NBSIR 83-2709

Status of Safety Net Standards for Construction and Research Needs

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Washington, DC 20234

September 1983

Prepared for
U.S. Department of Labor
Occupational Health and Safety Administration
Washington, DC

NBSIR 83-2709

STATUS OF SAFETY NET STANDARDS FOR CONSTRUCTION AND RESEARCH NEEDS

James H. Pielert

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Washington, DC 20234

September 1983

Prepared for
U.S. Department of Labor
Occupational Health and Safety Administration
Washington, DC

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, ***Secretary***
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

ABSTRACT

This report represents the status of standards for safety nets used in construction and identifies areas of technical inconsistency. Typical applications of safety nets are reviewed including the results of literature and field surveys. Major technical sections of seven standards are compared in a tabular format to highlight areas of agreement as well as requirements which vary and indicate lack of consensus. This information is analyzed and used to develop a list of research needs for safety nets.

Key words: construction; construction safety; occupational safety; safety nets.

PREFACE AND ACKNOWLEDGMENTS

This research was conducted by the Construction Safety Group of the Structures Division of the Center for Building Technology, National Engineering Laboratory, National Bureau of Standards (NBS). The work was sponsored by the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor as part of its effort to improve safety in the construction industry. Falls from elevated surfaces during construction are a principal source of worker casualties. Safety nets are used to impede falls in progress in many situations where active fall-protection devices are either impractical or ineffective. Areas of technical inconsistency have been identified in safety net standards along with needed research.

Special appreciation is extended to Dr. H.S. Lew and Dr. G. Fattel of the NBS Construction Safety Group for guidance and encouragement throughout this effort. Mr. Roy Gurnham and Mr. Allan Martin, technical representatives of OSHA, were also very helpful. Sinco Products Inc. provided many of the photographs of safety net installations used in this report.

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

1.1 BACKGROUND

Falls from elevated surfaces constitute a major portion of losses in human life and injuries in construction. The construction industry has one of the highest occupational disability and death rates, and it has been estimated that one of five workers faces the prospect of being injured or killed at a construction site [1, 2][1/]. Falls from walking or working surfaces are a major cause of these accidents.

The use of active fall protection equipment by construction workers, such as lanyards, safety belts, lifelines, rope grabs and shock absorbers, and controlled ascent and descent devices, tend to inhibit freedom of movement, particularly in congested work areas. The need for mobility, the speed of the erection process, and the lack of attachment points often make use of such devices difficult. As a result of this "nuisance" factor, workers are frequently reluctant to wear safety belts, upon which the effectiveness of an active system depends. The problem can be reduced significantly by using passive systems such as safety nets which can provide safety without requiring the active involvement of the person working above it. There are no statistics on the number of lives saved annually by safety nets. Safety net manufacturers claim that nets not only save lives and prevent injury, they also improve worker productivity [3, 4, 5]. However, it should be recognized that safety nets are but one of several approaches for insuring worker safety and safety nets are not always the most desirable approach.

While the safety nets used in construction were initially manila cargo nets, most manufacturers today use synthetic fibers, such as nylon, dacron and polypropylene. These synthetics have higher strengths than natural materials, weigh less, are more resistant to wear and the environment, and are more resilient, thereby providing a softer landing. Safety nets come in square patterns, with the mesh running at right angles to the edges, and in diamond patterns, with the mesh running at an angle of 45 degrees to the edges. They generally come in panels that range in size from 8 ft (2.4 m) x 8 ft (2.4 m) to 25 ft (7.6 m) x 50 ft (15.2 m). The attachment hardware, usually safety hooks, permits the panel increments to be joined to accommodate various configurations, or the nets can be spliced together by using a line threaded between the panels.

A report by Pals, Kane, and Marcello [3] evaluates the Occupational Safety and Health Administration (OSHA) standards regarding the use of safety belts, safety nets and training at the point of erection[2/] in steel and concrete structures.

1/ References are listed on page 34.

2/ Reference [3] defines "point of erection" 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."

While there are the obvious benefits to the use of nets described above, the report points out several limitations which should be considered:

1. Nets are generally more expensive than active protection systems.

2. Without advanced planning, there is often no secure anchorage to which nets can be attached.

3. It is often necessary to span large distances with nets (e.g., bridges) which can be time-consuming and expensive.

4. Time must be spent to assemble, disassemble, and move the net system as the construction process continues.

5. Safety nets can have significant impact on the use of cranes to handle construction materials by interfering with crane movement within or adjacent to the structure.

However, many of these concerns can be minimized with advanced planning if the use of safety nets is considered during the design process. As an example, the U.S. Corps of Engineers determines if safety nets are required before a project goes to bid and includes the requirements in the bid specifications. 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 by the successful bidder.

1.2 PURPOSE AND APPROACH

This research was conducted to identify the content and technical bases of criteria in standards related to the application of safety nets in construction, to determine areas where the technical bases are inadequate and to formulate a research agenda to address identified needs.

The approach used in this project was as follows:

A. U.S. and international standards for safety nets were critically reviewed and evaluated in terms of comprehensiveness, consistency, clarity, technical adequacy, and enforceability. Where possible, deficiencies in these standards were attributed to a lack of adequate technical information and/or underutilization of available data.

B. Available technical information on safety nets was compiled including research in the literature, information provided by net manufacturers, and data available from governmental agencies.

C. Selected construction sites were visited to identify current trends in safety net installations. Pertinent structural and geometric aspects of the various installations were documented along with physical constraints of the work environment.

D. Telephone and personal contacts were made with representatives of the safety net industry, contractors, enforcement officials, and unions.

E. Information collected above was used to develop a research agenda for safety nets used in construction.

No attempt was made to compile statistics other than those available in the literature on the types and locations of construction accidents. Where such data are given in this report, the pertinent references are cited.

2. TYPICAL SAFETY NET APPLICATIONS IN CONSTRUCTION

Safety nets have been used in a number of construction situations: buildings, bridges, power plants and other structures. The most common applications are discussed below. References [3, 4] present discussion of various net types from which much of the following is taken. The results of the field investigation are also incorporated into this discussion.

2.1 PERIMETER NETS

Perimeter safety nets, as shown in figure 2.1, have been used for some time as a type of safety device for workers in possible fall situations. The geometry of this type of net is controlled by the applicable standards shown in table 4.3. The minimum horizontal projection from the side of the structure is either 8 ft (2.4 m) or 10 ft (3.1 m), and the net must be positioned within 25 ft (7.6 m) or 30 ft (9.1 m) of the working surface above. The net must also have passed a prototype load test (table 4.2) and, according to some standards, an on-site load test as well (table 4.3).

Figure 2.2 shows schematically some of the available perimeter net systems. These systems differ primarily in the method of support and attachment to the structure. System A consists of a metal frame supporting the nets and attached to the building at floor level and supported by cables from the floor above. The net is sloped toward the building with the perimeter of the net higher than the perimeter of the building so that if a worker falls into the net, he will be thrown toward the structure. This system can be moved up and down the structure as needed and the frame support members can be taken apart and stored when not in use. However the system has two disadvantages; (1) the worker could fall onto the cables supporting the net and be thrown out of the building, and (2) the worker could fall on the net's metal support frame and be injured.

Perimeter net system B consists of movable metal pipes attached to the columns of the building with cables strung between them to support the safety net. The net and cables are attached to the pipe within the building and the pipes are then extended to the necessary distance from the building, unfolding the net to provide perimeter fall protection. When in position, the pipe is secured to the column. The net is at an angle to throw a worker back toward the building. The poles can easily be pulled back into the building to allow cranes or other equipment to work near the building. There are two disadvantages of the system; (1) a falling worker may hit the pole instead of the net and be injured, and (2) since the net is not at floor level, a worker could possibly fall under the net and out of the building.

Perimeter net system C consists of a net attached to a floor with cables and supported from the floor below with support arms. Since the supporting structure for this system is below the net, a worker falling into the net would be less likely to hit one of the pipe supports. The net will fold against the building when catching a worker or debris. The net can be folded against the building to allow cranes or other equipment to work near the building. As with other perimeter net systems, the attachment mechanism must be preplanned during the design phase.

