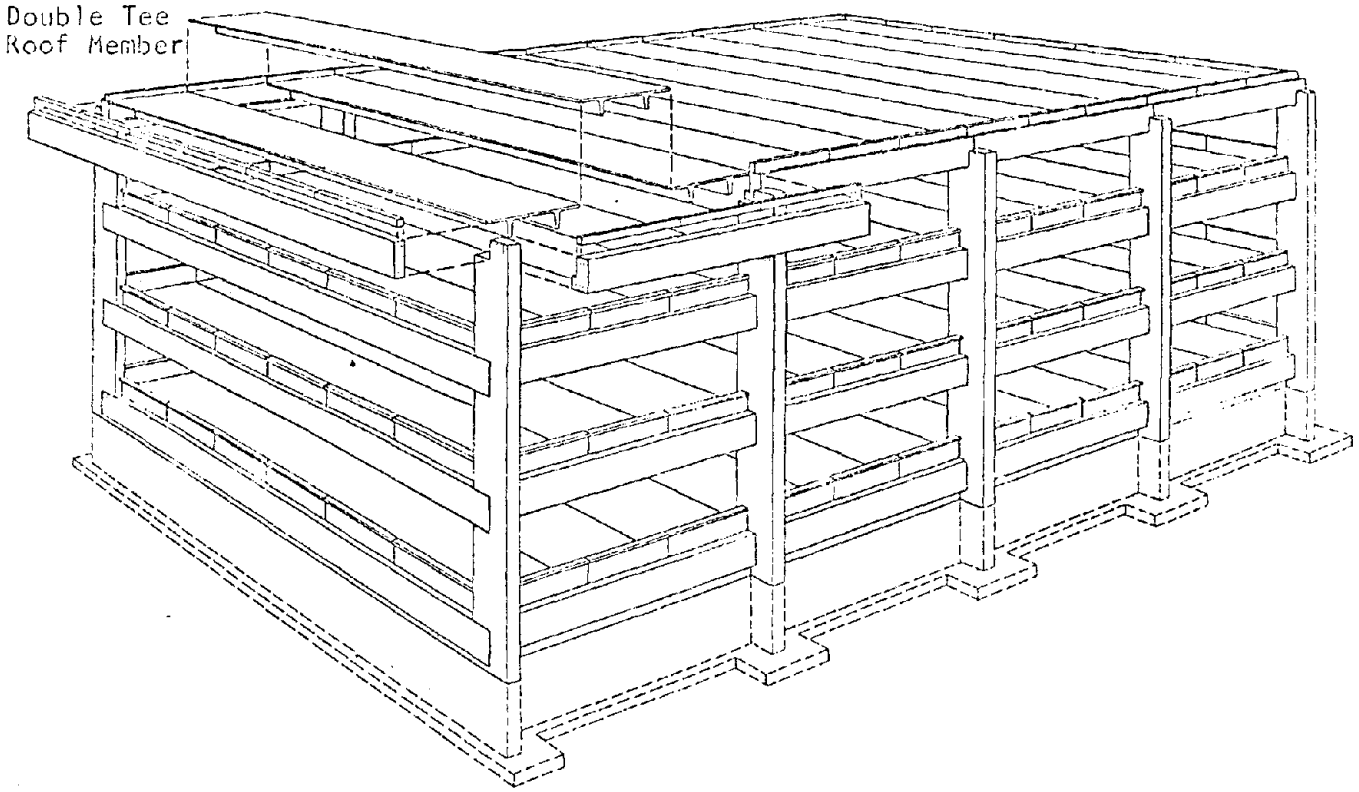


In this building three types of three-story wall panels support double-tee floors on corbels. Central core provides lateral stability for this column-free building.

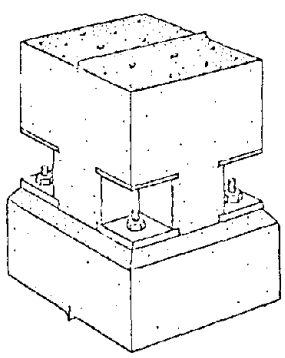


Single-story bearing wall units are stacked on a cast-in-place frame to form this 10-story curvilinear building. Double tees provide the floor system.

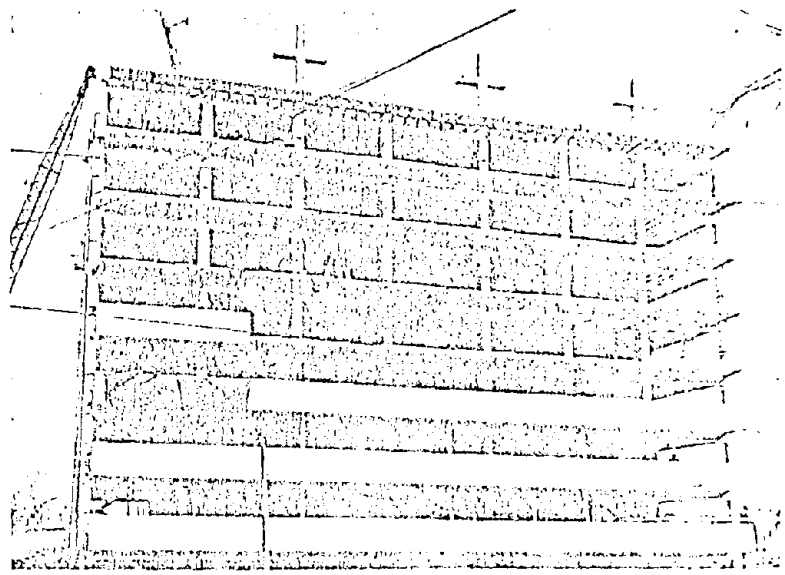
MULTI-STORY CONSTRUCTION
Beam-Column Framing



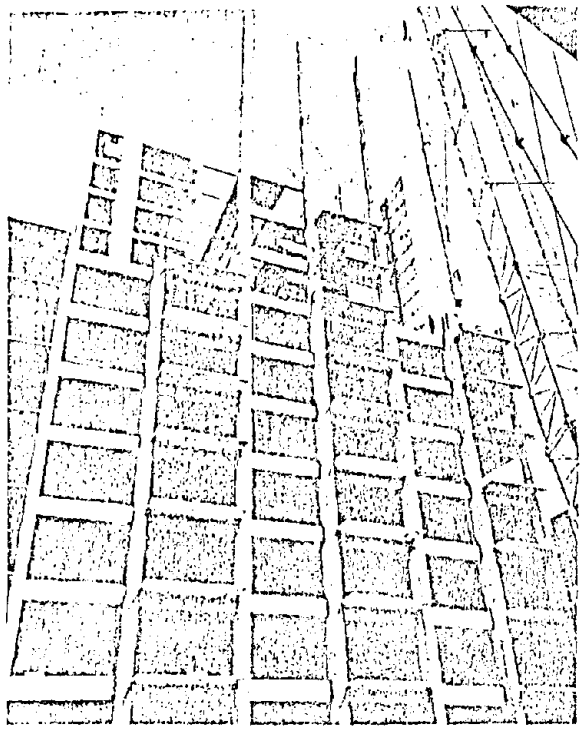
Precast prestressed beams and columns can be used for any type of low or high rise structure. In many buildings, the beams and columns become an architectural feature, and aesthetic consideration is given to the connection between the beams and columns. Architectural and engineering considerations dictate whether the beams are continuous with single story columns, or whether multi-story columns are used with single span beams. In some cases, so-called "tree columns" have been used so that the beam connection is made away from the column, usually about the quarter point or at mid-span. These "tree columns" have been cast in single-story or multi-story units.



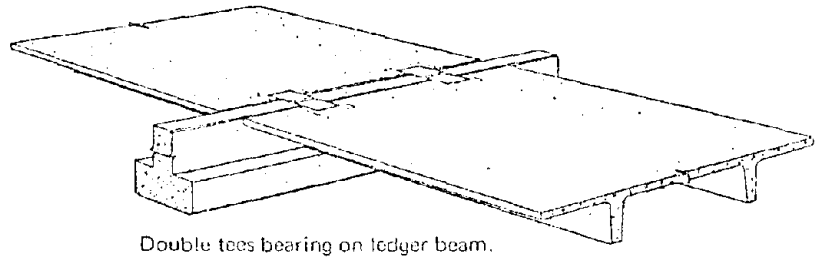
Multi-story column connection.



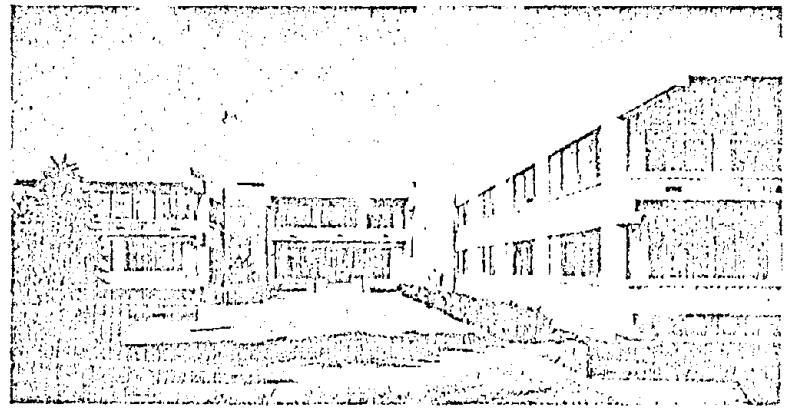
Two-story tree column sections with staggered butt joints were used to frame this multi-story precast concrete building.



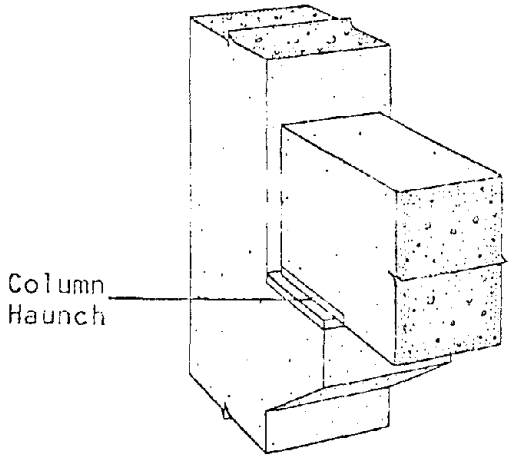
Columns were precast in two sections – the upper 7-story section connects with the lower 8-story section by means of 4-in. diameter dowels, 3 ft 6 in. long.



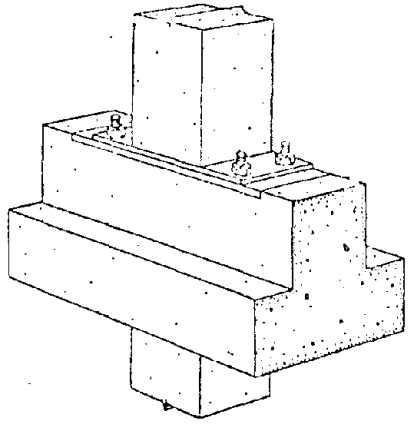
Double tees bearing on ledger beam.



