

IEEE Guide to the Assembly and Erection of Metal Transmission Structures

Sponsor

**Towers, Poles, and Conductors Subcommittee
of the
IEEE Power Engineering Society**

Approved 10 December 1996

IEEE Standards Board

Reaffirmed 11 September 2009

IEEE Standards Board

Approved 15 May 1997

American National Standards Institute

Abstract: Various good practices that will enable users to improve their ability to assemble and erect self-supporting and guyed steel or aluminum lattice and tubular steel structures are presented. Construction considerations after foundation installation, and up to the conductor stringing operation, are also covered. The guide focuses on the design and construction considerations for material delivery, assembly and erection of metal transmission structures, and the installation of insulators and hardware. This guide is intended to be used as a reference source for parties involved in the ownership, design, and construction of transmission structures.

Keywords: guyed structures, helicopters, lattice structures, metal transmission structures, tubular steel structures

The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street, New York, NY 10017-2394, USA

Copyright © 1997 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 1997. Printed in the United States of America.

ISBN 1-55937-877-8

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Authorized licensed use limited to: Tsinghua University. Downloaded on February 26, 2026 at 10:01:41 UTC from IEEE Xplore. Restrictions apply.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE that have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

Note: Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying all patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; (508) 750-8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Introduction

(This introduction is not part of IEEE Std 951-1996, IEEE Guide to the Assembly and Erection of Metal Transmission Structures.)

This guide is one of several covering all aspects of overhead transmission line construction that have been prepared by the Working Group on Overhead Line Construction. This particular guide presents design and construction considerations for material delivery, assembly and erection of structures, and the installation of insulators and hardware. This guide was originally published as a standard in 1988.

The membership of the working group during the preparation of this guide was as follows:

Keith E. Lindsey, *Chair*

F. Leonard Consalvo
Vic Corrie
Robert Donelson
George E. Fortney

Chuck O'Malley
Patrick D. Quinn
Lee Ramage

Ron Randle
Ken Simpson
Dan Thiemann
Brian White

The following persons contributed review and comments as organizational representatives:

W. Brenner	Standards Coordinating Committee 14 (SCC 14), Quantities, Units, and Letter Symbols
J. Mallory	CIGRE (International Conference on Large Voltage Electric Systems) Committee 22
R. J. Wehling	Power Engineering Society (PES)/Substations Committee
A. Shah	American Society of Civil Engineers (ASCE)
G. Engmann	PES/Substations Committee

The following persons were on the balloting committee:

Ted R. Aggeler	Kenneth L. Griffing	Charles O'Malley
Tomas J. Alderton	Jerome G. Hanson	Robert G. Oswald
James E. Applequist	Christopher W. Hickman	Robert L. Patterson
Joseph F. Buch	Magdi F. Ishac	Robert C. Peters
Kris K. Buchholz	Ralph O. Jones	Joe C. Pohlman
Vernon L. Chartier	Robert O. Kluge	Patrick D. Quinn
Glenn A. Davidson	Donald E. Koonce	Ron Randle
Frank A. Denbrock	Robert C. Latham	Stephen J. Rodick
John B. Deye	Joel H. Mallory	John S. Rumble
Dale A. Douglass	Mike McCafferty	Neil P. Schmidt
Donald A. Gillies	Andrew R. McCulloch	Dan Thiemann
Edwin J. (Tip) Goodwin	George B. Niles	H. Brian White



When the IEEE Standards Board approved this standard on 10 December 1996, it had the following membership:

Donald C. Loughry, *Chair*

Richard J. Holleman, *Vice Chair*

Andrew G. Salem, *Secretary*

Gilles A. Baril
Clyde R. Camp
Joseph A. Cannatelli
Stephen L. Diamond
Harold E. Epstein
Donald C. Fleckenstein
Jay Forster*
Donald N. Heirman
Ben C. Johnson

E. G. “Al” Kiener
Joseph L. Koepfinger*
Stephen R. Lambert
Lawrence V. McCall
L. Bruce McClung
Marco W. Migliaro
Mary Lou Padgett
John W. Pope

Jose R. Ramos
Arthur K. Reilly
Ronald H. Reimer
Gary S. Robinson
Ingo Rüschi
John S. Ryan
Chee Kiow Tan
Leonard L. Tripp
Howard L. Wolfman

*Member Emeritus

Also included are the following nonvoting IEEE Standards Board liaisons:

Satish K. Aggarwal
Alan H. Cookson
Chester C. Taylor

Kristin M. Dittmann
IEEE Standards Project Editor

Contents

CLAUSE	PAGE
1. Overview.....	1
1.1 Scope.....	1
1.2 Purpose.....	1
1.3 Application.....	1
1.4 Safety	1
1.5 Legal disclaimer.....	2
2. References.....	2
3. Definitions	2
4. Project planning	3
5. Structure design considerations	3
5.1 Construction and maintenance loads	3
5.2 Material delivery	5
5.3 Constructability of structures.....	5
5.4 Trial assembly	8
6. Material delivery.....	9
6.1 Introduction.....	9
6.2 Material yard.....	9
6.3 Receipt and inspection of material.....	10
6.4 Handling and storage of materials	11
6.5 Overages, shortages, and replacement material.....	13
6.6 Surplus material	13
7. Assembly and erection of lattice structures	13
7.1 Introduction.....	13
7.2 Foundation tolerances	14
7.3 Field assembly	14
7.4 General method of erection.....	15
7.5 Crane erection	17
7.6 Gin pole erection.....	17
7.7 Helicopter erection.....	21
8. Assembly and erection of tubular steel structures	21
8.1 Introduction.....	21
8.2 Handling and transportation of poles, arms, and component parts.....	22
8.3 Single pole structures.....	22
8.4 Framed structures.....	27
8.5 Attaching pole structures to various foundations	29
8.6 Helicopter methods (refer to Clause 9).....	30
8.7 Post-erection	30

CLAUSE	PAGE
9. Helicopter methods of construction	31
9.1 Introduction.....	31
9.2 Economic considerations	31
9.3 Helicopter structure placement	33
10. Assembly and installation of insulators and hardware	36
10.1 Introduction.....	36
10.2 Assembly of insulators and hardware	36
10.3 Installation of cotter keys.....	37
10.4 Installation of assemblies.....	37
11. Quality assurance	38
Annex A (informative) Bibliography	38

IEEE Guide to the Assembly and Erection of Metal Transmission Structures

1. Overview

1.1 Scope

This guide presents various good practices that will enable users to improve their ability to assemble and erect self-supporting and guyed steel or aluminum lattice and tubular steel structures. It also covers construction considerations after foundation installation (see IEEE Std 977-1991¹), and up to the conductor stringing operation (see IEEE Std 524-1992).

1.2 Purpose

The purpose of this document is to assist the parties involved with the installation of steel transmission structures. This document focuses on the design and construction considerations for material delivery, assembly and erection of metal transmission structures, and the installation of insulators and hardware.

1.3 Application

This guide is intended to be used as a reference source for parties involved in the ownership, design, and construction of transmission structures. Since methods will be strongly influenced by the nature of each project, various methods that have been successfully employed are presented.

If any of the recommendations contained within this guide are to be adopted, they should be specifically stated in the owner's design and construction specifications. Any legal and environmental requirements of national, state, provincial, or local regulations shall be observed.

¹For information about references, see Clause 2.

1.4 Safety

Handling, assembly, and erection of metal structures may require conducting a safety and health program that takes all reasonable precautions to protect the safety and health of workers and members of the public. Workers should not be allowed to work in surroundings or under working conditions that are unsanitary, hazardous, or dangerous to their health or safety. Any safety requirements of national, state, provincial, or local regulations shall be observed (see [B5]²).

1.5 Legal disclaimer

The support data for this guide were collected from a great number of sources and are believed to be reliable and true. Care has been taken during the compilation and writing to prevent error or misrepresentations. The authors make no warranty with respect to the accuracy, completeness, or usefulness of the information contained in the guide, nor do they assume any liabilities with respect to the applicability or use of any information, method, or process presented in this publication.

The use of trade names is for the information and convenience of the user of this guide and does not constitute an endorsement by the authors.

2. References

This guide shall be used in conjunction with the following publications:

IEEE Std 977-1991, IEEE Guide to Installation of Foundations for Transmission Line Structures (ANSI).³

IEEE Std 524-1992, IEEE Guide to the Installation of Overhead Transmission Line Conductors (ANSI).

ASTM A780-93a (1996), Standard Practice Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.⁴

3. Definitions

This clause contains key terms as they are used in this guide.

3.1 constructor: A party who undertakes the assembly and erection of a transmission structure. The constructor can be an owner or an agent acting for an owner. *Synonyms:* contractor, installer, construction agency, construction department.