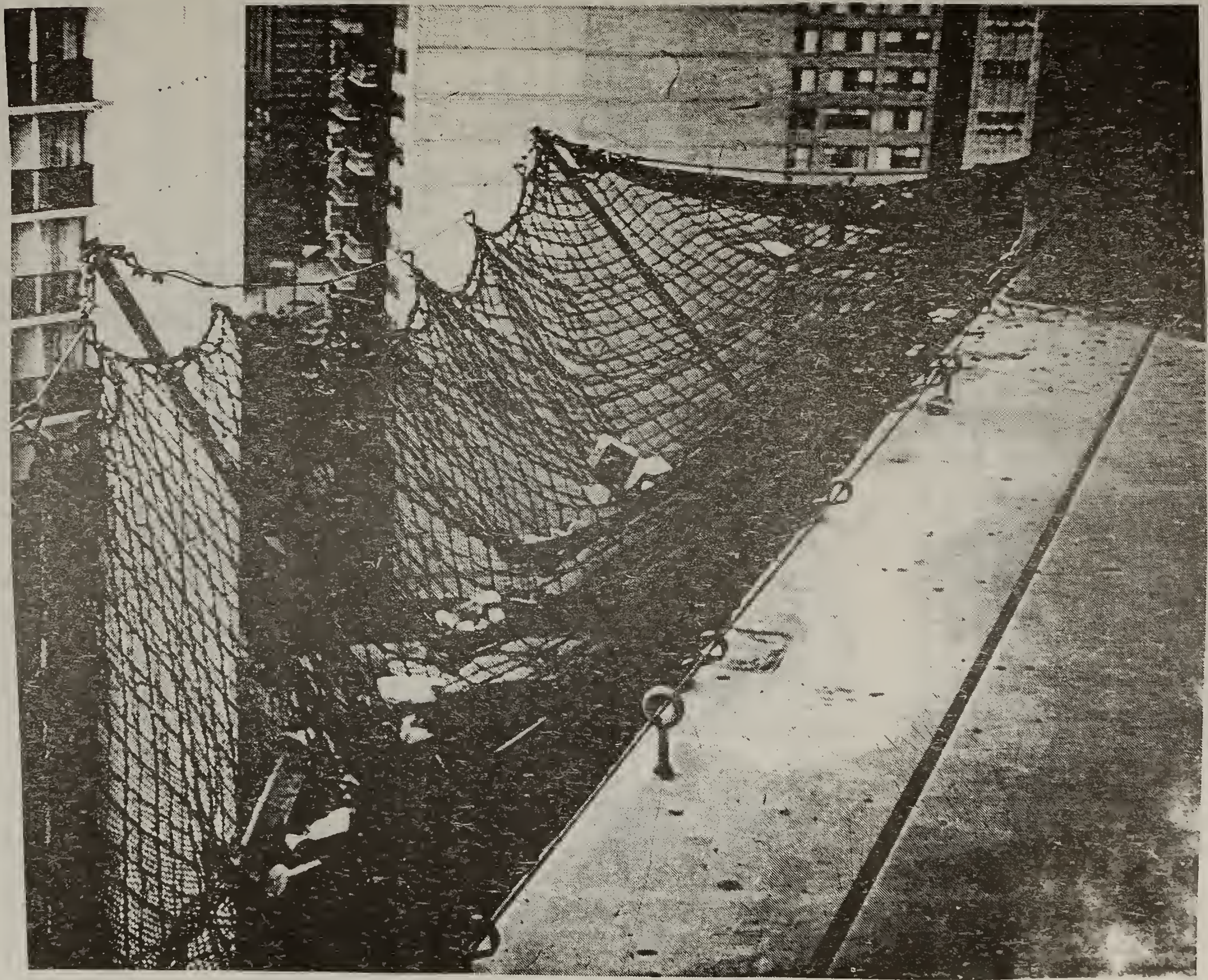

Figure 2.1 Use of perimeter safety nets in building construction

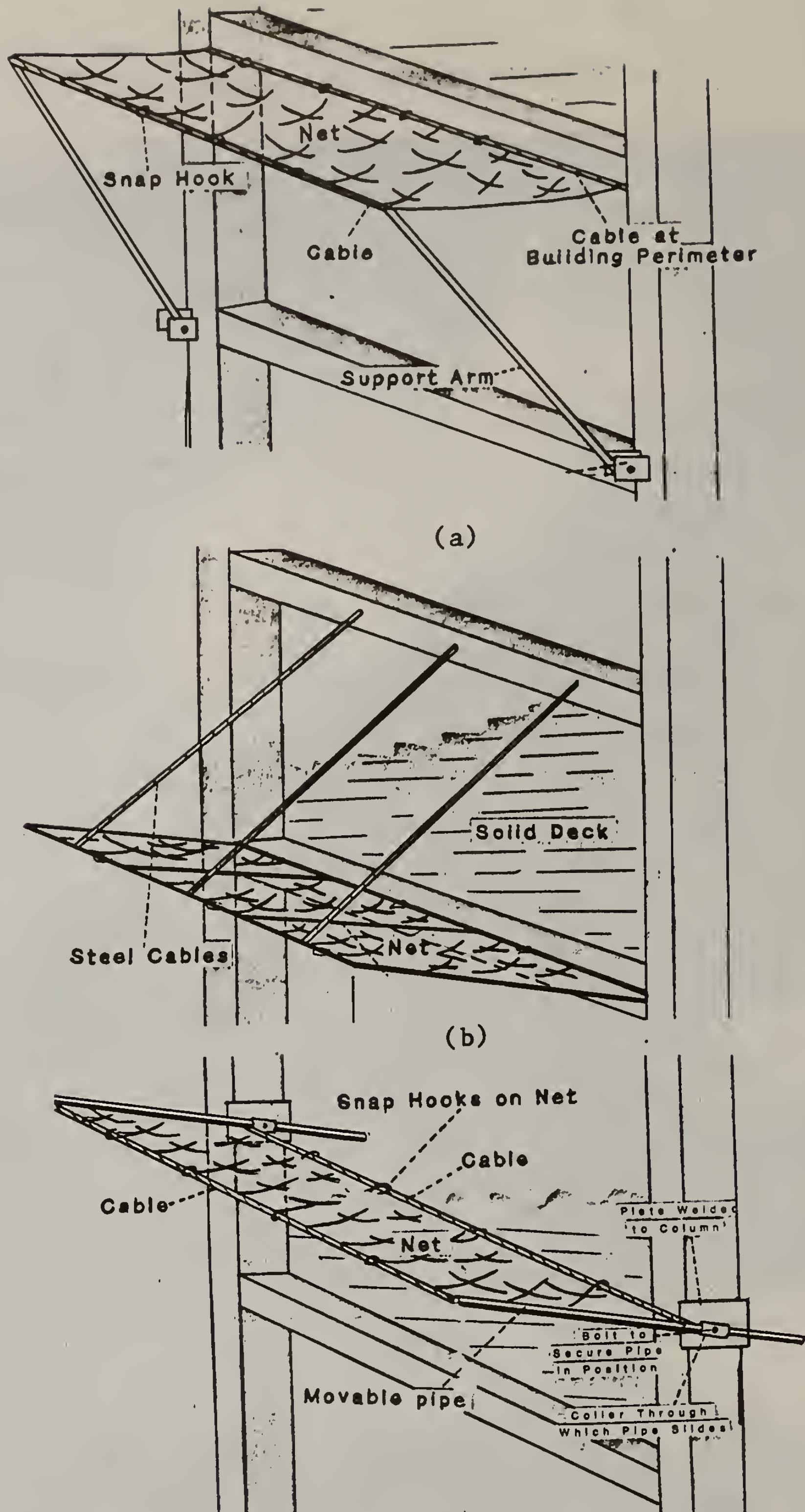

Figure 2.2 Various types of perimeter net systems 1/

1/ Figure is taken from reference [3]

Cost estimates have been developed for a perimeter net installation for a 10-story steel frame structure covering an area of approximately 250 ft (76.2 m) x 70 ft (21.3 m) [3]. The cost for rental of nets and supporting hardware and labor for installation and movement was estimated at about $14,000 (1982). This did not include cost effects caused by crane use and delays in project completion caused by installation of nets.

The discussion of typical perimeter net systems is not intended to be all inclusive, but only representative of many possible configurations. While using the basic configuration, manufacturers may vary attachment methods, support hardware, and installation/removal procedures which could have a significant impact on costs. Costs will also be affected by configuration of the structure, accessibility of the structure for construction equipment, and the construction sequence used.

2.2 INTERIOR NETS

Interior nets can be installed in a variety of ways when a substantial structure is available beneath the construction operation. Figure 2.3 shows an interior net system in a steel tier building. There are various methods for attaching the nets to the structure: (1) the nets could be connected to the steel frame as shown on figure 2.3; (2) when support beams are not available; cables can be run from column to column to encompass the area with the nets mechanically attached to the cable; and (3) a separate frame can be constructed to support the nets which could be moved from location to location as protection is needed. There are, of course, many other possibilities for interior net configurations which depend on specific site conditions. The use of safety nets should be considered during the construction management phase in order that special connectors can be fabricated into the building members to provide for more efficient net installation.

Although interior nets are very effective for catching personnel and debris, there are several disadvantages (see figure 2.3): (1) a falling worker could strike the steel structure supporting the net instead of the net; (2) a worker could impact a structural member higher up in the building before hitting the net; (3) an impact force could cause the net to be cut by any sharp edges present on structural steel members on which the net is draped; and (4) the nets could interfere with vertical movement of material and equipment in the building. Costs of interior net systems are difficult to generalize because of the many different construction situations encountered.