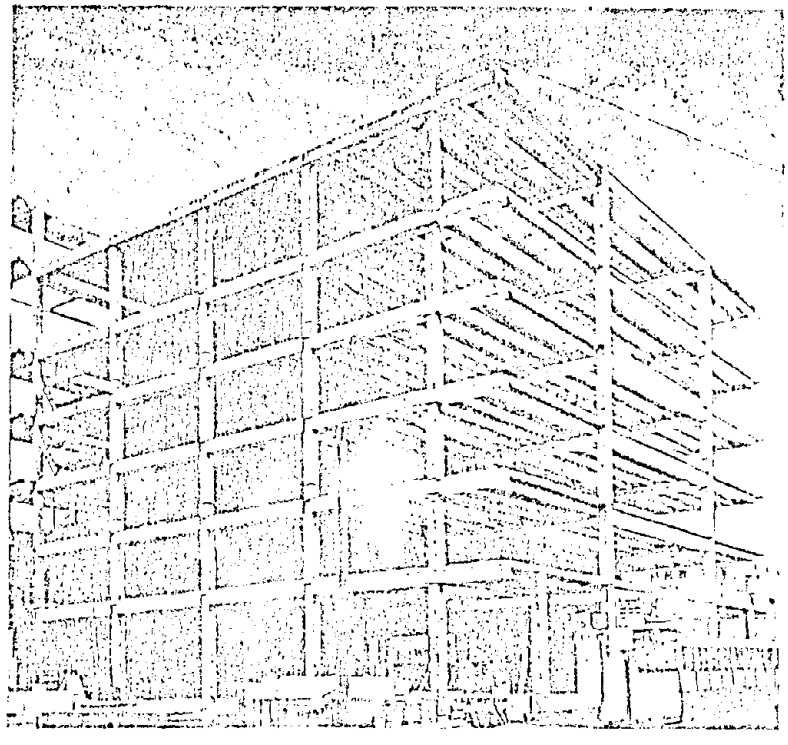
Ledger beams on two-story columns support prestressed concrete stemmed slabs.



Beam-column connection.



Continuous ledger beam with one-story columns.



Multi-story columns with simple ledger beams support double-tee floors and roof. One-story columns are used to accomodate the cantilever beams. Reinforcement in floor topping provides continuity.

APPENDIX F - REGION VIII LETTER OF CLARIFICATION

U.S. DEPARTMENT OF LABOR
OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION
ROOM 15010 – FEDERAL BUILDING
1961 STOUT STREET
DENVER, COLORADO 80202

837-3883
Area Code: 303

September 14, 1977

Steve Cooper
Stanley Structures
3 Park Central Building
Suite 440
1515 Arapahoe Street
Denver, Colorado 80202

Dear Mr. Cooper:

This will affirm telephone conversations between Mr. Al Klashak and members of my staff concerning installation of prestress concrete structural members.

Employees engaged in the initial placement and connection of prestress concrete members at elevated worksites are not required to be tied off. Other employees who might be working at elevated work stations and who are involved with prestress erection must be tied off, when required by 1926.28(a) and 1926.105(a), or be protected by perimeter protection as required by 1926.500.

Sincerely,

CURTIS A. FOSTER
Regional Administrator
for Occupational Safety and Health

APPENDIX G - TEXT OF APPLICABLE CALIFORNIA/OSHA STANDARDS*

Article 3. General. 1510. Safety Instructions for Employees.
(a) When a worker is first employed he shall be given instructions regarding the hazards and safety precautions applicable to the type of work in question and directed to read the Code of Safe Practices.

Article 24. Safety Belts and Nets.
1669. General. (a) When work is to be performed from thrustouts or similar exposed locations, suitable protection such as temporary guardrailings of wire or manila ropes, or equivalent, shall be provided, or workers shall be protected by safety belts with attached lifeline.

Note: Safety belts will customarily be used when exposed to the hazard of falling from buildings, bridges, structures, or construction members such as trusses, beams, purlins, or plates of 4-inch nominal width, or greater, at elevations exceeding 15 feet or 1 story above ground, water surface, or continuous floor level below.

(b) When requirements in (a) above are impractical, use shall be made of approved-type safety nets as provided in Section 1671.
(c) When the work is of short duration and limited exposure and the hazards involved in rigging and installing the safety devices required by this Article equals or exceeds the hazards involved in the actual construction, these provisions may be temporarily suspended, provided adequate risk control is recognized and maintained under immediate, competent supervision.

1670. Safety Belts and Lifelines. (a) Approved safety belts and lifelines shall be worn by those employees whose work exposes them to falling in excess of 15 feet from the perimeter of a structure or through shaftways and openings not otherwise adequately protected under the foregoing provisions of the Article. The anchor end of the lifeline shall be secured at a level not lower than the workman's waist, and at a horizontal distance not to exceed 6 feet, except where the waist level connection is not possible, connections at feet level may be permitted, provided that adequate risk control procedures are followed. Lifelines shall be secured to a substantial member of the structure or to securely rigged lines, using a positive-descent control device.

Note: The use of nylon rope is recommended.

(b) If worker's duties require horizontal movement, rigging shall be provided so that the attached lifeline will slide along with him.
Such rigging shall be provided for all suspended staging, outdoor advertising sign platforms, floats, and all other catwalks, or

walkways 15 feet or more above the ground or level beneath.
(c) Life lines (sic), safety belts, and safety lines shall be used only for employee safeguarding. Any life line (sic), safety belt, or safety line actually subjected to in-service loading, as distinguished from static load testing, shall be immediately removed from service and shall not be used again for employee safeguarding.

Note: For the purpose of this Subsection, "in-service loading" shall mean loading equivalent to that received in a drop test.

(d) Safety lines and life lines (sic) shall be capable of supporting a minimum dead weight of 5400 pounds.
(e) Life lines (sic) subject to excessive fraying or rock damage shall be protected and shall have a wire rope center. Seriously worn or damaged rope shall be promptly removed from service.
(f) All safety belt and life line (sic) hardware shall be drop-forged steel, or equivalent, with a corrosion resistant finish. Surfaces shall be smooth and free of sharp edges.
(g) All safety belt and life line (sic) hardware, except rivets, shall be capable of withstanding a tensile loading of 4,000 pounds without cracking, breaking, or taking a permanent deformation.

1671. Safety Nets. (a) Where the elevation is 25 feet or more above the ground, water surface, or continuous floor level below, and when the use of safety belts and lifelines or more conventional types of protection are clearly impractical, the exterior and/or interior perimeter of the structure shall be provided with an approved-type safety net extending at least 8 feet horizontally from such perimeter and being positioned at a distance not to exceed 10 feet vertically below where such hazards exist, or equivalent protection provided. Nets shall be hung with sufficient clearance to prevent user's contact with the surfaces or structures below. Such clearances shall be determined by impact load testing.
EXCEPTION: See Section 1710 (d), (e) and (f) for flooring requirements and nets for steel erection in tiered buildings and structures.
(b) Only one level of nets shall be required for bridge construction.
(c) The mesh size of nets shall not exceed 6 inches by 6 inches. All new nets shall meet accepted performance standards of 17,500 foot-pounds minimum impact resistance as determined and certified by the manufacturers, and shall bear a label of proof test. Edge ropes shall provide a minimum breaking strength of 5,000 pounds.
(d) Forged steel safety hooks or shackles shall be used to fasten the net to its supports.
(e) Connections between net panels shall develop the full strength of the net.

1672. Tests. (a) The tests for approval of safety belts and attachments shall be the capability of withstanding three drop tests of 250 pounds dead weight (not sand) falling a distance of 6 feet without failure.
(b) In testing the belt and attachments, the anchor terminal of the lifeline shall be an overhead support. The waistband of the belt shall support the test weight in the same manner as it would support the worker.

(c) Safety nets shall be on-the-job tested for their ability to withstand the maximum load that may be imposed without failure and for suitable clearance from the surface below. The test shall conform to the manufacturer's recommendation for height and weight.

Article 29. Erection and Construction.

1710. (b) Erection Guide for Trusses and Beams Over 25 Feet Long. During erection the magnitude and placement of intended loads shall be held within safe limits. The employer shall provide an erection plan and procedure prepared by a civil engineer currently registered in California which shall be followed and kept available on the job site for inspection by the Division.

(e) Temporary Flooring—Skeleton Steel Construction in Tiered Buildings.

(1) (A) The derrick or erection floor shall be solidly planked or decked over its entire surface except for access openings. Planking or decking of equivalent strength, shall be of proper thickness to carry the working load. Planking shall be not less than 2 inches thick full size undressed, and shall be laid tight and secured to prevent movement.

(B) On buildings or structures not adaptable to temporary floors, and where scaffolds are not used, safety nets shall be installed and maintained whenever the potential fall distance exceeds two stories or 25 feet. The nets shall be hung with sufficient clearance to prevent contacts with the surface of structures below.

(C) Floor Periphery—Safety Railing. A safety railing of 3/8-inch wire rope or equal shall be installed between 42 and 45 inches above design finish floor height around the periphery of all temporary planked or temporary metal decked floors of tier buildings and other multi-floored structures during structural steel assembly.

(D) When connecting beams at the periphery of a building or structure where the fall distance is greater than 25 feet, employees shall be tied-off by approved safety belts and lifelines to either peripheral columns, pendant lines secured at the tops of peripheral columns, catenary lines, or other secure anchorage points. Employees shall also coon or walk the bottom inside flange of peripheral beams when it is necessary to release chokers, land intermediate members, or perform other work on the peripheral beams.

(E) Pendant lines, catenary lines and other lines used to secure workers shall be capable of supporting a minimum dead weight of 5400 pounds.

(F) If the procedure specified in (D) above is impractical, perimeter safety nets shall be installed at a distance of no more than 25 feet below the work surface and extend at least 8 feet beyond the perimeter of the building or structure. Nets shall meet the requirements set forth in the applicable portions of Sections 1671 and 1672.

*Source - Title 8 - Industrial Relations. California Administrative Code.

APPENDIX H - TEXT OF APPLICABLE ONTARIO STANDARDS*

Part II

General Construction

14—(1) During the construction of a building, temporary or permanent flooring shall be installed progressively as the building is erected.
(2) Subject to subsection 3, all work shall be carried out not higher than two storeys (sic) above the temporary or permanent flooring installed as prescribed by subsection 1.
(3) Where the vertical distance between the tiers of column splices exceeds two storeys (sic), work may be carried out not higher than three storeys (sic) above the temporary or permanent flooring.
(5) Subsections 2 and 3 do not apply to work carried out,
(a) from a scaffold;
(b) above an area where the worker has the protection of a safety net; or
(c) where the workers are protected from falling by means of parachute-type harnesses or safety belts attached to the project.

Personal Protective Clothing, Equipment, and Devices

29. A worker required to wear or use any protective clothing, equipment or device shall be instructed and trained in its care and use before wearing the protective clothing, equipment or device.

35.—(1) Subject to subsection 6, where a worker is exposed to the hazard of falling,
(a) more than 3 metres (sic);
(b) into operating machinery; or
(c) into or onto hazardous substances or objects,
he shall wear a safety belt or parachute-type harness adequately secured to,
(d) a fixed support; or
(e) a lifeline that is securely fastened to the project,
or be protected by a safety net.
(2) A safety belt or parachute-type harness shall be so arranged that should a worker fall he will be suspended at a distance of not more than 1.5 metres (sic) below the position where he was sit te (sic) for the purpose of working immediately prior to his fal .
(3) A fall arrest system shall not apply a peak fall arrest force greater than 8 kilonewtons to a worker.
(4) Where a lanyard is used, it shall have a nominal diameter of at least 16 millimetres (sic) and be made of nylon rope or other

durable material of equivalent impact strength and elasticity and adequate for the work to be done.