3.2 line designer: A party who develops structure loading criteria, structure types, and structure locations based on line routing, maintenance, and construction requirements. The line designer establishes design criteria for construction and maintenance that will affect the structure designer and constructor. The line designer could be an owner or an agent acting for the owner.

3.3 owner: A party who owns the transmission line during the construction phase of the line and may include a person who acts for or on behalf of an owner as his or her his agent or delegate.

²The numbers in brackets correspond to those of the bibliography in Annex A.

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁴ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

3.4 structure designer: A party who designs the structure based on criteria given by a line designer. The structure designer could be an owner, an agent acting for the owner, or a fabricator.

3.5 subcontractor: A party having a direct contract with the constructor for performing work covered by the Contract Documents, when the constructor is not the owner.

4. Project planning

The line designer should consider all aspects of the project before proceeding with design. This includes a review of all available options for construction techniques and equipment with respect to the specific conditions of the proposed line route. Access conditions, environmental restrictions, and/or schedule constraints may dictate the need to consider alternative, nontraditional construction techniques. If these requirements are understood early in the project, the selection, design, and detailing of structures and foundations can be tailored to accommodate these construction techniques. This early planning can result in a more cost-effective project.

The following factors can influence the selection of construction methods and equipment and should be considered in the early planning of a transmission line:

- a) Line route and right-of-way conditions
- b) Environmental constraints and public concerns
- c) Accessibility of structure sites
- d) Configurations, sizes, and weights of structures
- e) Structure details and capability of sectionalizing
- f) Foundation types and sizes
- g) Availability and location of marshalling yards
- h) Material delivery schedules
- i) Constructor capabilities and available equipment (if known)
- j) Inspection and maintenance requirements and practices

Clauses 7, 8, and 9 of this guide describe a number of different construction techniques. If the items listed above or any other considerations indicate that a particular technique and/or type of equipment will be most appropriate for a project, then this should be considered throughout the design and detailing of the line components to incorporate any special provisions that will facilitate construction operations. In particular, if helicopter construction is planned, qualified helicopter operators should be consulted to ensure that the line construction will be as efficient as possible.

At the time of line design, the constructor may not have been selected. However, the line designer should consult with knowledgeable construction and maintenance personnel and utilize their experience to develop a reasonable balance between design optimization, constructibility, and maintainability.

5. Structure design considerations

5.1 Construction and maintenance loads

The line designer should review and define limits for acceptable methods of construction and maintenance appropriate to the structure types, site conditions, applicable equipment, and skill level of the workers. Structural or other details that relate to the safety of construction and maintenance work should be considered in the design of the structure.

The line designer should anticipate the more common operations of construction and maintenance and indicate the maximum allowable loads and acceptable loading or lifting points. The responsibility lies with the contractor to confirm with the line designer any lifting practices that deviate from those indicated.

Some of these loading considerations are

- a) Partially assembled lattice structure sections will be subjected to dead-weight loads, dynamic loads, temporary guying loads for stability, worker loads, wind loads, and rigging loads during assembly and erection. Reasonable combinations of these loads should be anticipated by the designer and discussed with potential constructors to ensure safety and efficiency and prevent structural damage.
- b) Members on which one or more workers are expected to climb or stand should be designed for a mid-span load of the workers, their equipment, and an appropriate safety factor (see [B6] and Figure 1).

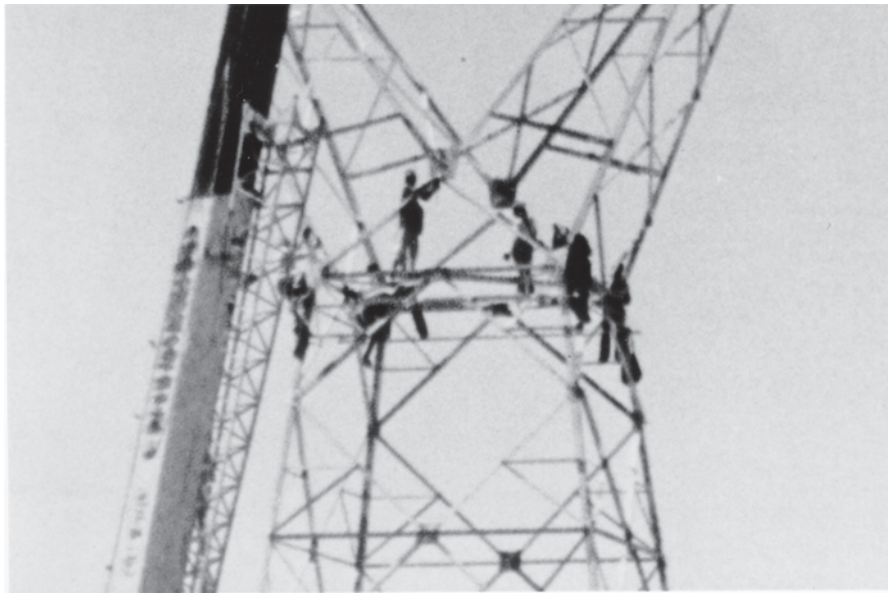


Figure 1—Portions of a structure subjected to additional loads due to one or more workers