2.3 BRIDGE NET INSTALLATIONS

Safety nets are commonly used in bridge construction and maintenance. During construction of the Golden Gate Bridge, 19 men who fell from the structure were caught in safety nets [5]. It is relatively easy to install nets on the erected bridge structure to protect those installing the deck and doing other jobs (figure 2.4). A major problem is how to provide nets for workers who are installing 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 section being erected.

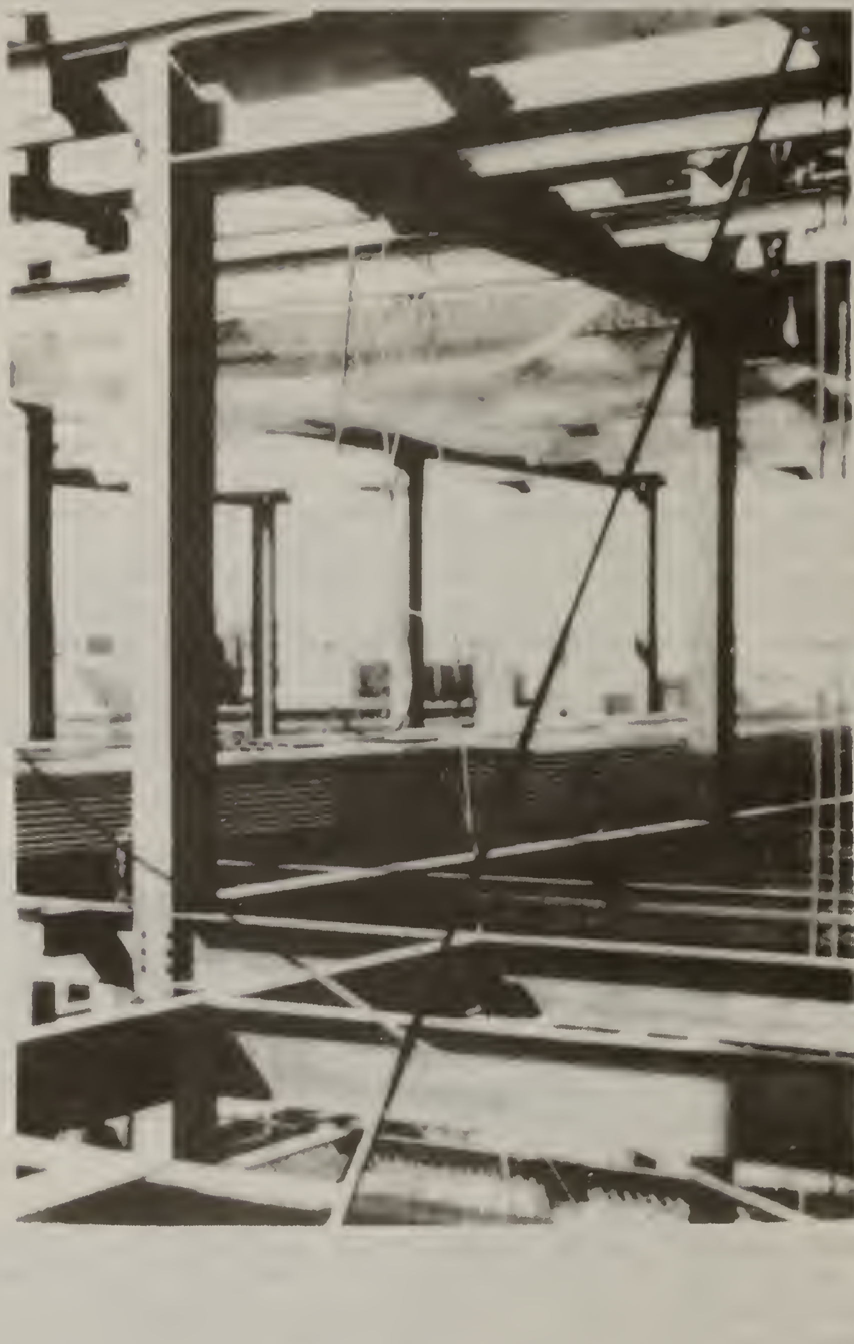

Figure 2.3 Interior net system in steel tier building[1/]

1/ Photograph courtesy of Sinco Products Inc.

Figure 2.4 Use of safety nets under bridge structure[1]

[1] Photograph courtesy of Sinco Products Inc.

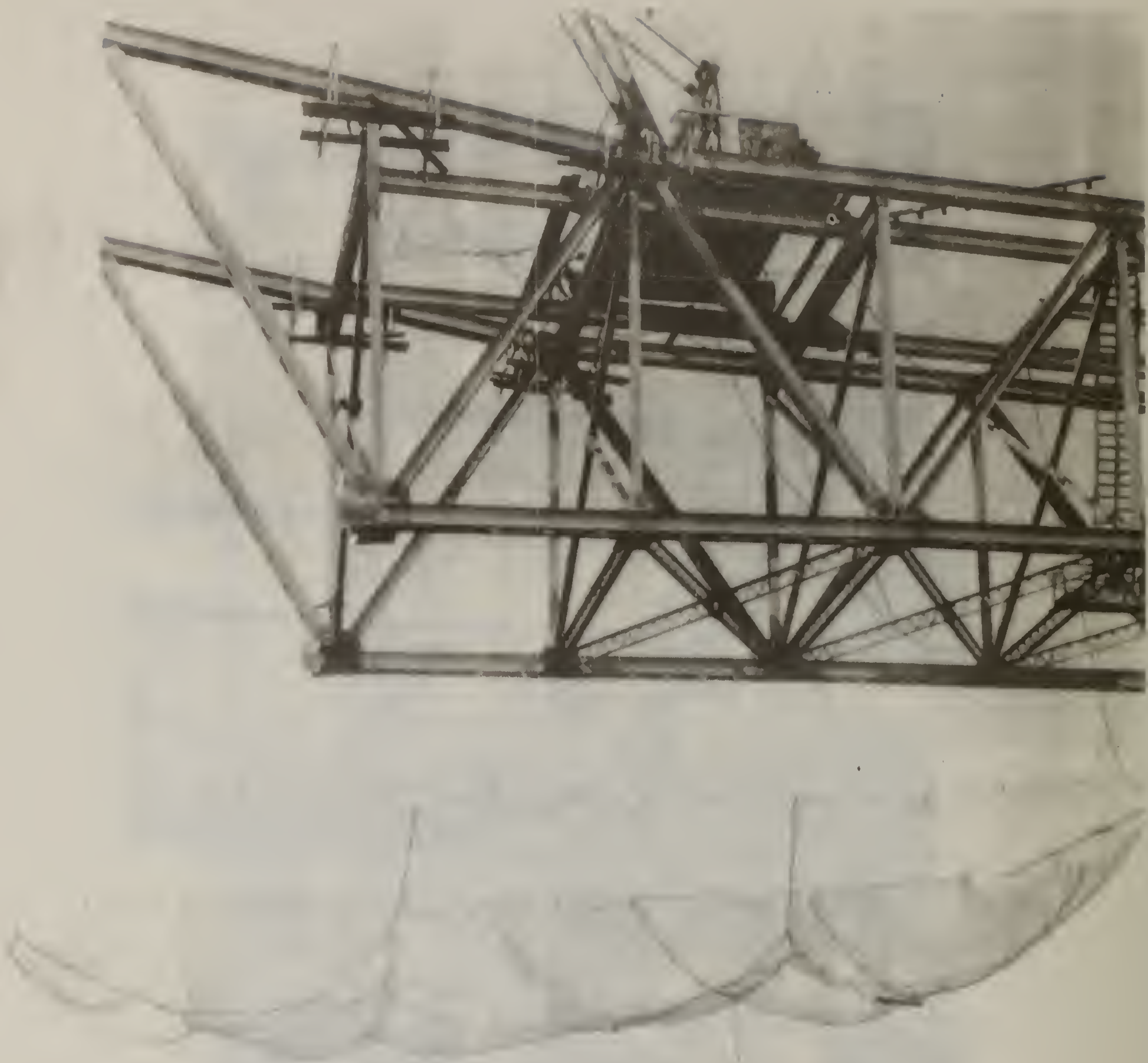

Figure 2.5 Safety nets on cables between bridge piers to protect workers installing new sections of bridge[1/]

1/ Photograph courtesy of Sinco Products Inc.

It is often possible to install cables between bridge piers to support the nets before the structure is in place as shown on figure 2.5. Application of this concept depends on the location of the bridge, type of terrain spanned (land, water), construction techniques used to place bridge members, length of bridge span, etc. Reference [3] provides case studies of actual bridges where innovative approaches for safety net installation were used.

A U.S. Corps of Engineers study of net installations on five bridges showed that costs ranged between 0.3 and 3.2 percent of total contract costs [3]. These estimates included only costs of nets and labor, but not the cost of additional design nor of hardware nor special support structures.