(5) Where a vertical lifeline is used, it shall,
(a) have a nominal diameter of at least 16 millimetres (sic) and be made of polypropylene or other durable material of equivalent impact strength and elasticity and adequate for the work to be done;
(b) be used by only one worker at a time;
(c) be free from the danger of chafing on any sharp edge; and
(d) extend to the ground or be provided with a positive stop which will prevent the safety belt or parachute-type harness from running off the end of the lifeline.

(6) Subsection 1 does not apply to a worker who,
(a) is proceeding to or from his work position; or
(b) is engaged in connecting structural members of a skeleton structure.

*Source - Occupational Health and Safety Act, 1978, Statutes of Ontario, 1978, Chapter 83

APPENDIX I - TEXT OF APPLICABLE U.S. ARMY CORPS OF ENGINEERS STANDARDS*

INSTRUCTION AND TRAINING

01.A GENERAL

01.A.05 Prior to the start of a project or any major phase of work a job hazards analysis developed the prime contractor will be reviewed with designated government personnel. The analysis will identify and evaluate the hazards and outline the proposed methods and techniques of accomplishing each phase in a safe manner.

01.B. INDOCTRINATION

01.B.01. Each employee shall be provided initial indoctrination and such continued training to enable him/her to perform his/her work in a safe manner.

01.C. ON-THE-JOB

01.C.01. Regularly scheduled safety meetings shall be held at least once a month for all supervisors on the project to review past activities, to plan ahead for new or changed operations, and establish safe working procedures for anticipated hazards. An outline report of each meeting shall be submitted to the designated authority.

01.C.02. At least one safety meeting shall be conducted weekly by field supervisors or foremen for all workers. An outlined report of meeting giving date, time, attendance, subjects discussed and who conducted it shall be maintained and copies furnished the designated authority on request.

01.C.03. All persons required to enter into confined or enclosed spaces or atmospheres immediately dangerous to life shall be instructed as to the hazards involved and precautions to be taken. They shall be trained in the use and care of such emergency and protective equipment as self-contained breathing apparatus, hose line masks, and respirators. Training shall be by a qualified person. The employee shall comply with any regulations that apply to work in dangerous or potentially dangerous areas.

01.C.11. The employer shall provide training in handling emergency situations that may arise in the use of any equipment on the project.

PERSONAL PROTECTIVE APPAREL, AND SAFETY EQUIPMENT

07.A GENERAL

07.A.13 Drop lines, lanyards and lifelines independently attached or attended, shall be used when performing such work as the following when requirements of 22.A.02. and 07.D.01. cannot be complied with.

07.A.14. Lifelines, drop lines, safety belts, and lanyards shall be used only for employee safeguarding. Any lifeline, safety belt, or fiber lanyard actually subjected to impact loading shall be immediately removed from service, and shall not be used again for employee safeguarding. For definitions of the above, see ANSI A 10.14.

b. Work on hazardous slopes, structural steel, or poles; erection or dismantling of safety nets; tying reinforcing bars; and work from boatwain's chairs, swinging scaffolds, or other unguarded location at elevations greater than 6 feet.

07.A.15. Lifelines and drop lines used on rock-scaling operations or in areas where the line may be subject to cutting or abrasion shall be a minimum 7/8-inch manila-rope with wire core. For all other lifeline applications, a minimum of 3/4-inch manila or equivalent, with a minimum breaking strength of 5400 pounds (2454 kg) per person shall be used.

07.A.16. Lifelines and drop lines shall be secured above the point of operation to an anchorage or structural member capable of supporting a minimum dead weight of 5,400 pounds (2454 kg) per person.

07.A.17. Safety belt lanyard shall be a minimum of ½-inch nylon, or equivalent, with a maximum length to prevent a fall of no greater than 6 feet (1.83 m). The rope shall have a nominal breaking strength of 5,400 pounds (2454 kg) per person.

07.A.19. Defective safety belts, harnesses, lanyards, lifelines, and drop lines shall be replaced.

07.A.20. Safety belts, harnesses, lanyards, lifelines, and drop lines shall meet the requirements of ANSI A 10.14, for Safety Belts, Harnesses, Lanyards, Lifelines and Drop Lines for Construction and Industrial Use or Section 07.I. Safety belts shall be free from additional metal hooks and tool loops other than those permitted in the ANSI standard.

07.A.21. Safety belts, harnesses, lanyards, drop lines, and lifelines shall be inspected before use each day to determine that they are in safe working condition.

07.D. SAFETY NETS

07.D.01. Safety nets shall be provided when workplaces are more than 25 feet above the ground, machinery, water surface, or other surfaces where the use of ladders, scaffolds, catch platforms, temporary floors,

lifelines, or safety belts is impractical. (See 07.A.13. and 22.A.18). Nets shall be installed as close under the work surface as practical but in no case more than 25 feet (7.62 m) below such work surface. Nets shall be hung with sufficient clearance to prevent user's contact with the surfaces or structures below. Such clearance shall be determined by impact load testing. Only one level of nets is required for bridge construction.

07.D.02. Safety nets may be provided where traffic or workers are permitted to be under a work area. (See paragraph 22.A.28.)

07.D.03. Nets for overhead protection shall be lined with wire or synthetic netting of not more than 1-inch (2.54 cm) mesh. Wire mesh shall be made of not less than 22-gage wire and synthetic mesh of not less than Number 18 twine.

07.D.04. Operations requiring safety net protection shall not be undertaken until the net is in place and has been tested.

07.D.05. Nets shall extend 8 feet (2.44 m) beyond the edge of the work surfaces where workers are exposed.

07.D.06. The maximum mesh size of nets shall be 6 inches by 6 inches (15 cm x 15.2 cm).

07.D.07 All new nets shall meet accepted performance standards of 17,500 foot-pounds (255,325 Newton/metres) minimum impact resistance as determined and certified by the manufacturers and shall bear a label of proof test. Edge ropes shall provide a minimum breaking strength of 5,000 pounds (2.3 kg).

07.D.08. The net suspension system shall be designed and constructed with a safety factor of four and as a minimum shall withstand the test loading without permitting contact between the net and any surface or object below the net.

07.D.09. Forged steel safety hooks or shackles shall fasten the net to its supports.

07.D.10. Connections between net panels shall develop the full strength of the net.

07.D.11. The net installation shall be tested by dropping a 400 pound (181.4 kg) bag of sand, not more than 30 inches ±2 inches (76.2 cm ±5.1 cm) in diameter, onto the center of the net from a height of 25 feet (7.6 m) above the net or from height equal to the distance from the net to the highest surface for which protection is furnished, whichever is greatest.

07.D.12. Nets shall be tested immediately after installation, relocation, or major repair. Tests shall be repeated at not more than six-month intervals.

07.D.13. Nets shall be inspected daily for cuts and damage from abrasions, chemicals, or heat. Repairs shall be made before work above the net is resumed. Rapid loss of strength of small net components should be considered.

07.D.14. Debris shall be removed from safety nets at least daily and combustible materials shall be removed before welding, cutting, or other operations producing sparks, slag, or other ignition sources are done above the net.

22.A.18. Employees on runways, ramps, scaffolds, roofs, floors, platforms, cofferdams, or other working surfaces from which they may fall 6 feet (1.8 m) or more or working over water or machinery shall be protected by guardrails with intermediate rail and toeboard, catch platforms, temporary floors, safety nets, safety belts, or equivalent. See 07.A.14., 22.A.02., and 07.D.

22.A.28. Overhead protection shall be provided contractor and government personnel and the public exposed to hazards from falling objects.

STEEL ERECTION

34.B TEMPORARY FLOORING

34.B.02. On structures not adaptable to temporary floors, and where scaffolds are not used, safety nets shall be installed and maintained whenever the potential fall distance exceeds two stories on 2 feet (7.62 m). (See also 07.D.01.)

*Source: Safety and Health Requirements, U.S. Army Corps of Engineers, April, 1981.

APPENDIX J - TEXT OF APPLICABLE AMERICAN NATIONAL STANDARDS INSTITUTE STANDARDS

Safety Nets*

1.General

1.1 Scope. These requirements shall apply to safety nets made of ropes or webbing fabricated of natural or synthetic fibers.
1.2 Purpose. The purpose of this standard is to provide minimum design, test, and use requirements for safety nets.
1.3 Exceptions. For cases of practical difficulty and unnecessary hardship, or where other extenuating circumstances exist, the enforcing authority may grant exception to the literal requirements of this standard and permit alternate methods, but only when it is clearly evident that equivalent safeguards are provided.

3. Conditions Requiring Nets

Safety nets shall be provided wherever:
(1) Persons are working 25 feet or more above ground, water, machinery, or any other solid surface and are not otherwise protected by safety belts and safety lines, scaffolds, or working surfaces properly guarded in compliance with other applicable American National Standards. (2) Public traffic or workers are permitted to be underneath a work area not otherwise protected from falling objects. In such cases, nets shall be lined with a mesh of size and strength sufficient to contain tools and materials capable of causing injury. (See 5,3.)

4. Materials

4.1 Material and fabrication shall provide impact strength per unit of net width or length equal to 6 x 6 inches spacing of 3/8-inch diameter No. 1 grade pure manila, ¼-inch nylon, or 5/16-inch polypropylene rope. Rapid loss of strength and susceptibility to damage of smaller members should be considered.
4.2 Materials used shall be compatible with each other.

5. Design of Nets

5.1 Maximum size of mesh shall not exceed 36 square inches nor be longer than 6 inches on any side measured center-to-center of mesh ropes or webbing, and no mesh member shall exceed 6 inches in length measured center-to-center of mesh crossing. All mesh crossing shall be anchored to eliminate frictional wear and prevent enlargement of the mesh opening.
5.2 Each net (or section of it) shall have a border rope or webbing. The minimum size of border rope shall be 3/4-inch diameter for manila and ½-inch diameter for synthetic; no border rope,

however, should have a breaking strength of less than 5000 pounds when new. The meshrope or webbing shall be anchored to the border at each crossing.
5.3 Net linings, when used, shall be of not more than 1-inch mesh and be constructed of synthetic twine not less than No. 18-inch size or of wire of not less than 22 gauge.

7. Manufacturer's Test
7.1 Each safety net shall be certified by the manufacturer that a qualification test has been performed on a prototype net of identical construction and that the net successfully passed the performance test described in 7.2.
7.2 The impact resistance of a safety net shall be such as to be able to absorb the impact of one drop of a 3[illegible]-pound bag of sand 24 inches (±2 inches) in diameter, dropped 50 feet into the net at each quarter-point of the long dimension (6 feet from the end of the net) and the centerpoint of the short dimension (8½ feet from side of the net).
7.2.1 Tests shall be performed using a 17 x 24-foot net secured in frame as detailed in Fig. 1. The test frame should provide an opening that is the same size as the net as hung.
7.2.2 Net sag when hung shall not be more than 3 feet at the center of the net. Border rope shall be level.
7.2.3 There shall be no broken strands nor significant distortion of the net pattern after two drops of the test weight, with five-minute intervals between drops to allow time for net recovery.
7.2.4 The test frame shall be elevated sufficiently to prevent net sag from contacting any surface below the net during tests.

8. On-the-Job Test
8.1 The safety net shall be tested on-the-job in the suspended position immediately following installation or major repair and at six-month intervals thereafter.
8.1.1 The test shall consist of dropping a 400-pound bag of sand not more than 30 inches (±2 inches) in diameter from a height of 25 feet above the net into the center of the net.
8.1.2 There shall be no broken strands nor significant distortion of the net pattern or the suspension system.