- c) Portions of a structure may be subjected to additional loads while they support one or more workers during construction and maintenance (that is, the end of a cross arm or at a leg splice) (see Figure 1). These loads, in addition to the normal wire loads anticipated during construction and maintenance, should be considered.
- d) If fall arrest systems are required, attachment points should be designed for the anticipated load.
- e) Rigging attachment points should be provided for lifting the structure, hoisting insulators and travelers, stringing, clipping in, deadending, and maintenance. All of these points should be explicitly identified. A diagram giving the allowable construction loads on the erected structure should be prepared and provided to the constructor.

Particular attention should be given to the following loading conditions:

- Rigging methods (see [B8]) used in hoisting may multiply the load at the attachment point.
- At the beginning and end of each conductor stringing setup, the conductors may be brought down to stringing equipment, anchors, or both. The vertical and horizontal components of tension imposed on the structure may become significant at these locations, and failures have occurred on both sus-

- pension and deadend structures. The positioning of the stringing equipment or anchors is critical, especially in mountainous terrain (IEEE Std 524-1992).
- Various deadending techniques will apply different loads. For example, aerial deadending techniques may impose lower vertical loads than deadending on the ground. Temporary back-guying may be required depending on the longitudinal strength and flexibility of the deadend structure and dead-ending technique used.
 - Short spans between deadends with high conductor tensions are sensitive to overpulling and may result in loads in excess of maximum design tensions.

5.2 Material delivery

The design and detailing of the structures should consider limits on the length, size, and weight of individual members due to shipping, handling, erection, terrain, and equipment restrictions as well as manufacturing limits (see 6.4).

5.3 Constructability of structures

Construction can be enhanced by a number of considerations, both in the design of the structure and in detailing of the connections.

It should be noted that these considerations could increase material costs, although these costs may be offset by reduced field costs and improved safety. The following are applicable to all types of metal structures:

- a) Each member should be clearly and permanently marked by stamping or welding. This mark should be legible after any coatings are applied to facilitate identification and possible field replacement. These permanent markings should be visible after the structure is erected. Stencilling with water-proof paint will further facilitate field identification; however, care should be taken to avoid adverse visual impact. See 6.4 regarding stencilling of weathering steel.
Identification marks may include the following information:
 - 1) General location of the member in the structure by using a logical numbering sequence
 - 2) Structure type
 - 3) Special material types
- b) The structure should be designed with a minimal assortment of bolt diameters and types.
- c) Adequate clearance around nuts and bolt heads for wrenches or sockets should be provided.
- d) For safety and ease of erection, a place for a worker to stand should be provided below each leg splice. As an example, two step bolt holes could be provided 1.37 m (4 ft, 6 in) below each splice for optional step bolts.
- e) The bill of materials should provide an approximate finished (that is, galvanized or painted) weight of each structure item (that is, members, plates, fills, bolts, and nuts) in order to determine the loads to be lifted.
- f) Legible erection drawings and data sheets for line sections should be provided. The drawings should show the member mark identification, bolt size, and length, bolt pattern, orientation of angle members, and whether a member is inside or outside its connecting member (that is, use hidden lines and detailed or enlarged views). In addition, these erection drawings should show the rigging attachment points identified in 5.1e).
- g) Fabrication tolerances that are either too restrictive or too liberal can result in increased field costs.
- h) Consideration should be given to the method of locking fasteners. The method selected will influence construction efficiency. Typical methods and devices are lock nuts, lock washers, pal nuts, punched threads, weathering steel, etc.
- i) Designs should be checked for worker accessibility. Design of structures sometimes results in large spaces between members, making it difficult for workers to reach the joints. In such cases, it may be necessary to lift workers to install or check bolts.