3. LITERATURE SURVEY RESULTS

A survey was conducted to find available literature relating to technical aspects of safety net systems used in construction. The content of each of these is summarized below:

A. A Study of Personal Fall-Safety Equipment [1]

This research was directed towards providing a valid basis for developing a comprehensive OSHA performance standard for fall-safety systems and their components. The project methodology included a literature search, work site visits, and laboratory testing. The primary components in the investigation included active fall-arrest equipment such as safety belts, harnesses, lanyards, and lifelines. Safety nets were not included. However, information which could be useful in safety net research is provided on the physics of fall arrest, physiological aspects of fall injuries, and anthropometric applications.

B. Occupational Injuries in the General Building and Heavy Construction Industries [2]

This study was conducted to identify significant hazards in the general building and highway construction industries and to recommend solutions to reduce the injury and severity rates. The study involved an analysis of Federal and state regulations and an evaluation of relevant safety problems. Actual accident/injury case records were reviewed to identify causal factors and to determine the extent of OSHA coverage. Safety nets were listed as one of the five problem areas highlighted in the 261 accident/injury case reports reviewed during the field investigation effort. The other areas listed are education and training, protective headgear and medical screening. The only recommendation made relative to safety nets was to reduce the vertical distance between the working level and the safety net to 10 ft (3.1 m) from 25 ft (7.6 m). Experience in California showed this reduced distance has caused a significant reduction in both the number[1/] and severity of accidents.

C. Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection [3]

The effectiveness of OSHA construction standards at the point of erection was evaluated for steel and precast/prestressed concrete erection. Construction workers at the point of erection install the first members in the structure where there is little support or room for error. According to the study, the need for mobility, the speed of the erection process, and the lack of attachment points often make it difficult to implement construction safety standards. An extensive field assessment of the construction process is documented and related to the OSHA enforcement process. The

---

1/ Cases where workers are successfully caught by safety nets are often not reported as accidents.

feasibility of using various safety belt systems, safety nets, and implementation of training programs are discussed. Various safety net standards are evaluated and economic comparisons of various fall protection systems are provided. Research areas for safety nets are identified as follows:

"1. Design criteria are needed for determining if a net system is safely designed and constructed. There is currently no way to evaluate the adequacy of an installed net except by load testing prior to use. There are no specifications on the way a net should be rigged, the force it will withstand, or the strength requirements of support elements.

2. A standardized procedure should be specified for impact testing an installed net system. Currently, standards vary from very general performance requirements to specific criteria for net configuration, loading system, and test results evaluation. A technically valid procedure is needed.

3. Specific information should be provided to establish how often debris should be removed from a net and when inspections should take place."

Comparison of the various standards indicated that the OSHA [13] and the CAL/ OSHA [20] standards expressed a preference for safety belts over safety nets. The CAL/ OSHA steel erection standard specifies that nets should be used to protect connectors[1/] when tying off to the structure is not possible. The need 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 is not covered in the standards. An example is provided in the reference where a fatality occurred because of rebound from a net system installed in compliance with the standard.

D. Perimeter Net Systems - A State-of-the-Art Study [6]

An analytical model is presented on perimeter net systems which includes the interrelationships between the impact force and net response. Parameters considered in the model include safety net properties, horizontal component of velocity, weight of the falling person, and the distance of the fall to the net. Simplified tables are presented for evaluating these variables. There were no test data presented to validate the model.

The following conclusions are presented relative to the perimeter safety net parameters evaluated:

1. The horizontal velocity and fall height of a falling person are the two major factors for determining the required net width projection.

2. Connections, type of net support system, and the behavior of net rope under impact forces are the principal parameters in the determination of net deformation and deceleration forces.

1/ Personnel who erect steel members.

3. Rope construction and mesh configuration are important factors in calculating the force distribution of the system.

4. Magnitude of impact force is significantly dependent upon the location at which the falling person strikes the net.

5. A light weight falling person results in less tensile force in the rope, but is subject to a large impact deceleration G value.

6. Net dimension does not significantly affect the tensile force acting on the net rope.

7. The maximum value of the allowable impact deceleration is an important and non-negligible parameter in the determination of the net application.

8. The most effective way to achieve the desired softer landing is by reducing the fall height or by providing the most flexible system.

The paper calls for additional research including: (1) accurate information on mesh-rope properties under various loading; (2) maximum human tolerance limits for the falling person; (3) effect of non-uniform flexibility of net and its support system; and (4) on-site tests and field inspection procedures.

E. <u>Safety Nets - Fall Protection for the Construction Industry [7]</u>

A general discussion of safety nets is provided including definitions, specifications, installation techniques, job testing, and care and maintenance. This is a revision of the National Safety Council Data Sheet 608 published in 1974 [8]. The data sheet explains with the aid of illustrations and charts the hazards and benefits of safety nets and procedures to follow in their use and placement.

F. <u>Safety Belts, Lifelines, Harnesses and Nets Offer Fall Protection [8]</u>

This paper is primarily concerned with belts, lifelines, and harnesses including applicable regulations, and care, testing and inspection. Safety nets are discussed only briefly and the reader is referred to ANSI A10.11-79 [12] for further information.

G. <u>The Safety Net Standard: When Does it Apply [10]</u>

A United States Court of Appeals decision on an interpretation of OSHA's safety net standard 1926.105(a) is discussed. The effect of the ruling in the case was to make some form of fall protection mandatory for all workers stationed higher than 25 ft (7.6 m) above ground. Ladders, scaffolds, lines, and lanyards are acceptable, but if it is not practical to use any of them, the employer must provide safety nets.

H. Safety Net Result: Money Spent, Lives Saved [11]

A general discussion on the use of safety nets in construction is given including typical applications, safety concerns, and cost considerations. Instances where workers were saved by nets are described; nine workers were saved on the construction of the Sears Tower in Chicago and 19 men who fell during the construction of the Golden Gate Bridge were caught by nets. Advantages of safety nets are discussed including saving lives, preventing injuries, and making construction workers more productive because they are more confident about their safety. Disadvantages include costs and time of net erection, interference with the erection process, and hazards associated with net installation.

I. Net Gains for Accident Prevention [12]

Applications of safety nets by the English firm of Bridport-Gundry Ltd. are described including the history, market perspective, costs, and testing and inspection procedures. Specific costs are not provided but they are often justified by the knowledge that insurance premiums would increase if a worker was killed or badly injured.

J. Guidebook on Anthropomorphic Test Dummy Usage [13]

This report discusses the role which may be played by impact testing of anthropomorphic test devices (dummies) in coping with the high incidence of safety problems related to building structures. It discusses their use in safety countermeasure development, compliance testing, and problem identification through accident reconstruction. The primary emphasis on dummy applications is for simulating human injuries which occur during the normal and abnormal usage of common structures such as doors, railings, floors, and a variety of products utilizing architectural glazing materials. The role of dummy testing in saftey net applications is not specifically covered.

4. TECHNICAL COMPARISON OF CONSTRUCTION SAFETY NET STANDARDS

The following standards for safety nets used in construction have been reviewed and the technical provisions are compared in tables 4.1 through 4.4. Criteria in these standards have been broken down into the following categories; material-specifications, prototype testing, installation, and on-site testing.

A. OSHA Part 1926.105, Safety Nets [14]
B. ANSI A10.11-79, Minimum Requirements for Safety Nets [15]
C. U.S. Army Corps of Engineers, 07.D Safety Nets [16]
D. British Standard CP93-72, The Use of Safety Nets on Construction Workers [17]
E. British Standard BS3913-73, Specification for Industry Safety Nets [18]
F. Proposed OSHA 29 CFR 1926, Subpart M, Safety Net Systems [19]
G. California/OSHA Standard, Article 24, Safety Belts and Nets [20]

4.1 MATERIAL SPECIFICATIONS (table 4.1)

Only the ANSI A10.11 [15] and the Corps of Engineer standards [16] give a general prescriptive designation of minimum acceptable rope material used in the net; "3/8-inch diameter No. 1 grade pure manila, 1/4-inch nylon or 5/16-inch polypropylene rope." Additionally, the ANSI A10.11 standard [15] states that the net "shall be fabricated of materials that provide a minimum breaking strength of 4000 pounds (17.8 kN)."

The OSHA 1926 [14], ANSI A10.11 [15], Proposed OSHA [19], and the California/OSHA [20] standards require a minimum breaking strength of 5000 pounds (22.2 kN) for edge ropes. The Corps of Engineers standard [16] requires performance equivalent to a prescriptive rope while the British standards [17, 18] have no similar requirements.

The British standards [17, 18] require that the length of mesh size shall not be greater than 4 in (100 mm) while all other standards specify a maximum size of 6 in (152 mm) by 6 in (152 mm).

The OSHA 1926 [14] and California/OSHA [20] standards requires that the nets bear a label of proof test. ANSI A10.11 standard [15] requires a label stating name of manufacturer, identification of net material, date of manufacture, date of prototype test, and name of testing agency. The British standards [17, 18] require a label with manufacturer's name, nominal size of net, number of applicable British standards, date of manufacture, and maximum distance below the working height at which the net is designed for use.