9. Installation
9.1 Nets shall be installed in accordance with the net manufacturer's specifications and instructions.
9.2 Nets shall be installed as close under the working level as practical but not lower than 30 feet and shall be hung with sufficient clearance to prevent contact with the surface or structure below when user's impact load testing is applied. (Exception: On bridge construction the lowest part of the structure should be considered the highest working surface. It is intended that only one level of nets be required for bridge construction.)
9.4 Drop-forged safety hooks and shackles which will support the design load shall be used to attach nets to supporting cables, structures, or beams projecting from structures. Such attachments shall be spaced at intervals of not more than 4 feet.

9.5 Safety nets shall extend outward 10 feet horizontally from the outermost projection of the structure.

10. Inspection
Each safety net, mesh rope, perimeter rope, connectors, suspension system, etc., shall be completely inspected by a qualified person after each installation and not less than once each week thereafter. Additional inspections shall be made after alterations, repair, impact loading, and welding or cutting operations above the nets. Nets which show mildew, wear, damage, or deterioration which affect their strength shall be immediately removed from service for complete inspection and repair or disposal.

11. Care, Maintenance, and Storage
11.2 Debris shall be removed from safety nets at least daily and combustible materials shall be removed before welding, cutting or other operations producing sparks, hot slag, or other sources are done above the net.

Safety Belts, Harnesses, Lanyards, Lifelines, and Drop Lines**
1. General
1.1 Scope. This standard establishes performance criteria for the construction and use of safety belts, harnesses, lanyards, lifelines, and drop lines, and their appurtenances. It does not include linemen's body belts and pole straps, window washer's belts, or safety ladder belts.
1.3 Variations. Variations from the requirements of this standard may be granted by the authority having jurisdiction when it is clearly evident that the workers are equally protected by the procedure or equipment permitted by the variation. The authority having jurisdiction should recognize and approve newly developed techniques, methods, or equipment when it has been established that they will provide equal or greater safety.

3. Belts and Fittings
3.2 Materials
3.1.1 Strength Members. Strength members of belts may be made of any material, except leather, that will result in a finished belt capable of meeting the specified minimum performance tests described in Section 5.
3.1.2 Hardware. All hardware, except rivets, shall be of drop forged or pressed steel with a corrosion-resistant finish (footnote omitted). Surfaces shall be smooth and free of sharp edges.
3.1.5 Lanyards. Lanyards may be made of any fibrous or metallic material satisfactory for the application and which will result in a finished lanyard capable of meeting the qualification tests indicated in Section 5.
3.2 Construction
3.2.6 Drop lines shall have 5400 pounds minimum tensile strength (2450 kg) and at least a 3/4-inch (19-mm) nominal diameter if natural fiber rope is used or a 3/8-inch (9.5-mm) nominal diameter if wire rope is used, and be at least equal in strength to the fixed anchorage specified in 2.5. Not more than one person shall

be tied off to a fiber rope drop line. If more than one person is tied off to a wire rope drop line, the fixed anchorage strength shall be increased in proportion to the number of persons tied to the drop line.

3.2.7 Lifelines shall be of wire rope, at least ½ inch (12.5 mm) in diameter, attached to at least two fixed anchorages. The fixed anchorages shall be capable of supporting a 5400-pound (2450-kg) deadweight load per person applied at the center of the lifeline.

3.3 Classification according to Use

3.3.1 Safety belts, harnesses, and lanyards are classified according to their intended use as:

Class I: Body belts (work belts), used to retrain (sic) a person in a hazardous work position and to reduce the probability of falls.

Class II: Chest harness, used where there are only limited fall hazards (no vertical free fall hazard) and for retrieval purposes, such as removal of a person from a tank or bin.

Class III: Body harness, used to arrest the most severe free falls.

Class IV: Suspension belts, independent work supports used to suspend or support the worker.

3.3.2 Lanyards shall be kept as short as reasonably possible to minimize the possibility and length of a free fall. Whatever the length of the lanyard, it shall be tied off as short as possible. Care shall be used to see that the lanyard is attached to a fixed anchorage by means that will not reduce its required strength. A knot will reduce the strength of a rope lanyard by at least 50%.

3.3.5 When subjected to a fall, body belts (Class I) together with their associated lanyards shall produce a stopping force of not more than 10% gravity.

3.3.6 Chest harness (Class II) and suspension belts (Class IV) shall not be used for stopping falls and are not subject to impact requirements.

3.3.7 When subjected to a fall, body harnesses (Class III) together with their associated lanyards shall produce a stopping force of not more than 35X gravity.

3.3.8 Belts and lanyards that have been subjected to impact loading shall be removed from service and destroyed.

4. Certification and Inspections for Belt and Lanyard Assemblies

4.1 Manufacturers' Certification. Each belt and lanyard assembly shall bear identification marks, either indelibly printed into the belt or stamped into permanently attached tags, which shall identify the manufacturer. The identification shall also bear the date of manufacture and the number of this standard. The number of this standard shall constitute a certificate that the minimum requirements have been met. All of these markings shall be in easily legible characters and so applied that they shall be indelible during the life of the belt.

4.2 Users' Inspections. Each belt and lanyard assembly shall be visually inspected for defects prior to each use. The assembly shall be inspected according to the manufacturer's recommendations not less often than twice annually. The date of each such inspection

shall be recorded on an inspection tag that shall be permanently attached to the belt.

5. Qualification Tests
5.3 Samples of each type and class of belt, harness, and lanyard assembled together as a unit shall withstand without failure a test consisting of three successive drops of a 250-pound (113-kg) rigid weight falling free through a distance of 6 feet (1.8-m). (Figures omitted.) The free fall distance shall be established by permitting the weight in the belt to hang free supported by the lanyard. The weight shall then be lifted 6 feet (1.8 m) plus or minus 1 inch (2.5 cm) and released by a quick-release trip. The weight shall be a rigid cylindrical or torso-shaped object with a girth of 38 inches (97 cm) plus or minus 2 inches (5.0 cm) and shall weigh 250 pound (113 kg) plus or minus ¼ pound (0.1 kg). The lanyard for this test shall be 6 feet (1.8 m) plus or minus 1 inch (2.5 cm) from the anchorage to the attachment on the belt. The anchorage shall be rigid. The belt or harness shall be applied to the weight as it would be to a man. Failure shall consist of any breakage or slippage sufficient to permit the weight to fall.
5.4 Belts, harnesses, and lanyards that have been subjected to drop tests shall not be used except for display and education.

*Source - American National Standards Institute, Inc. American National Standard Minimum Requirements for Safety Nets. A10.11 - 1971.

**Source - American National Standards Institute, Inc. American National Standard Requirements for Safety Belts, Harnesses, Lanyards, Lifelines, and Drop Lines for Construction and Industrial Use. A10.14 - 1975.

APPENDIX K PROPOSED RESEARCH PROTOCOL

K.1 INTRODUCTION

Within the current structure of government, there is increasing interest not only in ensuring the safety of the working public, but also in judging the effects and benefits of having safety standards. A methodology is needed to allow a specific safety standard to be studied to determine if it is, in fact, accomplishing the intended objective--that is, protection of the worker.

In some areas, one of which this project addresses, there is disagreement between industry, labor and the government regarding whether compliance with a specific standard, when applied to a particular work situation, might actually place the worker at greater risk than if it did not exist.

The following presents a proposed research methodology or protocol which can be utilized to scientifically evaluate the effectiveness of specific OSHA standards. The presentation is divided into two discussions. The first approaches the research problem in a generic way with the intention that it can be used to evaluate any OSHA standard. The second discussion addresses the specific problem area being investigated by this project.

K.1.1 STATEMENT OF THE RESEARCH PROBLEM

There exists in government, many standards designed to regulate specific industries so that the workers are protected and accidents are prevented. These standards exist, but there are questions as to whether or not safety standards have the effect that they were designed and intended to have. Are the workers actually protected? Do they follow the standards? Are the number and severity of accidents greater, lesser, or the same as they would be if no standard existed? If these standards are not accomplishing what was intended, are there recommendations which can be made to accomplish the intended results?

K.1.2 THE TRADITIONAL APPROACH

The most typical approach to a research problem such as this would be to proceed with the collection of primary data. In this particular case, the procedure would involve collecting first-hand information about job-related accidents from industry. This process can reveal a great deal of information, but there are several items to be considered if this approach is to be employed.

The first item to be considered is the fact that primary data collection is a costly and time-consuming process. A data-generating survey instrument must be prepared for use. This step alone requires that such an instrument be

written, piloted, revised, and validated within the confines of existing government regulations. This can entail significant expense. Once this is achieved, the instrument must be distributed.

The most cost efficient means of primary data collection is to mail the survey. Response rates then, depend entirely upon the voluntary cooperation of the people or companies being surveyed. As the level of personal contact increases, whether due to telephone contacts to prompt higher response rates or actually gathering data by physically reviewing the respondent's records, the cost increases rapidly. As this procedure is completed, by whatever means, the time-consuming task of organizing the data into a manageable form and of analyzing it remains.

Another factor to consider here is that even if an instrument is developed and distributed, the response and/or rate of return may not be sufficient to adequately answer the research questions. A primary reason for the lack of response in such a procedure is that the persons responding to the survey may not be motivated to respond. In this particular case, the research question involves a sensitive area for many in industry. Companies have a number of reasons for not releasing information regarding job-related accidents. One reason might be that the accidents have resulted in cases presently in litigation. Another is that information about such accidents is considered confidential. Finally, these companies may simply be reluctant to share information with the government or government-sponsored contractors. It is probable that responses will be more likely from companies which experienced no accidents; therefore, some procedure must be designed to assure that bias can be estimated.

The survey instrument must be packaged in such a way that it can be simply and quickly answered. Persons responding to a research instrument seldom have the time or patience necessary to read detailed instructions, much less to respond to a large number of questions. This limits the amount of information that can be gathered.

Perhaps the most limiting factor in collecting this information by mail is the need for a company to base the answers to survey questions on information compiled in their accident reports (assuming that these exist, are reliable, and contain detailed enough information to answer the questions). This factor increases significantly the amount of work required to respond to the questionnaire, which in turn depresses the response rate. It is anticipated that many respondents would not take the time to thoroughly review their records and would most likely respond from "memory" rather than documented fact. Thus, many of the returned questionnaires may not present totally reliable information. To overcome this problem, the level of personal contact may have to be increased, requiring a significant increase in time and expense.

An additional factor to be considered is that in the collection of primary data, a large sample must be employed to insure that sufficient information is available to allow a detailed enough analysis to answer the needed questions. The sample would also have to include a cross section of the types and sizes of companies to which the standard applies.

There are various ways to overcome these obstacles; however, it seems

reasonable to first explore other means of answering the research question which would not be as time-consuming and costly.

K.1.3 UTILIZATION OF SECONDARY DATA

With these factors in mind, the question arises as to whether or not there is possibly a faster and more efficient method of assembling information by the collection of secondary or existing data. Examining secondary data may also allow questions concerning the number of people at risk and the seriousness of the safety hazard to be evaluated to determine the value of extensive research in a particular area. The procedure of collecting secondary data is more cost effective, primarily because the data already exists and can usually be collected in a shorter period of time with fewer contacts and considerations than encountered in the process discussed above. One time-consuming process which would be eliminated is that the collection of secondary data would probably not require government clearance, as would the collection of primary data. If the data can be collected faster, then the analysis process can be started and ended at an earlier point in time.

