

Lattice towers and masts —

Part 3: Code of practice for strength assessment of members of lattice towers and masts

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Foreword

This part of BS 8100 has been prepared under the direction of Technical Committee B/525, Building and civil engineering structures. BS 8100 is a series of standards combining codes of practice with a guide covering the loading and design of lattice towers and masts of metallic construction. It comprises the following parts:

- *Part 1: Code of practice for loading;*
- *Part 2: Guide to the background and use of Part 1: “Code of practice for loading”;*
- *Part 3: Code of practice for strength assessment of members of lattice towers and masts;*
- *Part 4: Code of practice for loading of guyed masts.*

This part of BS 8100 incorporates clauses to complement BS 8100-4.

The need for this code of practice to give guidance on the determination of the strength of lattice towers and masts arises out of the difficulty in applying consistently the general structural strength codes to these often tall, slender three dimensional lattice structures.

The document is based upon DD 133:1986, which in turn brought together the collective experience of the European transmission line tower industry, where each new design of structure was subjected to full-scale “type” testing. It was considered invaluable to have such relatively unique data built into a code as well as enabling the limit state loading rules to be accurately calibrated.

The additional clauses dealing with the special aspects of guyed masts represent the collective extensive experience of the drafting committee. It is considered that they will provide efficient solutions to the strength assessment problem, whilst avoiding some of the causes of problems which have occurred on this type of structure.

By liaison with the relevant Eurocode drafting team, the rules drafted into this code of practice have been based upon a common approach and should result in the minimum amount of variation when the National Application Document is prepared following the issue of the ENV.

This part of BS 8100 does not apply to other metallic structures. Other British Standards exist for some of those structures.

It has been assumed in the drafting of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people.

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Annex A, annex B and annex C are informative.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 26, an inside back cover and a back cover.

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Introduction

The strengths given in this part of BS 8100 are characteristic (95 % probability) values for use with BS 8100-1 and -4. The design strengths are obtained by dividing the characteristic strengths by the appropriate partial factor γ_m defined in this part. Connection eccentricities assumed in this part of BS 8100 are those that are traditionally applied to lattice masts and towers in the UK.

1 Scope

This part of BS 8100 provides guidance on the assessment of the strength of members and connections for masts and towers of lattice construction consisting mainly of bolted, rivetted or welded steel angle or tubular or solid round sections. The recommendations given are valid for both equal and unequal angles, either rolled or cold formed, compound members fabricated from these sections, tubular members and solid rounds.

The specific components covered in this part of BS 8100 are:

- a) compression members and bolted and/or welded connections which are specific to typical mast and tower configurations and which are not comprehensively covered in general strength codes;
- b) mast guys, their fittings and assemblies. For such components their strength is closely related to practical considerations, and such guidance is included where relevant.

NOTE 1 Information on all other aspects of strength assessment can be obtained from BS 5950-1. Information for fatigue assessment can be obtained from BS 7608.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

- BS 302 (all parts), *Stranded steel wire ropes*.
- BS 443, *Specification for testing zinc coatings on steel wire and for quality requirements*.
- BS 463, *Specification for sockets for steel wire ropes*.
- BS 643, *Specification for white metal ingots for capping steel wire ropes*.
- BS 1554, *Specification for stainless and heat-resisting steel round wire*.
- BS 2763, *Specification for round carbon steel wire for wire ropes*.

BS 4429, *Specification for rigging screws and turnbuckles for general engineering, lifting purposes and pipe hanger applications*.

BS 5950-1:1990, *Structural use of steelwork in building — Part 1: Code of practice for design in simple and continuous construction: hot rolled sections*.

BS 6994, *Specification for steel shackles for lifting and general engineering purposes: grade M(4)*.

BS 7035, *Code of practice for socketing of stranded steel wire ropes*.

3 Definitions and symbols

3.1 Definitions

For the purposes of this part of BS 8100 the following definitions apply.

3.1.1

leg members

members forming the main load bearing chords of the structure

3.1.2

primary bracing members

members other than legs carrying the shear force due to imposed loads on the structure

3.1.3

secondary members

members used to reduce the effective length of the main legs and sometimes that of the bracing. They are normally considered unstressed and are only loaded due to deformation of the structure (see 5.4.)

NOTE Secondary members are sometimes referred to as redundant members.

3.1.4

system length

taken as the geometric length of a member between intersection points providing restraint in the relevant plane

3.1.5 mast guy assemblies

3.1.5.1

guy

tension only member which provides horizontal support to the mast column at discrete levels. The lower end of the guy assembly is anchored to the ground and normally incorporates a means of adjusting the tension in the guy

NOTE The terms “stay” and “guy” are interchangeable but in this British Standard the word “guy” has been used throughout.

3.1.5.2

wire

individual filament of steel, forming the smallest single tension component in a cable, usually circular in cross section with a diameter between 3 mm and 8 mm, with a high strength that is usually obtained by cold drawing or cold rolling

3.1.5.3

spiral strand

assembly of round wires formed helically around a centre wire in one or more symmetrical layers

NOTE Each successive layer is wound in alternate directions [see Figure 1a)].