Table 4.1 Comparison of Material Specifications in Safety Net Standards[1/]

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
General Net Materials Specification	None specified	4. Materials 4.1 Each unit of net width and length equal to 6x6 inches shall be fabricated of materials that provide a minimum breaking strength of 4000 pounds. This may be achieved by the use of 3/8-inch No. 1 grade pure manila rope, 1/4-inch nylon rope, 5/16-in. polypropylene rope, 1-inch nylon webbing or their equivalents.	0.7.D.07 Material and fabrication shall provide impact strength per unit of net width or length equal to 6-inches x 6-inches spacing of 3/8-inch diameter No. 1 grade pure manila, 1/4-inch nylon or 5/16-inch polypropylene rope. Rapid loss of strength of small members should be considered.	None specified	None specified	None specified
Mesh Size	(d) The mesh size of nets shall not exceed 6-inches by 6-inches....	5.1 The maximum size of mesh shall not exceed 36 square inches or 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 crossings shall be anchored to eliminate frictional wear and prevent enlargement of the mesh opening.	0.7.D.06 The maximum mesh size of nets shall be 6-inches by 6 inches.	BS3913 4.1.... Nets shall be made with a square or diamond mesh and the length of mesh size shall be not greater than 10cm.	(7) The maximum size of the safety net mesh shall not exceed 36 sq. inches (230 cm) nor be longer than six ins. ($15cm^2$) on any size measured center-to-center of mesh ropes or webbing. All mesh crossings shall be secured to prevent enlargement of the mesh opening.	Section 1671-Safety Nets (c) The mesh size of nets shall not exceed 6 inches by 6 inches.
Border of Net	(d)..... Edge ropes shall provide a minimum breaking strength of 5000 pounds.	5.2 Each net (or section of it) shall have a border of rope or webbing. The minimum sizes for border materials shall be 3/4-inch-diameter manila rope, 1/2-inch diameter filament nylon rope, 5/8-inch diameter spun nylon rope, 5/8-inch polypropylene rope, or 7/8-inch-wide nylon	07.D.07 Edge ropes shall provide a minimum breaking strength of 5,000 pounds (22.2 KN)	CP93 3.3.1 Nets, border cords, and ties should be of a minimum strength and quality at least equal to that required to comply with the requirements of BS 3913. BS3913-73 3.1 Cords. The mesh cord, border cord and tie cord	(8) Each safety net (or section of it) shall have a border rope for webbing with a minimum breaking strength of 5000 pounds (22.2 KN).	Section 1671-Safety Nets (c) Edge ropes shall provide a minimum breaking strength of 5,000 pounds.

1/ Standards are quoted without change.

Table 4.1 (Continued)

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
Border of Net (cont.)		webbing. Although other materials may be used, no border material shall have a breaking strength of less than 5000 pounds when new.		shall be flexible, uniform and as free as practicable from defects in the preparation of yarn, strands and in finishing.		
Identification of Nets	(d).....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 <u>label of proof test</u>.	6. <u>Identification of Nets</u> Each net shall be permanently labeled with the following information: 1) Name of manufacturer 2) Identification of net material 3) Date of manufacture 4) Date of prototype test 5) Name of testing agency	None specified	<u>BS 3913</u> 9.1 The safety nets shall have a label attached marked with: 1) the name, trademark or other means of identification of the manufacturer; 2) the nominal size of the safety net; 3) the number of this British Standard, i.e. BS3913; 4) the date of manufacture; 5) the maximum distance below the working height at which the net is designed for use.	None specified	<u>Section 1671-Safety Nets</u> (c) 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.

4.2 PROTOTYPE TESTING (table 4.2)

The prototype test loading procedures in the standards vary relative to energy input and method of load application.

OSHA 1926 [14], Corps of Engineers [16], and California/OSHA [20] standards specify a minimum net impact resistance of 17,500 ft-lb (23,700 J) without designating the weight or height above the net of the test load. The ANSI A10.11 [15] standard specifies a 350 pound (159 kg) bag of sand dropped 50 ft (15.2 m) for an energy input of 17,500 ft-lb (23,700 J). The Proposed OSHA standard [19] requires that safety nets and their installation be capable of absorbing the impact of a 400 pound (180 kg) of sand dropped into the net from the walking/working level to be protected. The British standards [17, 18] specify that a 309 pound (140 kg) bag of sand be dropped from a height equal to the duty of the net but not less than 19.7 ft (6 m) and not more than 39.4 ft (12 m). The ANSI A10.11 standard [15] and the British standards [17, 18] require drop tests into three different locations.

The ANSI A10.11 standard [15] and British standards [17, 18] provide configuration criteria for the prototype test frame. ANSI A10.11 standard [15] requires a 17-ft (5.2-m) by 24-ft (7.3-m) test frame elevated sufficiently to prevent the net, when hung, from contacting any surface below the net during the test. British Standard BS 3913 [18] specifies that the dimensions of the frame conform to the net being tested with necessary sag being provided.

Pass/fail criteria in the standards range from meeting acceptable performance levels to specific prescriptive criteria. OSHA 1926 [14], Proposed OSHA Standards [19], and California/OSHA [20] require that the prototype net meet acceptable performance standards of 17,500 ft-lb (23,700 J). ANSI A10.11 standard [15] specifies that there be no broken strands or significant distortion after the prototype test. Corp of Engineers standards [16] requires that the net suspension system be designed and constructed with a safety factor of four. British Standard BS 3913 [18] specifies that the net shall retain the test load without failure or excessive displacement of any of the chords of the net.

4.3 INSTALLATION CRITERIA (table 4.3)

Safety nets are generally required when the work surface is higher than a specified distance above the ground, machinery, water surfaces, or other surfaces where the use of other safety devices may be impractical. All the standards specify such a minimum distance above which safety nets are required. The Proposed OSHA standard [19] specifies 6 ft (1.9 m). The British standards [17, 18] specifies 6.5 ft (2.0 m) while all others use 25 ft (7.6 m). The ANSI A10.11 [15], Corps of Engineers [16], and British standards [17, 18] specifically discuss the need for safety nets to protect public traffic and workmen from falling objects.

All the standards specify a maximum distance between the working surface and the safety net: 25 ft (7.6 m) in OSHA 1926 [14], Corps of Engineers [16], and Proposed OSHA [19]; 30 ft (9.1 m) in ANSI A10.11 [15]; 19.7 ft (6 m) to 39.4 ft

Table 4.2 Comparison of Prototype Testing Procedures in Safety Net Standards[1/]

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
Prototype Test Loading	(d) 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.	7.2.3 A 350-pound bag of sand 24 inches (±2 inches) in diameter shall be dropped into the net from a height of 50 feet once at each of the three points formed by the intersection of the quarterpoints of the long dimension (6-foot intervals from the end of the net) with the center-point of the short dimension (8-1/2 feet from the side of the net).	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.	BS 3913-Appendix A .....The test is conducted by dropping a free falling bag of sand of mass 140 Kg three times from a height equal to the duty of the net but not less than 6 m and not more than 12 m above the test frame on table centre of the net, and, in addition, one drop on to a point on a diagonal 100 cm from one corner of the net and one drop halfway along any side 60 cm from the border cord of the net (see Fig. 1). The bottom of the test load shall be hemispherical with a radius of 20 cm (1260 cm^2 cross sectional area).	(4)(i) Each safety net and safety net installation shall be drop-tested in accordance with subparagraph (ii) below or be certified by a qualified person to be in compliance with the provisions of this subsection. (ii) See Table 4.4	Section 1671-Safety Nets (c) 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.
Prototype Test Frame Configuration	None specified	7.2.1 A 17x24-foot net shall be secured in a frame as shown in Fig. 1. The test frame should provide an opening that is the same size as the net as hung. The frame shall be elevated sufficiently to prevent the net, when hung, from contacting any surface below the net during the test. 7.2.2 When hung, the net shall sag not more than 3 feet at its center. The border rope shall be level.	None specified	BS 3913-Appendix A The net shall be supported on a rigid framework so as to be suspended as shown in Fig. 1	None specified	None specified

1/ Standards are quoted without change.