K.2 OVERVIEW OF PROPOSED GENERIC APPROACH

The general approach to collecting and utilizing secondary data is presented in a flow diagram on the following page. The following will discuss each stage of the process and provide a brief overview. A more detailed discussion of the techniques to be used is provided in later sections.

K.2.1 STAGE 1 - ESTABLISH AN APPROPRIATE PRIORITY

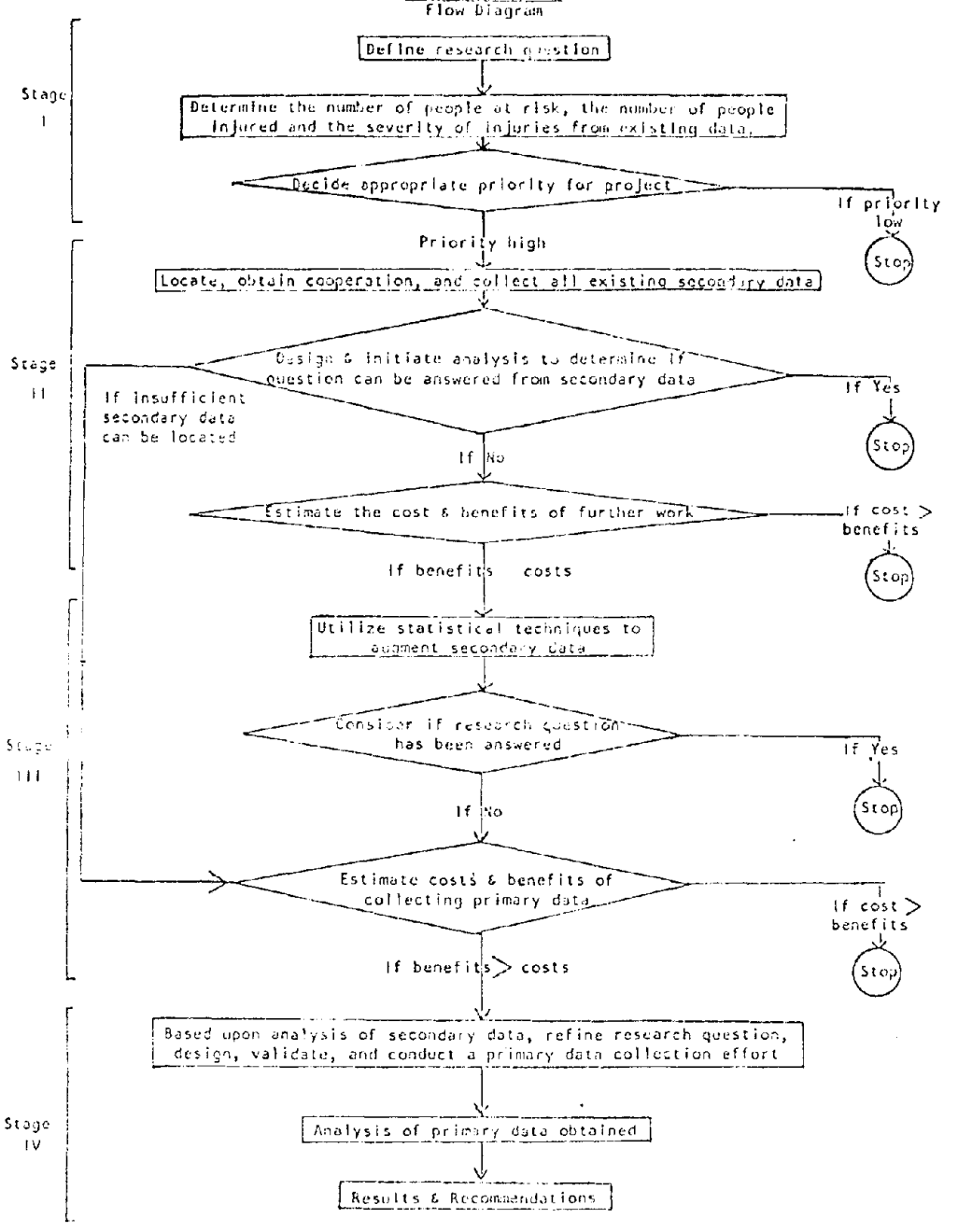
Before committing to an extensive research project readily available secondary data should be collected to attempt to establish the answer to the following concerning the standard in question:

- How many accidents occur?
- How many people are exposed to the hazard?
- How severe are the injuries?

Based upon the answers to these questions, a decision can be made concerning the priority the project should have. For example, a project designed to assess the value of a standard which affects relatively few people who are unfrequently injured might receive a low priority. Another project assessing the effectiveness of a standard designed to protect people where a large percentage of the population at risk are being injured frequently might logically receive a higher priority.

It is also important to determine the size of the population and the number of incidents occurring, because it will affect how the research is conducted. A large number of incidents will allow a smaller sample to be considered and will increase the ability to utilize statistical techniques to analyze the information. If fewer incidents are anticipated more in-depth information-

Generic Research Approach for Evaluating Safety Standards
Flow Diagram



gathering techniques would be used to reconstruct each incident. A case study of each incident might be prepared, for example, based upon interviews with various people involved in the accident. These case studies would then be compared and contrasted to establish trends in standards compliance and the circumstances of the accidents.

K.2.2 STAGE II - COLLECT AND UTILIZE AVAILABLE SECONDARY DATA

If the priority set in Stage I indicates that the study should proceed, a number of additional questions might be answered using secondary data. For example, the degree of compliance with the standard might be determined from trends in OSHA citations. Further information may also be available concerning how accidents are happening, experience of the person injured, contributing causal factors, and other hazardous conditions. If the questions involving the effectiveness of the standard can be answered based upon the information from secondary data which is available, the process may stop at this point.

K.2.3 STAGE III - ENHANCEMENT OF SECONDARY DATA

Several statistical techniques may be valuable to enhance the secondary data on a probability basis. The benefits of such an enhancement process should be considered to determine if the probability of error for the answers based upon secondary data can be improved. (This process is discussed further in section K.3.3.)

K.2.4 STAGE IV - PRIMARY DATA COLLECTION

If satisfactory answers to the research question have not been determined, the project would move into a primary data collection phase. A process would be devised for gathering information from employers and employees affected by the standard. The probability for the success of this effort will be greatly increased by the information developed in the first three stages. The research staff will have a much better idea of the information which is available and the proper questions which should be asked.

K.2.5 CONTROL OF SPONSORING AGENCY

Of particular interest in this approach is the ability for the government to retain control over expenditures and time being spent to answer the research question. After each of the major activities in the research approach, an evaluation would take place regarding the sufficiency of the answer which has been developed. An estimate would then be made to determine the cost of the next step in the work plan and the amount of benefit that would be derived. Based upon this estimate, a decision would be made by the government whether to proceed with further expenditures or whether the answer is sufficient for their needs.

It must be remembered that research of this nature seldom can supply conclusions in which 100 percent confidence can be placed. The basic objective of any

research study is to balance margin for error with the amount of money being spent. (For example, a 15 percent error factor might be acceptable if it were estimated that it would take an additional 2 million dollars and three years of effort to improve to a 5 percent possibility of error.) The ability to stop at prearranged points to consider how much additional analysis and/or data collection is likely to contribute to the accuracy of the study findings is of significant value.

Such an analysis depends to a great extent upon the experience of the people working on the project regarding the techniques to be used. It also depends upon the amount of secondary data that has been found in Stage I & II of the flow diagram and the susceptibility of that data to the statistical procedures contemplated in Stage III. In addition, the type and degree of detail found in the secondary data will provide important clues concerning the design of a primary data collection effort.

K.3 GENERIC SECONDARY DATA APPROACH

K.3.1 POTENTIAL SOURCES OF SECONDARY DATA

Several potential sources of secondary data exist. These include:

- Occupational Safety & Health Administration (OSHA)
- OSHA State Plan Agencies
- Mine Safety and Health Administration (MSHA)
- The Bureau of Labor Statistics
- Government contracting agencies which collect and maintain safety information regarding the contracts being administered (e.g., U.S. Army Corps of Engineers, U.S. Tennessee Valley Authority)
- Operations of government agencies subject to the same or similar standards (e.g., the Military, Department of Interior)
- State workers' compensation agencies
- Major private employers
- Labor unions
- Information developed by NIOSH and government contractors
- Industrial associations
- National Safety Council

The potential of using each of these sources will depend on the particular standard being studied and the degree of specificity required of information from accident records.

K.3.1.1 Government Agencies

Several government agencies collect safety information for various purposes. Generally they fall into two categories, those responsible for regulation and those responsible for monitoring worker safety on specific projects contracted by the agency. In the first category are OSHA, OSHA State Plan Agencies, and MSHA who maintain records regarding compliance with a specific standard and who also investigate major accidents and fatalities. These records can be accessed through computerized record keeping and by surveying area offices

regarding a particular problem. (The project team discovered that many of the compliance people in the OSHA Area Offices were quite helpful in locating accident cases of a particular nature.)

The second category of government agencies includes those agencies who contract to obtain buildings or goods and maintain some management control over safety. Primary examples of this type of agency would be the U.S. Tennessee Valley Authority, the U.S. Army Corps of Engineers, and various branches of the Military. Many of these agencies establish contractual safety controls and receive copies of all accident reports generated by contractors on their jobs. Some of these are computerized and would potentially be available.

K.3.1.2 Workers' Compensation Insurance

State workers' compensation agencies are a potential source of information, provided the area of investigation is relatively broad (i.e., falls from an elevation as opposed to falls involving only connectors in steel or precast/prestressed erection).

Problems exist because each state independently developed its own system of records and many are not totally comparable. A great deal of effort will most probably be needed to mold the state workers' compensation system into a unified data base which is comparable. However, this fact does not exclude the usefulness of this data.

Twenty-eight states are cooperating in a program which provides a standardized format for occupational injury and illness data. These data tapes are available from the National Technical Information Service. The tapes have been added to NIOSH computer files and are already being used to provide a method of examining safety issues quickly. While definitive answers may not be possible, based upon this information alone, it can be useful in identifying broad trends and examining potential research approaches.

Private workers' compensation insurance carriers offer an important source for accident data. Several problems have been encountered by various contractors in the past when seeking information from these sources. It would be advantageous to direct a fairly high level of activity toward obtaining cooperation from these companies, because once these sources of data are made accessible, a substantial data base might become available for future studies of this nature.

In dealing with insurance companies, traditional arguments revolve around the confidentiality issue. With some care in preparation, a persuasive argument could be constructed which demonstrates that it is to the advantage of the insurance carrier to cooperate. More workable safety standards which perform as intended and could reasonably be enforced, would aid in preventing accidents for which the insurance company would eventually have to pay. Providing access to this information would also help the clients of the company by possibly clearing away bothersome safety standards which do not improve the safety of workers but do increase overhead. In fact some progress has been made in this regard, as some insurance carriers, such as Employers Insurance of Wausau, have begun using their data bases to answer basic research questions.

K.3.1.3 Major Employers

The best source of secondary data is the employer. It is at this level that information is generated and transmitted to all the other sources. While it is clearly impractical to draw secondary data from a large number of businesses, it might well be possible to form a small group of the major employers who must comply with the subject standard. These employers could help assess the value of the standard by allowing access to their accident records regarding a specific type of injury.