5.3.1 Constructability of lattice structures

Considerations specific to lattice structures include the following:

- a) Where members are connected by one bolt at each end, the detailer should require a spud hole at the lower or main leg end. The tapered end of a spud wrench or drift pin is inserted into this hole to facilitate positioning of the member. This hole should be indicated as a spud hole on the erection drawing. The spud hole may indicate that the member was detailed slightly short in order to introduce prestress into the member. Spud holes in weathering steel should be bolted tight.
- b) Depending on the method of erection, the location of leg and crossarm splices can affect the assembly and future maintenance of the structure. Leg splices located above the crossarm hanger or below the chord of the crossarm (not between them) will facilitate aerial erection as shown in Figure 2. If the structure is assembled on the ground, the leg splices may be located between the crossarm hanger and crossarm chord as shown in Figure 3. Aerial erection can also be helped if leg splices are located just above horizontal bracing as shown in Figure 4. This helps to maintain proper geometry and structural integrity of the lower body.

Crossarm and ground wire peak splices located outside the body of the structure, as shown in Figure 2, may facilitate aerial assembly. In addition, arm and ground wire peaks can be removed or replaced without affecting the integrity of the remaining structure if their splices are located as shown in Figure 2, as opposed to Figure 3.

- c) When tilting up structure sections diagonal braces extending below the main legs can be damaged. Two possible solutions are shown in Figures 5 and 6. The method shown in Figure 5 is necessary when helicopter erection is planned. The method shown in Figure 6 has the advantage of requiring no additional permanent material and is suitable for crane erection only.

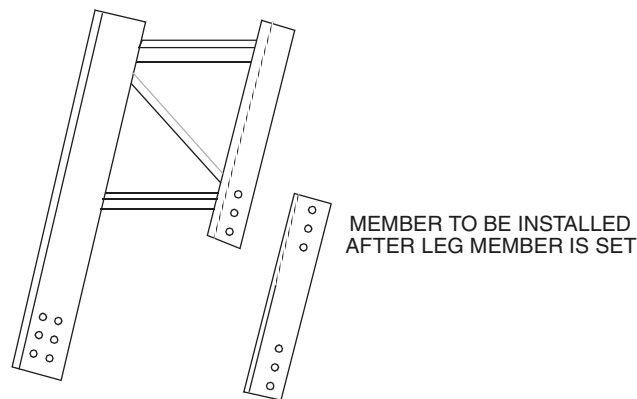


Figure 5—Leg splice detail recommended for helicopter erection

- d) When butt splices are used on main structure legs, gin pole or crane assembly may be facilitated by bolting outside splice plates to the upper leg and inside splice plates to the lower leg as shown in Figure 7.
- e) When using lap splices, assembly and erection with crane and helicopter techniques are facilitated by providing outside splices when the structure tapers inward (see Figure 8).
- f) When helicopter erection is used, temporary stops are installed in both butt and lap splices. For lap splices, two additional holes on each face of the leg angle should be provided as shown in Figure 8.
- g) Design internal structure leg bracing to facilitate its assembly and erection with each main structure leg as shown in Figure 9.
- h) In order to facilitate raising and lowering tools and equipment with handlines, it may be unsuitable to obstruct the interior of the structure by using cross bracing for diaphragm bracing.

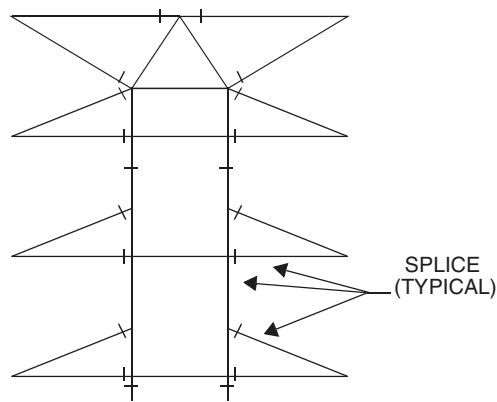


Figure 2—Splice location recommended for aerial erection

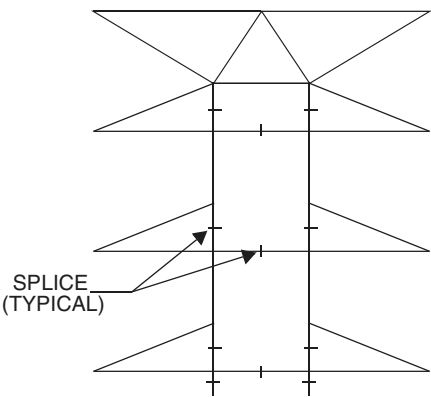


Figure 3—Splice location *not* recommended for aerial erection or future maintenance