Table 4.2 (Continued)

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
Prototype Test - Pass/Fail Criteria	See (d) previous page	7.2 The impact resistance of the net shall be such that it will absorb three drops of test weight described in 7.2.3. There shall be no broken strands or significant distortion of the net pattern at the end of the second drop. The test procedure shall be as outlined in 7.2.1 through 7.2.4.	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.	CP 93 5.1 Testing Safety nets should be tested only in accordance with BS 3913. The strength of the net should be proved by the loading test described in BS 3913 on a standard net of the same type or construction. In no circumstances should a net which is to be used for the safety of personnel be subjected to a loading test. 7.3 ... The net shall retain the test load without failure or excessive displacement of any of the cords in the net.	None specified	See (c) previous page
Certification of Prototype Test by Msnufacturer	See (d) previous page	7.1 The impact resistance of each safety net shall be certified by the manufacturer after a prototype of the identical construction has been subjected to and successfully passed the qualification test described in 7.2.	None specified	BS 3913 9.3 The manufacturer shall supply a certificate with each net or batch of nets of the same type and construction which specifies: 1) the type of net, the method of construction and the materials used; 2) the breaking strengths of the mesh and border cords in the net supplied; 3) the breaking strengths of the mesh and border cords in the net which hss been tested in accordance with Appendix A; 4) the height of drop with the proof net of the same construction successfully withstood.	(4) Safety nets and their installations shall be capable of absorbing the impact of 400 pound (180 kg) bag of sand 30 ± 2 inches (76 ± 5 cm) in diameter dropped into the net from the walking/working level to be protected. (i) Each safety net and safety net installations shall be drop-tested in accordance with subparagrsph (ii) below or be certified by a qualified person to be in compliance with the provisions of this subsection. (ii) See table 4.4	See (c) previous page

Table 4.3 Comparison of Installation Criteria in Safety Net Standards[1/]

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
Use of nets vs. location of workplace above surface.	(a) Safety nets shall be provided when workplaces are more than 25 feet above the ground or water surface, or other surfacea where the use of ladders, scaffolds, catch platforms, temporary floors, safety lines or safety belts is impractical.	3.1 Safety nets ahall be provided when persons are working 25 feet or more above the ground, water, machinery, or any other aolid surface and are not otherwise protected by safety belts, lanyards, life lines, and scaffolds, or working surfaces guarded in compliance with other applicable American National Standarda.	07.D.01 Safety nets ahall be provided when workplacea are more than 25 feet above the ground, machinery, water surface, or other surfacea where the use of ladders, acaffolds, catch platforms, temporary floora, lifelines, or safety belta ia impractical.	CP93 2.1 During building operations and works of engineering construction, aafety neta should be auapended at or below areas or places from which men may fall a diatance of more than 1.98 m (6.5 ft) and other precautions are impractical or where neta are considered to be an esaential addition thereto.	501(b) Employees on floors, roofs, and other walking/working aurface 6 ft (1.8 m) or more above lower levels ahall be protected from falling to these levela, and from falling through or into the walking/working level by the uae of guardrail aystems, body-belt aystem, or safety net ayatem (with certain acceptions).	Section 1671-Safety Nets (a) Where the elevation is 25 feet or more above the ground, water surface, or continous floor level below, and when the use of safety belts and lifelinea 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.
Use of nets over public traffic areas	None Specified	3.2 Public traffic or workers shall not be permitted underneath a work area unlesa they are protected from falling objects. In auch cases, neta shall be lined with a mesh of the size and strength aufficient to contain tools and materials capable of cauaing injury (see 5.3).	07.D.02 Where public traffic or workmen are required to be under a work area, aafety neta shall be required.	CP93 2.1.1 Consideration ahould also be given to the use of aafety neta where conditions are such that the aafety of persons and the protection of property below cannot be adequately ensured without their use. (See Table 4.3, Net Lininga)	None specified	None specified
Net Location vs. Working Level	(c)(1) Nets ...... 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 structurea below. Such clearances ahall be determined by impact load testing.	9.2 Nets ahall 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 structures below when the user's impact load teating is applied. (Exception: On bridge construction the lowest part of the atructure should be considered the highest working surface.)	07.D.01 ... Nets shall be installed as cloae under the work as practical but in no caae more than 25 feet (7.62 m) below such work surface.	CP 93 3.1 Siting Neta ahould be inatalled as cloae under the working levels as practicable and no lower than 6 m for neta complying with the requirementa of BS 3913. Special design consideration ia needed when it is necesaary to exceed 6m but in such caaes it ia recommended that the height should not exceed 12m.	(1) Safety neta shall be installed aa cloae as practical under the walking, working surface on which employees work, but in no case more than 25 feet (7.7 m) below such level. Exception: the 25 foot (7.7 m) limitation does not apply to nets uaed on bridge construction.	Section 1671-Safety Nets (g) The exterior and/or interior perimeter of the structure shall be provided with an approved-type safety net extending at leaat 8 feet horizontally from such perimeter and being positioned at a distance not to exceed 10 feet vertically below where auch hazards exist (25 feet for steel erection).

1/ Standards are quoted without change.

Table 4.3 (Continued)

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
Horizontal projection of Net from Structure	(c) (1) Nets shall extend 8 feet beyond the edge of the work surface where employees are exposed....	9.5 Safety nets shall extend outward 8 feet horizontally from the outermost projection of the structure.	07.D.05 Nets shall extend 8 feet (2.44 m) beyond the edge of the work surfaces where workmen are exposed.	CP 93 3.3.1 ...When erected, outrigged nets should project horizontally a minimum of $(2 + \frac{1}{5} H)$ m beyond the outermost working point above the net, where H = the vertical distance in meters between the net and the outermost working point above.	(3) Safety nets shall extend outward at least ten feet (3 m) from the outermost projection of the work surface.	Section 1671-Safety Nets (a) 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.
Attachment of Nets	(f) Connections between net panels shall develop the full strength of the net.	9.3 When two or more nets are secured together to form a larger unit, they shall be laced at not more than 6-inch intervals with a lacing material equal in strength to the mesh rope or webbing. Drop-forge shackles or safety hooks may be used instead of lacing.	07.D.10 Connections between net panels shall develop the full strength of the net.	CP 93 3.3.3 ...Connections between adjacent nets should be capable of developing a strength at least equal to that of the net.	(10) Connections between safety net panels shall develop the full strength of the net and shall be spaced at intervals not more than six inches (15 cm) apart.	Section 1671-Safety Nets (e) Connections between net panels shall develop the full strength of the net.
Attachment of Nets to Support Structure	(e) Forged steel safety hooks or shackles shall be used to fasten the net to its supports.	9.4 Drop-forge safety hooks or shackles shall be used to fasten the net to its supports.	07.D.09 Forged steel safety hooks or shackles shall be used to fasten the net to its supports.	CP 93 3.3.3 Attachment of the net to the supporting framework - The net should be securely attached to the supporting framework using tie cords, hooks, rings or thimbles.	(9) Attachments to the supporting cable, structure or beam shall be spaced at intervals not more than four feet (1.2 m) apart and shall be capable of supporting without failure, the load specified in paragraph (4) above.	Section 1671-Safety Nets (d) Forged steel safety hooks or shackles shall be used to fasten the net to its supports.
Installation	See (c)(i) above	9.1 Nets shall be installed in accordance with the net manufacturer's specifications and instructions.	None specified	CP 93 3.1 ...Nets should not be stretched taut when erected, but should have an initial sag of between a quarter and one fifth of the length of the shortest side.	(2) Safety nets shall be installed with sufficient clearance under them to prevent contact with the surface or structures below if subjected to the drop test specified in paragrapn (4).	Section 1671-Safety Nets (a) Nets shall be hung with sufficient clearance to prevent user's contact with the faces or structures below.

Table 4.3 (Continued)

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
Installation (cont.)				Because nets deflect when arresting a falling body, they should be hung with a minimum clearance equsl to one half of the length of the shortest side or 2 m, whichever is the greatest to prevent contact with surfaces or structures below (see Fig. 2).		
Net Linings	None specified	5.3 Net linings, where used, shall be of not more than 1-inch mesh and shall be constructed of synthetic twine (or its equivalent) of a size not less than No. 18 nylon seine twine, or of wire not less than 22 gage (AWG).	07.D.03. Nets for overhead protection shall be lined with the 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.	CP93 2.1.2 An overlay net or other suitable precautions, may be required to be used in conjunction with a safety net to catch small objects such as tools and small pieces of debris. Particular attention is drawn to the need to take additional and/or alternative precautions where there is a danger to persons below from objects falling through or piercing the net.	None specified	None specified
Levels of Nets for Bridge Construction	(c)(1) It is intended that only one level of nets be required for bridge construction	9.1 It is intended that only one level of nets be required for bridge construction	07.D.01. Only one level of nets is required for bridge construction.	None specified	See (1) above.	Section 1671-Safety Nets (b) Only one level of nets required for bridge construction.

(12 m) under special circumstances for the British standards [17, 18]; and 10 ft (3.0 m) or 25 ft (7.6 m) for steel erection for California/OSHA [20]. All standards require sufficient clearance under the net to prevent user's contact with the surface below. The British Standards [17, 18] specify a minimum clearance under the net equal to one half of the length of the shortest side or 6.6 ft (2 m), whichever is the greatest. They also specify an initial sag of between 1/4 to 1/5 of the shortest side of the net.

Horizontal projection of the net from the edge of the structure varies among the standards: 8 ft (2.4 m) in OSHA 1926 [14], ANSI A10.11 [15], Corps of Engineers [16], and California/OSHA [20]; 10 ft (3.1 m) in the Proposed OSHA Standard [19]; and 2 + 1/5 H ("H" is the vertical distance between the net and the outermost working point above) in the British standards [17, 18].