Care must be taken in this area to assure that the bias of the information made available is controlled. Bias could be controlled by examining all the OSHA 101 Forms completed by the company during the period being studied. This information, of course, is available to OSHA by law. Nor could this source of information stand alone; it would have to be only one component of the secondary information base that is analyzed.

K.3.1.4 Labor Unions

Labor unions collect useful data regarding accidents affecting workers they represent. It is reasonable to assume that these unions would be very interested in a study of this nature, particularly if information is also being obtained from employers. Many would request that their information be considered.

K.3.1.5 Other Government Projects

The use of systems and information being developed for other purposes by researchers funded by NIOSH and other government agencies can also be put to use. For example, a current NIOSH study involving the safety of using ladders has developed a system of working with hospital emergency rooms to trace accidents. Hospital records may also have value in tracing injuries of a specific nature which typically result from a particular type of accident (e.g., puncture wounds in the sole of the foot).

K.3.1.6 Associations

Finally there is information collected by industrial associations and the National Safety Council which could provide useable data depending on the standard being investigated.

K.3.2 A LOGICAL ANALYSIS PROCESS

It is obvious that data from any one of these sources would be of only marginal value in that it would represent only a portion of the universe of people or companies affected. However, if data can be drawn from multiple sources, the reliability of that data is increased, and estimates of bias can be calculated.

Various sources of secondary data exist, therefore any research protocol must include:

1. A way of assessing the degree to which existing data is adequate to address the problem
2. A way of assessing the reliability and validity of the secondary data
3. A way of supplementing the secondary data with primary source data

The following is a listing of tasks (steps) appropriate as a generic research protocol to deal with the problems listed as number 1 and 2 above. The approach is predicated on the assumption that the first step is to find out what information is available and how that information can be best used, prior to resorting to any primary data collection. Within this, a logical analysis of the secondary source data is preferred over a statistical one.

K.3.2.1 Purpose Which Analysis Will Serve

The first step in the logical analysis process is to establish the purpose that the data will serve. For example, are we interested in standards that affect only a particular type of industry (e.g., construction) or standards that affect a particular job common to a number of industries (e.g., lathe operators)?

K.3.2.2 Analysis of Sources

Step two in the process involves determining which sources discussed above are likely to provide data relevant to the standard under consideration. Does the industry as a whole maintain records? Are OSHA records useful? What about state workers' compensation? Even though no single source may be adequate, a combination may be adequate, (i.e., a combination of sources may provide enough information for a particular combination of industry and standard).

K.3.2.3 Adequacy Of Data

For which standards and industries is there sufficient available information to make a decision about a standard? For example, if it can be determined that a standard is not having any effect in two or three industries where it applies, is that sufficient to conclude that the standard is not a useful one? Can knowledgeable people add to the usability of the data?

A central question concerning the adequacy of data will be the ability to divide the information into categories based upon an indication of general compliance or non-compliance with the standard in question. Several possible scenarios suggest themselves. For example, accident data from workers' compensation insurance companies might be grouped by the risk factors used in computing premiums or by considering the inspection histories developed by insurance safety people for various groups of companies. This could

allow the general attitude of companies concerning enforcement of safety standards to be estimated. Information supplied by government agencies which contract with private concerns could also be subdivided into groups who enforce or do not enforce a standard based upon the inspection histories developed by the agency for specific contractors. Such groupings could allow preliminary conclusions to be made concerning the effect of complying with the standard.

On a broader scale, combining information with the experience of knowledgeable people can also help to draw conclusions. For example, if the data indicate a particular type of accident seldom occurs and knowledgeable people agree that compliance with the subject standard is high, a preliminary conclusion about the adequacy of the standard could be made. Based upon this analysis, research efforts might be redirected into a more productive area.

K.3.2.4 Reliability Of Data

Is the information that is available reliable? That is, does it accurately reflect what really happened or happens? How do we validate the data? Data adequacy can be judged in a preliminary way by considering the volume of data available, the size of the segment of industry which that data represents, and the number of independent data sources which are available. On a broad basis, the validation of secondary data will depend upon the degree of agreement or disagreement between data gathered from relatively independent sources. For example, if information from a group of government contractors, from the Associated General Contractors, from the union and from OSHA records agree, the reliability of the conclusion would be relatively high.

K.3.2.5 Combine Standards And Industries

Are there standards and industries that are suffieiently similar so that they can be combined and increase the effective data base? Does, for example, an OSHA standard for construction really differ from a similar standard written for construction on a mine site or on a military base?

K.3.2.6 Decide If Secondary Data Approach Is Viable

The result of the process above will provide a basic description of what is available. At the end of this logical analysis and inquiries to various potential sources to determine the data that is available, a preliminary determination regarding the eventual success of the secondary data approach can be made. If the data is insufficient, the remaining steps in Stage I, II and III of the flow diagram would be omitted. An estimation of the benefits and cost of primary data collection would be made and the process would continue in Stage IV.

K.3.3 ANALYSIS AND ENHANCEMENT OF SECONDARY DATA

A number of statistical techniques can now be applied to enhance and analyze the data. The basic approach will be to compare accident and injury rates for those groups where the standard is likely to be utilized and those where it is not. The differences between the groups will define the impact of the standard. Even though straightforward and direct, such an approach presents some problems in that the dependent variable is not well defined. Specifically, what measurements of injuries and illnesses are available and what means can be developed to scale severity? If there are multiple dependent measures, as there probably are, how are they dealt with? These are relatively trival problems. For example, multivariate analysis is appropriate for a situation with multiple dependent measures. Thus, multiple regression, multivariate analysis of variance, etc., are probably relevant analytic techniques.

In addition, it may be possible to utilize regression estimation techniques combined with cross validation to enhance the data which has been collected and increase reliability. While this process is relatively complex, the principles are similar to a simple prediction process. For example, if the following series of numbers is known - 2, 6, 10, 14 - then it is possible to predict that the next number in the sequence will be 18. In another example, if it is known that total assets must equal total liabilities and that current liabilities minus total liabilities equal equity, one can use the figures of $300,000 in assets and $100,000 in current liabilities to predict an equity of $200,000. (A statistical explanation of the proposed techniques is presented in Appendix L.)

The usefulness of secondary data and the techniques discussed will vary greatly as a result of the standard being researched and the industries which are involved. However, considering the potential of analyzing secondary data, prior to entering the more extensive primary data collection stage, is a logical and valuable approach.

The feasibility of this approach for evaluating a specific standard can be assessed in far less time than obtaining the approvals for a primary data collection effort. The process of considering the research question and talking to various potential sources of secondary data will, at the very least, aid in exploring various aspects of the research question. Such contacts often lead to a redefinition of the research question so that the possibility of sucessfully collecting primary data is increased.

K.4 GENERIC PRIMARY DATA APPROACH

Five methods of primary data collection appear to be reasonable.

K.4.1 MAIL SURVEY WITH TELEPHONE FOLLOW-UP

A survey instrument could be constructed, validated, and mailed to a large sample of employers who do the type of work being studied. Names and addresses of such employers can be assembled from several sources including:

- Industry associations
- Department of Labor
- Census Bureau
- Industry periodical subscriptions
- Dodge Reports

Each company would be asked to review its accident records for a specific time period and locate accident records relating to the standards in question. Employers would be asked to provide copies of any accident reports or, at a minimum, copies of the Employer's First Report of Injury Form and the OSHA 200 Form upon which the accident is logged. Follow-up calls would be made to all companies where an accident occurred to gather more detailed information from the safety director and/or witnesses to the accident.

The feasibility of this approach is limited, as has been discussed earlier in the document. There will be a certain reluctance to respond in any detail; plus supplying the documentation required will be somewhat time consuming on the part of the respondent, which could depress the response rate.

K.4.2 USE OF OSHA PERSONNEL TO GATHER RESEARCH DATA

As it seems that many companies may be somewhat reluctant to respond on a voluntary basis to a survey, it would appear that the Department of Labor's legal right to examine accident records could be evoked by having OSHA compliance officers visit work locations to make observations and examine records. Since OSHA personnel are already employed nationwide, it could also eliminate much of the travel expense which would be necessary to mount such an effort using private contractors.

Several factors would influence a choice of this alternative. OSHA personnel might most reasonably be used to examine and collect existing data such as OSHA 200 and 101 forms. However, any observations concerning general work activity on the site and any personal interviews held with employees would most assuredly be colored by the very fact that the compliance officer's primary function is the enforcement of the law. For this reason the mere presence of this type of individual would result in a bias which would be extremely difficult to estimate or control. A second factor is the budgetary restraint faced by OSHA which limits the number of compliance officers which are available. The primary task of these people is the performance of compliance inspections. Any survey activity would probably receive a low priority.

K.4.3 OBSERVATIONAL DATA COLLECTION

An approach might also be considered which would not require the active involvement or approval of a company. Some types of work activity can be observed without entering the premises of the company. Observations of this activity could be made to determine if employees were following the standards or if they were not. This would eliminate the problem

of having to rely upon the policy statements issued by a company concerning adherence to a standard. The observation technique would clearly deliniate this matter.

Such a technique would also eliminate the problem of poor response as the data could be collected about every site chosen to make up the sample. This would also allow a smaller sample to be used. Following the observations at a site, the observer would personally request the contractor's accident records on a voluntary basis or through the use of NIOSH credentials, if necessary.

Problems with this approach revolve around the logistics of fielding a well-trained force of observers to visit the various sites chosen in the sample. This could be done by recruiting geographically distributed safety consultants who could be made responsible for visiting sites in their immediate areas.

K.4.4 WORKING THROUGH GOVERNMENT CONTRACTING AGENCIES TO MONITOR THE SAFETY ACTIVITIES OF CONTRACTORS

Several government agencies are responsible for hiring contractors to do various types of work. Among them are the U.S. Army Corps of Engineers, the U.S. Tennessee Valley Authority, the Department of the Interior, and various branches of the Military. In some cases, these agencies actively monitor the safety of people working on a project and place specific safety requirements in the contract.

It may be possible to gain the cooperation of these agencies for participation in a study of this nature. The study would be structured so that agency contracted jobs could be monitored over a specific period of time. Arrangements would be made with each contractor to provide accident reports concerning the type of accidents being studied to the project staff for review. The project staff would then determine if the accident applied to the project and would have the option of investigating the accident, in-depth, to determine what happened.

Since all accidents of a particular type would be reported, it may be possible to determine if some types of accidents are being caused by compliance with the standards. It would also be possible to determine whether a company was following the standards by maintaining contact with government safety and project personnel who visit these companies in the normal course of their duties.

Problems with this approach again involve possible bias. Contractors hired by the government are atypical in that they may tend to be union employers and thus may have more experienced and better trained employees. The fact that many of these agencies impose contractual safety requirements and monitor site safety would also presumably make these contractors more safety conscious than might otherwise be normal.

K.4.5 ASSEMBLE A GROUP OF PRIVATE EMPLOYERS WILLING TO ALLOW MONITORING ACTIVITIES TO TAKE PLACE

It may be possible to assemble a group of private companies who would alert the project staff when the type of accidents being studied occur. This would allow the project staff to follow up on each accident in order to assemble a more detailed report of the circumstances surrounding it. This group of employers might be used in conjunction with those working under contract to federal agencies to help estimate and control the bias.