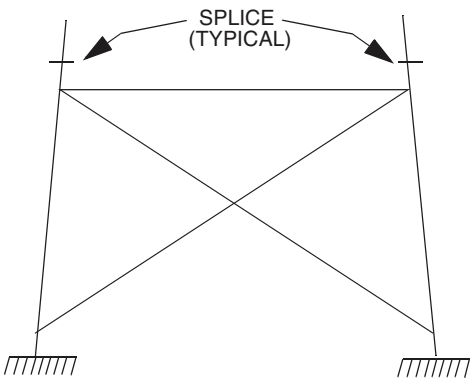


Figure 4—Recommended splice location for lower legs

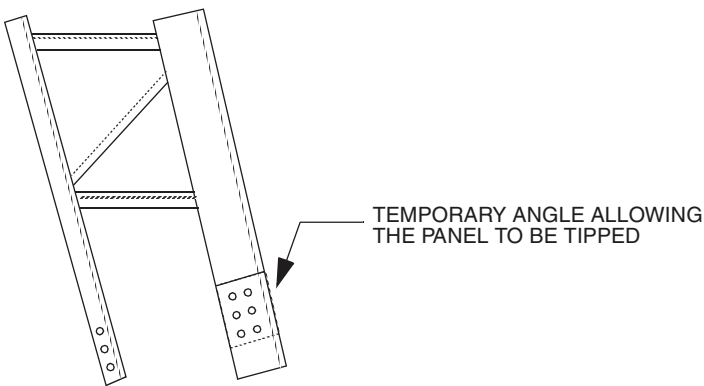


Figure 6—Leg splice detail recommended for crane erection

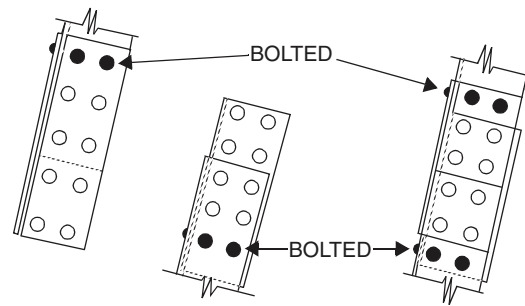


Figure 7—Recommended butt splice detail

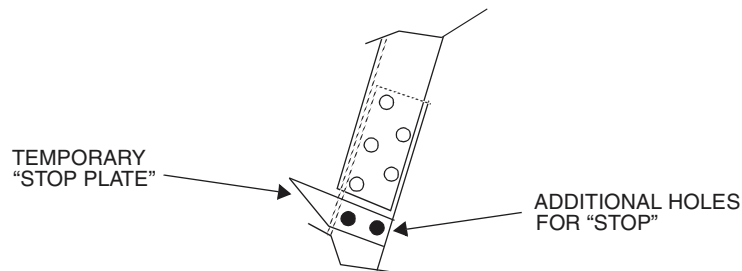


Figure 8—Leg splice recommended for helicopter or crane erection

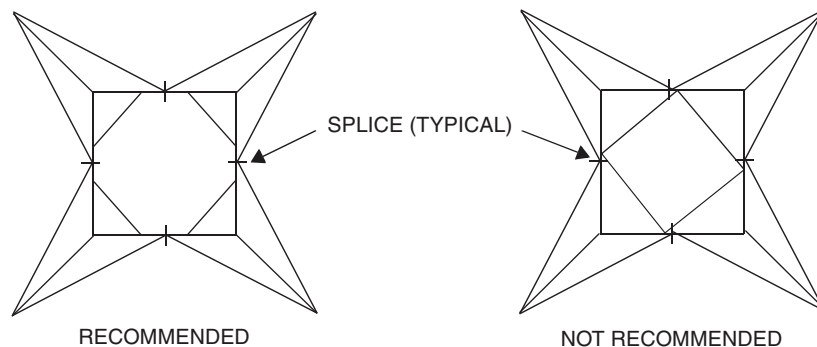


Figure 9—Internal leg bracing detail

5.3.2 Constructability of tubular steel structures

Some specific considerations to tubular structures include the following:

- Avoid structural detailing requiring workers to insert tools or their hands between large members during assembly.
- Provisions for lifting eyes or pick points to minimize damage to the finish of the pole. Position of the lifting eyes or pick points should take into account construction methods, equipment, and site restrictions.
- Provisions for the constructor to verify the lap joint distances and orientation as shown on the erection drawings. As an example, weld beads, inspection holes, or some other marks should be provided on the upper and lower pole sections.