There is some inconsistency in the standards relative to defining the location on the building from which the horizontal projection is measured. ANSI A10.11 [15] and the Proposed OSHA standard [19] define this point as the "outermost projection of the structure" which could be a main perimeter member or a secondary member which extents beyond the perimeter. Two standards (OSHA 1926 [14] and Corps and Engineers [16] define the point as the "edge of the work surface where employees are exposed." British standards [17, 18] specify the "outermost working point above the net" while the California/OSHA standard [20] uses the exterior perimeter of the structure.

All the standards specify that connections between net panels forming a larger net shall develop the full strength of the net. ANSI A10.11 [15] and the Proposed OSHA standard [19] require that connections between nets be spaced at intervals not more than 6 in (150 mm). Forged steel safety hooks, shackles, rings, etc. are required in all standards for attachment of the net to the support structure. The Proposed OSHA standard [19] is more specific by requiring such attachments to be spaced at intervals not to exceed 4 ft (1.2 m).

In regard to the use of safety nets on bridges, all the standards except one specifically point out that only one level of nets is required for bridge construction. The exception, the British standards [17, 18], do not provide unique considerations for bridges.

4.4 ON-SITE TESTING (table 4.4)

There is a difference of opinion in the standards regarding the need for on-site testing of safety nets. OSHA 1926 [14], ANSI A10.11 [15], Corps of Engineers [16] and Proposed OSHA standards [19] specify that operations shall not be undertaken until the net is in place and has been tested. All of these except for OSHA 1926 [14], and Proposed OSHA [9] further require testing at 6-month intervals thereafter. Corps of Engineers standards [16] also require testing after net relocation or major repair. California/OSHA standard [20] only requires testing to determine adequacy of clearance under net. The British standards [17, 18] take the opposite approach to site testing by stating that "in no circumstances should a net which is to be used for the safety of personnel be subjected to a loading test." (See also table 4.2.) Instead,

Table 4.4 Comparison of On-Site Testing Criteria in Safety Net Standards

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
On-Site Testing - Frequency Requirements	(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.	8. On-the-Job Test 8.1 The safety net shall be tested on the job in the suspended position immediately following initial installation or major repair and at 6-month intervals thereafter.	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.	CP 93 5.1 .....In no circumstances should a net which is to be used for the safety of personnel be subjected to a loading test. 5.1.1 Periodic testing. Test cords should be provided in accordance with BS3913. Test cords should be tested at regular intervals according to the conditions of use, but in no circumstances should this period exceed three months..... BS 3913 3.3 Test Corda Each net shall be supplied with at least eight test lengths of mesh cord for periodic testing.....	(4) (ii) Safety nets and safety net installations not certified by a qualified person in accordance with subparagraph (i) above shall be drop-tested at the jobsite before being used as a fall protection system. The drop-test shall consist of a 400 pound (180 kg) bag of sand 30 ± 2 inches (76 ± 5 cm) in diameter dropped into the net from the walking/working surface to be protected.	None specified. See (a) below
On-Site Testing - Loading	None specified	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.	07.D.04 Operations requiring safety net protection shall not be undertaken until the net is in place and has been tested. 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.	See 5.1 above	See (4) (iii) above	Section 1671-Safety Nets (a) 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.

1/ Standards are quoted without change.

Table 4.4 (Continued)

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
On-Site Testing - Pass/Fail Criteria	None specified	8.1.2 There shall be no broken strands or significant distortion of the net pattern of the suspension system.	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.	See 5.1 above.	See (4) (ii) above.	None specified
Net Inspection in Field	None specified	10. <u>Inspection</u> During use all safety nets, mesh ropes, perimeter ropes, connectors, suspension systems, 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 that show mildew, wear, damage or deterioration that substantially affects their strength shall be immediately removed from service for complete inspection and repair or disposal. 11.1 Csre, maintenance, and storage of safety nets shall be in accordance with the net manufacturer's recommendations with due attention being given to the factors affecting net safety (see Section 12).	07.D.13 Nets shall be inspected daily for damage from abrasions, chemicals or heat. Repairs shall be made before work above the net is resumed.	<u>CP 93</u> 5.2 <u>Examination</u> Nets should be thoroughly examined by a competent person, immediately before being erected. The net should be spread out on a clean floor flat and the whole surface carefully examined. The net should be turned over and the examination repeated. At intervals of about 300 mm the strands should be opened just sufficiently to allow examination of their inside surfaces. A record should be kept of the examination. 5.3 <u>Inspection</u> The net supporting framework and all anchorage points should be inspected immediately following erection and therafter at weekly intervals. Immediately after any sccident which may have affected the strength of the net, it should be thoroughly exsmined by a competent person (see 5.2)...a record should be kept of the inspection.	(5) Safety nets shall be inspected weekly for mildew, wear, damage or deterioration and shall be removed from service if their strength is adversely affected.	None specified

Table 4.4 (Continued)

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
Debris in Nets	None specified	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 ignition sources are done above the net.	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.	CP 93 5.3 ...It is important that safety nets should be kept free of all debris which may cause injury to persons falling into a net.	(6) Materials, scrap pieces, or tools which have fallen into the safety net shall be removed as soon as possible and at least before the next work shift.	None specified
Factors Affecting Net Life	None specified	12.1 Sunlight. Special precautions shall be taken to shield ropes 1/2 inch in diameter and smaller from the sun's rays. Ropes of natural or synthetic fibers can lose a significant amount of strength after prolonged exposure to direct sunlight. It is suggested that 6-6 nylon safety netting be dyed with an ultraviolet-absorbing dyestuff of known ability to significantly increase outdoor durability. Sunlight affects all fibers, including those commonly used. All nets not in use should be protected from direct and indirect sunlight. 12.2 Abrasion. There is no test which will predict the life of a net under the wide variety of abrasion conditions that may be encountered. The adverse effects of abrasion should be constantly borne in mind. Nets should not be dragged over the ground or other rough surfaces. 12.3 Sand. Embedded sand cuts fibers, 12.4 Rust. Prolonged contact with rusting	None specified	5.4 Care of Nets and Supporting Framework Care should be taken to reduce to a minimum unnecessary wear and mechanical damage likely to weaken the net. The following hazards should be avoided as far as possible: 1) dragging over rough surfaces, 2) contact with sharp edges, 3) stacking material on the net, 4) accumulation of debris in the net, 5) persons jumping or throwing objects in the net, 6)sparks, etc., from welding and burning operations, hot gases from blow lamps, hot ash from chimneys or furnaces, 7) chemical attack 8) radiation, e.g. due to radio frequency; 9) supporting framework being struck by a moving load, 10) unauthorized interference with any part of the net assembly.	None specified	None specified

Table 4.4 (Continued)

Table 4.4 (Continued)

CRITERION	OSHA 1926.105 [14]	ANSI A10.11-79 [15]	U.S. CORPS OF ENGINEERS [16]	BRITISH STANDARDS BS 3913-73 [18] CP 93-72 [17]	PROPOSED OSHA 29 CFR PART 1926 SUBPART M FEBRUARY 1981 [19]	CALIFORNIA/OSHA STANDARD [20]
Factors Affecting Net Life (cont.)		iron or steel can cause significant degradation and loss of strength. Nets should not be stored in metal containers that are rusty and should be suspended on nonrusting hooks. 12.5 Airborne Contaminants. Extremely high concentrations of many chemicals can adversely affect the strength of nets. Where high concentrations may exist, the chemicals should be identified and the concentrations measured. The effect on the net material involved should be determined by test if it is not known.				
Storage of Nets	None specified	See 12,3 above	None specified	5.6 Storage When not in use nets should be stored under cover protected from the weather and strong sunlight. In the case of nets made from natural fibers additional precautions are required to ensure proper ventilation, humidity and temperature and to keep free from vermin.	None specified	None specified

test cords built into the net are tested periodically for strength, but in no case should the period exceed 3 months.

Load test criteria for installed safety nets are given in only three of the standards. ANSI A10.11 [15] provides for dropping a 400-lb (181 kg) bag of sand from a height of 25 ft (7.6 m) into the center of the net. The Proposed OSHA standards [19] specifies dropping the same weight bag from the working level into the center of the net. Corps of Engineers standards [16] specifies a 400 pound (181 kg) bag of sand to be dropped into the center of the net from 25 ft (7.6 m) or from a height equal to the distance from the net to the highest surface for which protection is furnished, whichever is greater. ANSI A10.11 [15] specifies a pass/fail criteria: "there shall be no broken strands or significant distortion of the net pattern or the suspension system."