This group would also have built-in biases, although somewhat different than those in the federal agency group. The participants would, in effect, control the selection process (by deciding whether or not to participate) as opposed to being completely randomly selected as part of a sample. Although, the companies who are approached would originally be chosen on a random basis. It would also be most productive to approach larger companies with such a request, as they would tend to have the most effective accident reporting systems and would offer access to a broader range of activities.

K.4.6 FEASIBILITY OF DATA COLLECTION METHODS

Each of the above approaches has the advantage of being relatively affordable. Most would run in the range of $150,000 to $250,000 to accomplish. However, each has a particular problem in regard to bias or feasibility. Each is also limited in the amount of information which can be assembled.

An approach can be devised which amalgamates several of the strengths of each of the above approaches and provides much better control over bias and important variables for which records are not generated. However, as more definitive information is generated and more variables are controlled, cost may increase significantly.

K.4.7 PROPOSED GENERIC PRIMARY DATA COLLECTION

The primary data collection effort would be designed to collect information about two basic groups. These groups are those organizations where the type of accident being investigated occured and those where an accident did not occur. For each of these groups the data collected would ideally indicate:

- The number of accidents which occured compared to either the number of people exposed to the hazard or the number of man-hours worked by the people exposed
- For each accident was there compliance with the standard in question?
- What safeguards are used in addition or instead of those specified by the standard?
- If there is compliance with the standards in question what accidents have occurred because of compliance?
- If there is no compliance with the standard, what accidents have been avoided because of the non-compliance?

Alternately the formation of groups would be based upon the degree of standard compliance during an accident. The first group would be made up of those accidents where there was compliance with the standards in question and the second would be that where there was no compliance with the standards. The data collection effort would be designed to indicate for each group:

- The number of accidents compared to either the number of people exposed or the number of man hours worked by people exposed
- Did the accident occur because the employee was complying or not complying with the standard?
- Was the severity of the accident affected by the degree of standard compliance/non-compliance?
- What safeguards are used in addition to or in lieu of those stated in the subject standards?

The first approach, based upon comparing the conditions where an accident occurred and those where an accident did not occur, will be discussed in this section. The second approach is more fully developed in Section K.5.

K.4.8 ACCIDENT - NON ACCIDENT APPROACH

It is impossible to discuss the primary data collection process in a very specific way without knowing which standards are to be researched. Therefore, the following discussion will be limited to the general concept which would be utilized should the option be choosen of comparing the conditions in which accidents occurred and those where accidents did not.

The first consideration in this approach is how to identify accidents which are of interest. This might be accomplished by choosing a sample of metropolitan areas where the study will take place. The records generated by police and fire departments when they respond to an accident and from local hospitals where injuries are treated might be used to identify accidents. On a national basis it may be necessary to survey companies in the industries being studied to identify specific accidents which have occurred.

Once an accident has been identified the basic concept of this study approach is to determine if the worker and equipment involved in the accident was in compliance with the standards being studied. In addition, some basic information about the circumstances of the accident would be collected such as:

- The type of business
- The work function that was being preformed at the time of the accident
- The equipment that was being used
- The experience and training of the employee involved
- Other critical factors depending upon the requirements of the standards being studied (e.g., work surface, type of product being handled, other protective equipment being used, etc.)

The information obtained would then be used to identify a second site where a similar process was taking place using the same type of equipment but where

an accident did not occur. Information concerning the second situation would then be collected to determine if the standards had been complied with.

At the completion of the data collection phase at least four categories of data will exist.

- Accidents where there was standards compliance
- Accidents where there was no standards compliance
- Non-accidents where there was standards compliance
- Non-accidents where there was no standards compliance

The information from these catagories would then be compared and contrasted to determine if more accidents occur when the standard is complied with or when it is not. Analysis will also be done to establish whether the general industry complies with the standard or not and if accidents are caused as a result of either compliance or non-compliance.

K.5 PROPOSED CONNECTOR FALL RESEARCH

K.5.1 APPLICATION OF SECONDARY DATA APPROACH TO CURRENT PROJECT

The above discussion is the suggested approach for the evaluation of any OSHA standard. When considering the specific research question posed by this project, regarding fall protection for point of erection workers, it was determined early in the project that the secondary data approach was inappropriate. The primary reason for this determination is the somewhat unique aspect of this study which requires the study of a very specific small population of workers. A good deal of information could be identified which reported falls. In some cases those falls could be isolated for building construction and in some cases for iron workers. However, secondary data did not contain enough detail to allow an identification of the specific operation being performed at the time they all occurred (in this case, connection) to be identified. (The single exception to this was the record of fatality/catastrophy investigations compiled by OSHA discussed earlier in Chapter 2 Overview of Population at Risk and Fall Accidents). For this reason, insufficient secondary data was available and the process would have moved immediately to the primary data collection phase outlined in Stage IV of the flow diagram.

K.5.2 COLLECTION OF PRIMARY DATA REGARDING CONNECTOR FALLS

Several problems exist in regard to mounting an effort to collect data concerning connector falls. The primary difficulty is the suspicion that incidents involving connector falls are relatively rare. This suspicion is based upon the fact that OSHA fatality records revealed very few cases involving connectors during the three year period from 1978 through 1980. It is possible that information gathered from even a large sample of active erection sites would reveal very few incidents. A case study method would

then have to be used to gather as much detail about these isolated incidents as possible in order to compare and contrast this information. This, combined with several techniques which will be discussed below, such as interviews with connectors to collect anecdotal evidence about near misses which occurred but were not reported, could produce an answer to the research question.

While the following technique may be considered too elaborate for this research question, it will nonetheless be valuable to consider each step in terms of a real situation. Since the project team is now most familiar with the question of fall protection for connectors, examples will be drawn from the requirements identified for evaluating the standards in question. The procedures could be easily adapted for use in a broader context.

K.5.2.1 Redefinition of Research Question

For each of the following standards, determine if the safety of a person working at the point of erection in steel or precast/prestressed concrete construction is improved, degraded, or whether there is no effect.

The standards in question are:

29 CFR 1926.104 Safety Belts, Lifelines and Lanyards
29 CFR 1926.105 Safety Nets
29 CFR 1926.750(b)(1)(ii) Temporary Flooring-Skeleton Steel Construction in Tiered Buildings
29 CFR 1926.21(b)(2) Safety Training and Education

To determine the effect of any one standard, it will be necessary to assemble two groups of accidents. The first group will consist of those accidents where there was compliance with the above standards and a second group of accidents where there was little or no compliance.

K.5.2.2 Sample Selection

Due to the relatively small number of incidents which are expected to occur the entire industry would be surveyed in order to gather a sufficient amount of information to allow a useful analysis to take place. Dodge Report information would be used to identify all steel or precast/prestressed erection sites where erection work was completed within the past year. Estimates discussed in Chapter 2 would indicate that there may be as many as 11,374 sites; however the work on these sites would have been preformed by approximately 4300 contractors. Each of these contractors would be contacted by mail.

K.5.2.3 Survey Design

A mail survey will then be designed based upon the legal right of the Department of Labor or the Department of Health and Human Services to request information from an employer. The survey will request a contractor to supply

copies of all OSHA 101 or equivalent forms which record an accident involving a connector during the past year on each site.

It will also be requested that the contractor provide the total number of man-hours spent by connectors on that job. This number, combined with the classification of the structure into one of the catagories presented in Table 10 (information necessary for this classification is available from the Dodge Reports), will allow the amount of fall exposure time to be estimated. For example, connectors working on a tiered building are exposed to a fall a large percentage of the time in that virtually all of their work takes place on the open steel. In contrast, a connector in a precast/prestressed concrete multistoried building is normally exposed to a fall greater than one floor only when working at the perimeter of the structure or around interior shafts, such as those used for elevators and stairs. Therefore, the exposure time is far less.

K.5.2.4 Tactic for Increasing Survey Response

A minimum of two mailings would be made to all contractors chosen as part of the sample. The first mailing would basically ask for voluntary cooperation, while the second would carry a stronger request based on the contractors legal responsibility for response.

It is recognized that if the response is relatively low, that the information derived from these mailed surveys may be biased. That is, those who respond may well do so because they have a very good accident history regarding connector falls and would like to influence a decision to modify the legal requirements for connector fall protection. Thus, a percentage of non-responding contractors will be chosen at random and telephone or personal visits to obtain the needed information would be made. It is possible that such visits could be made by OSHA personnel, as by this time the number of contacts which must be made may have reached manageable proportions, particularly when the geographic distribution is considered. OSHA personnel would not bias the information collected, as they would not be asked to make observation or conduct interviews. Rather, they would be responsible only for collecting existing documents. This procedure will allow the bias of the information gathered through voluntary responses to be estimated.

K.5.2.5 Processing of OSHA 101 Forms

A manual sorting of OSHA 101 or equivalent forms received from the sample would be necessary. This would be practical as it is estimated that approximately 4500 connectors are employeed during a normal year. Therefore, even a high response rate should yield a manageable number of accident reports. A preliminary sort would be done by concentrating on answers to the form questions: "What was the employee doing when injured?" and "How did the accident occur?" These or similar questions appear on all Employers First Report of Injury Forms. The objective of the first sort would be to isolate all connector accidents and all connector fall incidents. This task could be performed by relatively inexperienced clerical personnel after being trained regarding the type of information to consider.

TABLE 10 CATAGORIES FOR CLASSIFYING STRUCTURES

Structural Steel Connection

. multi-storied building over 2 floors in height

. building with a roof or floor structure more than 25 feet above a solid surface (not a powerhouse)

. bridge structure erected by ground cranes

. bridge structure erected by cable way

. tower

. power plant structures, such as those used to house boilers, precipitators, or reactors

Precast/Prestressed Structures

. multi-storied building over 2 floors in height framed predominantly with columns and beams

. multi-storied building over 2 floors in height using predominantly load bearing wall panels

. building with a roof or floor structure more than 25 feet above a solid surface

. bridge structure

Prefabricated Steel Construction

. multi-storied building over 2 floors in height

. building with a roof or floor structure more than 25 feet above a solid surface

A second sort of the information identified in the first process, would then be done by personnel more experienced at reading and interpreting the information presented on these forms. This process would isolate those falls which appear to have occurred during the connecting process and any other accidents which might have been caused due to a lack of mobility, structural collapse, etc. The results of this sorting process will likely reduce the number of accidents to a great degree.

The material would also be sorted to isolate any accidents which might have been related to the use of safety equipment. For example, injuries sustained because a connector was caught by a safety belt would be identified as would accidents which indicate the worker was crushed against a part of the structure. These accidents will be investigated to determine if the use of the required safety equipment is perhaps detrimental to the safety of the connector.

K.5.2.6 Telephone Survey

Telephone contact would then be made to the contractor reporting an accident which has been isolated by the sorting process. The contact would be designed to confirm that the incident involved a connector working at the point of erection and to gain further information about the incident. The following telephone agenda is provided to indicate questions that could be asked. The agenda would have to be field tested and validated before it is used to collect data.

K.5.2.7 Telephone Survey Agenda

Ask to talk to the person in charge of construction safety.

Identify yourself and explain the purpose of the study.

Confirm the information contained in the OSHA 101 form.

Items for Discussion:

What type of building was being erected?

Please explain exactly what the connector was doing at the time of the accident.

What type of member was he working to connect?

Discuss the surrounding structure at the time of the accident.