All the standards except OSHA 1926 [19] and California/OSHA [20] provide guidance on field inspection of safety nets, connections, suspension systems, etc., for mildew, damage from abrasions, chemicals or heat, or other forms of wear, damage or deterioration. Weekly examinations of installed nets are required except that the Corps of Engineers standard [15] requires daily inspection. The British standards [17, 18] require a complete inspection of the net <u>prior</u> to erection including an examination of individual strands. The level of competence of the person inspecting the net is not specified in any of these standards. ANSI A10.11 [15] and the Corps of Engineers [16] standards require removal of debris daily while the British standards [17, 18] and the California/OSHA standard state that the net shall be kept free of debris.

The ANSI A10.11 [15] and the British standards [17, 18] provide guidance on factors affecting net life such as sunlight, abrasion, sand, rust, chemical attack, contact with sharp edges, and welding. Much of this is very general (e.g., high concentrations of chemicals can adversely affect nets) making enforcement difficult. The British standards [17, 18] provide guidelines on the storage of nets in order to prevent deterioration.

4.5 SUMMARY OF INCONSISTENCIES IN THE STANDARDS

The relationship between the various criteria in the standards and technical data is generally not very clear. The standards do not include such information and a study of available literature was not very helpful.

The primary areas where inconsistencies exist between the standards are as follows:

A. Procedures for prototype testing of a net by the manufacturer including specified loadings, test set-up, and evaluation criteria.

B. On-site testing of an in-place net including the need, frequency, loading criteria, and evaluation criteria.

C. Location of safety nets relative to the ground, working level, and horizontal projection of perimeter nets from the building.

D. Field inspection of safety nets including frequency, qualifications of inspector, and evaluation criteria.

5. RESEARCH NEEDS

The data discussed above has indicated a lack of a firm technical bases for much of current safety net regulations and has pointed out several areas where additional safety net research would be desirable.

A. Evaluation of Long Term Durability of Safety Net Material

The effects of light, moisture, heat, age and usage on safety nets as a function of time of exposure are not clear. Standards discussed in section 4.1 either prescriptively require a type of material (manila, nylon or polypropylene) or provide a minimum breaking strength. Criteria are needed for evaluating and ensuring the durability of a net while in service.

B. Development of a Uniform Prototype Net Test

As discussed in section 4.2, prototype test loading procedures in standards differ relative to energy input, method of load application, test frame configuration, and pass/fail criteria. The development of prototype test criteria with a firm technical base will provide for greater uniformity in the manufacture and use of safety nets.

C. Evaluation of Horizontal Projection Criteria for Perimeter Nets

Standards analyzed in section 4.3 specify a minimum horizontal projection of perimeter net systems ranging from 8 ft (2.4 m) to 10 ft (3.1 m). These minimum projections may be questioned relative to their adequacy in catching a worker who may fall as much as 25 ft (7.6 m) with some horizontal velocity at the point of fall initiation. Full scale test data along with a computer model to simulate falls into nets are needed to evaluate minimum projection criteria.

D. Development of Uniform On-Site Test Procedures

Criteria listed in table 4.4 for on-site testing of installed safety nets differ relative to the frequency and desirability of the test, test configuration and loading, and pass/fail criteria. It is necessary to reconcile these differences and to evaluate the long-term effect of on-site proof testing on net performance. It may be possible to delete the need for such a proof test.

E. Flexibility Criteria for Safety Nets

While current safety net standards specify both prototype and on-site test procedures, there are no flexibility requirements. It is possible that the catching surface may be excessively stiff, causing injury to workers falling into them. Full-scale laboratory tests using anthropomorphic dummies would provide acceleration/deceleration data which could be related to net flexibility and potential injury to workers.

F. Assessment of Maximum Vertical Drop to Safety Net

Table 4.3 shows that the maximum distances specified in U.S. standards between the working surface and the safety net range from 25 ft (7.6 m) to 30 ft (9.1 m). Reference [2] recommends that this distance be decreased since California data shows that a reduction to 10 ft (3.05 m) has caused a significant reduction in both the frequency and severity of accidents. Research is needed to determine the impact of such a reduction including the effect on the worker and economic impact to the construction industry.

G. Data Base for the Performance of Various Fall Arrest Systems

Currently available data on the performance of fall arrest systems does not contain sufficient data to determine inadequacies which can be addressed in standards or by equipment manufacturers. Such data are needed to show how safe such devices are and what are the problems with their use. A mechanism should be set up by Federal, state and local government agencies in conjunction with key elements of the construction industry (contractors, unions, manufacturers, etc.) to collect data in a meaningful format which can be of direct use to standards development bodies.

H. Application of Anthropomorphic Devices in Safety Net Research

The most important aspect of the performance of a safety net system is the effect on workers who are caught. Anthropomorphic dummies can be used to simulate such workers much the way they are used in the automotive and aerospace industries and in some aspects of the construction industries (e.g., guardrails). Related research to date should be determined and extended to safety nets and other fall arrest systems, if possible.

I. Performance Criteria for the Design of Net Support Systems

While standards are generally very specific about the performance expected of the safety net, criteria are less detailed concerning the design and construction of the support system. Performance criteria are needed in order that the total safety net system can be analytically evaluated in a consistent manner.

J. Mathematical Model for Safety Net System

Current safety net systems represent a wide range of configurations. A mathematical model representing a generalized safety net system would be extremely useful in evaluating various net configurations and support systems. Such a model could be validated by results of laboratory and field testing.

REFERENCES

1. Steinberg, Harold L., A Study of Personal Fall-Safety Equipment, NBSIR 76-1146, National Bureau of Standards, Washington, D.C., June 1977.

2. Planning Research Corporation, Occupational Injuries in the General Building and Heavy Construction Industries, Sponsored by NIOSH, Report PRC-R-2452, NTIS PB80-193345, McLean Virginia, May 1979.

3. Pals, James H., Kane, Joe D., and Marcello, Jody, S., Pilot Program to Evaluate the Effectiveness of OSHA Construction Standards at the Point of Erection, Western Institute for Research and Education, Inc., NIOSH #210-81-3008, January 1982.

4. Sinco Products Inc., The Fall Protection Handbook, East Hampton, Connecticut, 1980.

5. Safety Net Result: Money Spent, Lives Saved, Engineering New Record, Pages 16-18, July 8, 1976.

6. Wang, Chen H., Perimeter Net Systems - A State-of-the-Art Study, Professional Safety (pp. 36-41), February 1978.

7. National Safety Council, Safety Nets - Fall Protection for the Construction Industry, National Safety News, September 1982.

8. National Safety Council, Safety Nets for Construction Projects, Data Sheet 608, National Safety News, January 1974.

9. Safety Belts, Lifelines, Harnesses and Nets Offer Fall Protection, National Safety News, March 1978.

10. The Safety Net Standards: When Does it Apply?, Occupational Hazards, January 1975.

11. Safety Net Result: Money Spent, Lives Saved, Engineering News Records, July 8, 1976.

12. McKinnon, Robert, Net Gains for Accident Prevention, Occupational Safety and Health, London, April 7, 1977.

13. Robbins, D.H., Guidebook on Anthropomorphic Test Dummy Usage, Report No. UM-HSRI-BI-77-19, Highway Safety Research Institute, University of Michigan, March 1977.

14. U.S. Occupational Health and Safety Administration, General Construction Standards - 29 CFR 1926.104 Safety Belts, Lifelines and Lanyards, Washington D.C., 1979.

15. American National Standards Institute, Minimum Requirements for Safety Nets, A10.11-79, New York, 1979.

16. State of California, Administrative Code, Title 8 - Industrial Relations, Article 24, Safety Belts and Nets, Sacramento, 1980.

17. British Standards Institution, Code of Practice for the Use of Safety Nets on Construction Works, CP 93-72, London, 1972.

18. British Standards Institution, Specifications for Safety Nets, BS 3913-73, London, 1973.

19. U.S. Occupational Health and Safety Administration, Proposed Revisions to OSHA Construction Standards on Fall Protection, Prevention and Warning Line Systems, 29 CFR 1926 (Subpart M), Washington, D.C., February 1981.

20. State of California, Administrative Code, Title 8 - Industrial Relations, 1980.

NBS-114A (REV. 2-80)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO. NBSIR 83-2709	2. Performing Organ. Report No. -	3. Publication Date September 1983

4. TITLE AND SUBTITLE

STATUS OF SAFETY NET STANDARDS FOR CONSTRUCTION AND RESEARCH NEEDS

5. AUTHOR(S)

James H. Pielert

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

U. S. Department of Labor
Occupational Safety and Health Administration
Washington, D.C.

10. SUPPLEMENTARY NOTES

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

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

This report represents the status of standards for safety nets used in construction and identifies areas of technical inconsistency. Typical applications of safety nets are reviewed including the results of literature and field surveys. Major technical sections of six standards are compared in a tabular format to highlight areas of agreement, as well as, requirements which vary and indicate lack of consensus. This information is analyzed and used to develop a prioritized research plan for safety nets.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Construction; construction safety; occupational safety; perimeter nets; safety nets

13. AVAILABILITY

☒ Unlimited
☐ For Official Distribution. Do Not Release to NTIS
☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

35

15. Price

$8.50

USCOMM-DC 6043-P80