If the accident fits the profile of a connector fall accident or a profile of an accident caused by safety equipment, proceed with the remaining questions. If not, thank him for his time and politely end the call.

Determine the severity of the injury and the number of days lost.

How far was he from the nearest solid surface (i.e., a solid deck or the ground)?

Was he working at the perimeter of the structure? If so how far was he from the ground?

Was he wearing a safety belt at the time of the accident? If so, had he tied off the lanyard?

Was a safety net below him? If so, was he caught in the net? If not, why not?

If neither safety belts nor nets were being used, in your opinion, would this safety equipment have prevented the accident or decreased the severity of the injuries? Explain why or why not.

Was the connector a union member?

How many years of connecting experience did he have?

Did the contractor provide any additional training to the connector? If so, what did the training cover?

Should the training have helped to prevent the accident?

Did the connector receive any other training of which the contractor is aware?

Is any other technique used by their connectors to protect against falls?

If the accident involved crane operations, ask the following questions:

Determine exactly how the crane was involved.

Was the crane operator a union member?

How many years of experience did he have?

Had he worked on this type of job before?

How was he being signaled?

What was the capacity of the crane and the weight of the member being raised?

Did he receive any special training?

Could he see the location where the member was being placed?

Obtain the names and phone numbers (if possible) of the injured person, his foreman, and others who witnessed the accident. Explain that these people will be contacted to obtain additional information. When contacting these people use the telephone agenda presented above.

K.5.2.8 Collection of Unreported Data

In the evaluation of any standard, there are factors for which records are not generated. In this study, several factors fall into this catagory. One of the contentions of iron workers and contractors is that if they are forced to tie off which connecting, they will not be mobile enough to move away from pieces swinging out of control. If an accident is avoided because a man is not wearing a safety belt, no record is kept. Similarly, if a life is saved because a man falls into a net and is not injured, no record is kept.

It is vital that this information be collected for the evaluation of a standard. Research which only considers the fall accidents which have occurred would be naturally biased toward proving that compliance with the standard is necessary. Obviously, any fall would be less serious if the man is caught by a safety belt within a few feet or falls into a net system. The real question is how often would the installation of a net or the lack of mobility caused by a tied off safety belt have resulted in an accident? Some information regarding this question will be assembled as a result of identifying accidents that may have been caused by safety equipment (as explained in the previous discussion).

The most reasonable method of collecting non-reported information would be to accept anecdotal evidence gathered by interviewing connectors who have recently completed an erection job. To accomplish this, a sample of steel and precast/prestressed sites would be chosen. Personal or telephone contact would be made and an interview would be arranged with the people doing connecting work. Ideally the interview would be held soon after the completion of connection work.

An experienced interviewer, capable of conducting an informal, open-ended interview, and thoroughly familiar with connection procedures and safety would discuss incidents that happened on the job just completed. Information concerning near miss accidents falls into nets, use of safety equipment, and localized structural collapses would be sought. Each incident would be described in as much detail as possible. Collaborating evidence would then be sought from the site superintendent, raising crew foreman, safety officer, and other workers. Access to these people could be sought through the contractor, through the union, or if need be, by personal contact.

K.5.2.9 Personal Interview Agenda

Introduce yourself and explain the purpose of the project.

Items for discussion:

What type of structure was being erected?

What type of safety equipment was being used by connectors?

If safety equipment was being used, did it hamper the erection process or limit your safety?

If a net was being used, did a connector fall into it?

Was anyone injured installing the net?

Do you remember any situations where you had to quickly move further than 6 feet from your location to avoid being injured?

Did any member collapse or fall during the project?

What factors contributed to your safety on the job (i.e., experience of people, equipment used, good crane operator, etc.)?

What factors made your job more dangerous than it should have been?

For each of the above items use the questions listed on the telephone interview agenda to elicit more detailed information. Obtain as much detail about each specific incident as is possible. Also obtain the names of those that may have witnessed the incident.

K.5.2.10 Data Analysis

The basic line of analysis to be followed will be to compare and contrast the type of accidents which occurred and the anecdotal evidence concerning accidents that did not occur, for each of the major catagories of contractors. In very simplistic terms, the goal will be to determine, for each category of buildings, if the connector were safer when standards were followed, or safer when they were not. To do this, case histories of each incident will be prepared so they can be compared and contrasted.

Numerous statistical techniques can be used to analyze the data which has been assembled. Among these are regression analysis, analysis of variance, analysis of co-variance, and a host of multivariant techniques. The potential for using these techniques will depend partially upon the number of incidents for which data can be obtained. There may also be an excellent opportunity to use a relatively new technique, meta-analysis. This technique has proven to be valuable in analyzing and comparing information assembled by a variety of methods, such as the anecdotal information and the accident case histories as well as numbers of accidents, etc. The technique has proven remarkably adept at controlling bias to provide much more reliable conclusions than would otherwise be possible. A detailed discussion of authoritative analytic techniques would appear to be beyond the scope of this report and premature at this time.

K.6 RECOMMENDATIONS

An intensive pilot test and validation period is recommended. During this stage, the survey instruments would be further developed and tested with a small sample of typical respondents to assure that the items used provide appropriate information. Pretesting of several parallel items will probably be necessary, coupled with observations to determine the validity of the

information gathered. This study will also allow the quality of information provided on OSHA 101 or equivalent forms to be assessed. Completing the pilot test and validation phase will allow the techniques proposed above to be thoroughly tested to determine if the type of information which is needed is available and if it can be assembled.

At the end of the pilot test and validation phase, a cost/benefit analysis could be presented to predict the eventual success of the project and the cost of completion. At this time, the sponsoring agency would determine if work should proceed. It is estimated that the pilot test and validation phase, which would include obtaining Office of Budget and Management Approval for the survey instruments, would cost between $60,000 and $75,000. Total completion of the project is currently estimated to cost between $175,000 and $250,000.

APPENDIX L - STATISTICAL ENHANCEMENT OF SECONDARY DATA REGRESSION ESTIMATION

Subgrouping by industries and standards, and by other variables, will be important for the regression estimation. For the purposes of regression estimation of data, these classifications will serve an important purpose: They will allow us to determine the presence of regression discontinuities across different types of firms. There is no reason to believe that either bivariate or multivariate relationships among variables are the same for construction firms in the Southeast as for construction firms in the Northeast, as an example; or for residential construction firms as for commercial construction firms.

By including information aobut type of firm in regression equations (both as main-effect and as interaction vectors: the interaction between type and location of firm, for example, may be an important predictor), it may be possible to decrease estimation bias and to increase statistical predictive power by parceling error variance into regression vectors. It will be possible to control for regression discontinuity within the data sets, deriving potentially different regression equations for different types of construction firms and standards.

At first glance, simple multiple regression appears the method of choice for estimating data and deriving prediction equations. However, in addition to the typical problems associated with the use of linear multiple regression (e.g., error-fitting and multicollinearity), the present application presents some additional difficulties: a circularity enters the system. For example, if variables a and b are used to predict variable c, then the prediction becomes quite shakey when a, b, and c are used to predict d. Alternatively, if variables a and b are used to predict c, the use of b and c to predict a is clearly unfounded.

After logical analysis has been completed, we will have a better idea of the nature and inclusiveness of the data files. Until that point, we cannot be certain, but it may be that an extension of multiple regression, canonical correlation, would solve these problems. Briefly, canonical correlations derive the relationships between two composite sets of variables (canonical variates), instead of between one composite set of predictor variables and one predicted variable. An outcome of this process is the derivation of weights, multivariately analogous to the beta weights that are derived by simple multiple regression. These weights can subsequently be used to estimate data. They are the weak link in the chain, as they are in simple regression, but they are apparently the best route to impute any remaining missing data--and certainly canonical correlation appears the best means of solving the circularity problem noted above.

By judicious choice among the variables that currently exist and those that are created by the interactions of existing variables, it will be possible to develop a canonical correlation structure in which the two sets of variables are those with the least amount of multicollinearity within a canonical variate, and the greatest degree of relationship across canonical variates. By specifying that cases are to be rejected only on a pairwise basis (that is, rejected only when they have missing data on one of two variables and re-entered when they have valid data on both variables), as much data as possible can be retained for estimation purposes. So doing may introduce spuriously high relationships, and if there is a relatively large amount of remaining missing data, it may be preferable to delete cases entirely from the logical phase of the analysis and re-introduce them during the statistical phase.

Several equations, each associated with a different multivariate source of variation, can be extracted: each statistically independent of the other, each testable for statistical significance, and each providing a means of estimating remaining missing data.

It should be noted that several canonical correlation programs are in existence, most of them capable of accepting matrix input. Therefore, subsequent to the first logical process, a pass through the data should be made to extract a primary R-matrix of correlations among the file's variables (it should be noted that because the first estimation will not be done on a case-by-case basis, this R-matrix will contain some spuriously low relationships since certain vectors will be scalars within subgroups).

The same pass-through should also be used to test quadratic and higher-order relationships between variables which, owing to the results of the first data pass made during Phase I, are suspected to be nonlinearly related: the R-matrix will therefore contain variables that are the product of vectors that contain coefficients for quadratic (and higher) components with vectors that contain the original variables. This R-matrix can then be used, cheaply, for repeated executions of the canonical correlation routine, since the most expensive analytic portion of any regression analysis is the calculation of the zero-order correlations. We will substitute within the two sets of variables until attributed variance is maximized and multicollinearity is minimized. The canonical weights can then be applied to the file to estimate remaining data.

CROSS-VALIDATION

After the prediction equations have been replaced by estimators in the data, it will be desirable to cross-validate the equations. We can do this by gathering fresh data from selected firms in each industry. The selection can occur on a crossed- and stratified-random sample basis. It is not possible at present to specify the sampling criteria in full: the design matrix should be basedin large measure on the information obtained from the logical analysis results. However, it is clear that such a sample should be based in part on standard and type of firm.

Cooperation in providing a complete set of data may introduce sampling bias. It is quite likely that firms that are fully represented in any data source may well be substantively different from firms for which a few, several, or many data points are missing. Using a subset of firms that are currently fully represented in order to estimate data for other firms, or to cross-validate the estimated variables for other firms, relies on the assumption that intervariable relationships hold for both types of firms: formally, that orthogonality exists between number of missing data points and the size of the beta weights derived from the regression equations.

While, ex post facto, we have no control over this possibility, we can exert some control over the same possibility as it applies to data gathered from a sample of construction firms. Strictly, the same objection of non-orthogonality could apply in the latter case: we would depend on the cooperation of our sample of firms to supply us with the cross-validation data. However, the objection is a matter of degree: because our objective would be to collect complete data on a smaller number of firms, we would be able to exert more control over sampling bias due to respondent cooperation than we would by accepting, serindipitously, validation data from secondary sources.

If there is an insignificant departure in the size of the beta weights in the cross-validation sample from those in the prediction equations from secondary source data, then we can be confident of our estimation procedures. Should such a departure be significant, however, considerable doubt will be cast on the validity of the missing data estimators, and the only remaining course of action will be to recalculate the regression equations using both the original data and the cross-validation data. This would, of course, be an unsatisfactory approach; but it would be the best available in the event that the cross-validation failed to substantiate the regression estimation results.

After existing secondary sources have been amplified with the regression estimation procedures and cross-validations, each data set will be re-evaluated with an eye toward determining whether there is sufficient information, with the statistical amplification, to address the effectiveness of the standard. In those cases where there is not adequate data, secondary data sources will have to be supplemented by primary data collection.