3.1.5.4

wire rope

assembly of spiral strands wound helically around a centre core, normally in the opposite direction to the outer layer of the strands [see Figure 1b)]

3.1.5.5

cable

assembly of one or more strands or ropes of the types described in 3.1.5.3 and 3.1.5.4

NOTE The strands may be bound in tight contact or kept apart by spacers. [See Figure 1c).]

3.1.5.6

locked coil

strand comprising a central core of round wires, spirally bound with layers of shaped wires

NOTE The inner layers of shaped wires are sometimes of a trapezoidal cross section, but more usually all layers are of Z section wires which overlap and provide a relatively watertight envelope. Each successive layer is wound in alternate directions. [See Figure 1d).]

3.1.5.7

parallel wire strand

assembly of wires laid side by side in parallel and either bound tightly together or with the spaces between the wires held constant by spacer elements

3.1.5.8

core

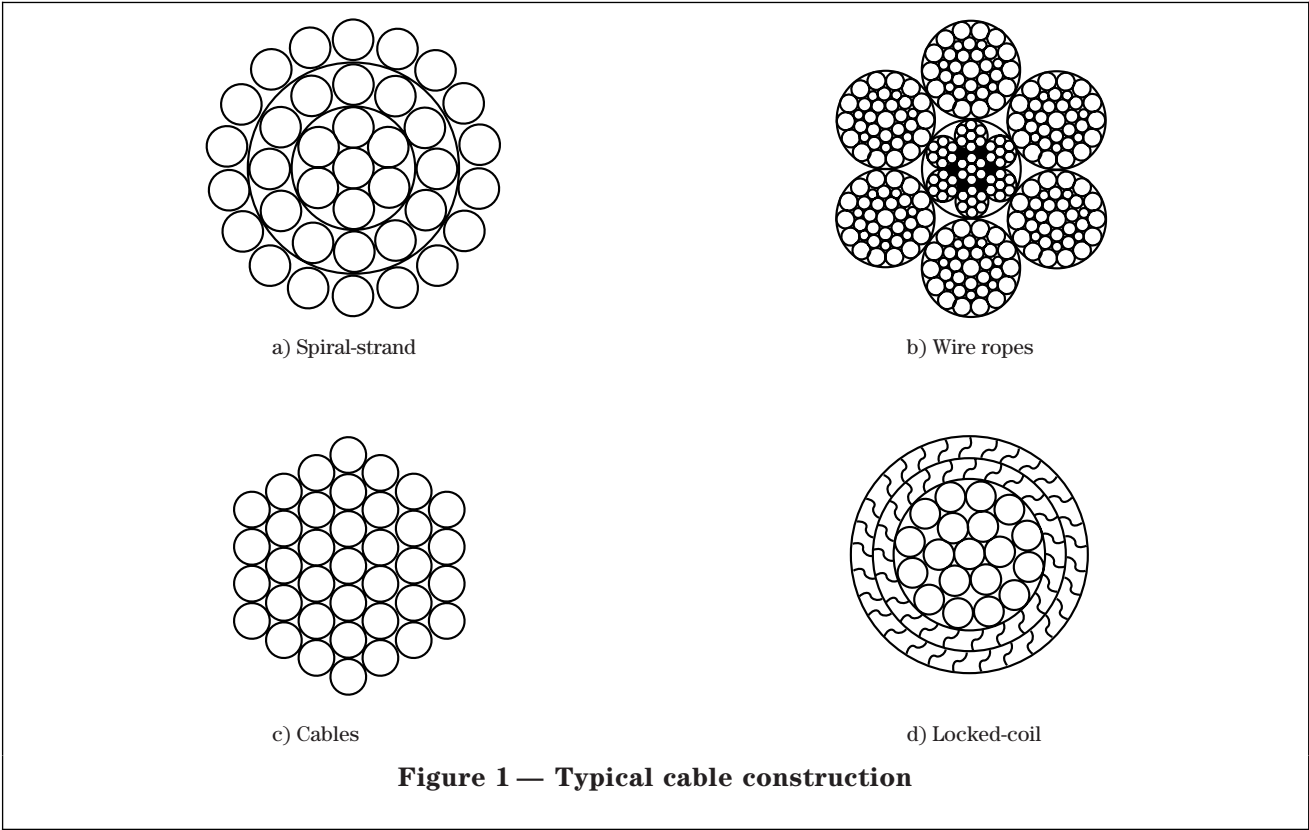
central foundation for the strands, providing support and keeping them in their proper position throughout the life of the rope

NOTE Fibre cores impregnated with grease are used to provide internal lubrication of moving ropes. However, only steel wire cores should be used for mast guys.

3.1.5.9

termination

device fixed to the ends of a cable, strand or wire to enable the loads to be transferred between it and the mast column or the steelwork attached to the guy foundation



3.2 Symbols

For the purposes of this part of BS 8100 the following symbols apply.

NOTE They are based on those given in BS 8100-1 and -4 but it has not been possible to follow those conventions in all cases.

A	cross-sectional area of the member
A_s	cross-sectional area of bolt in shear plane (shank or threaded section as relevant) (in mm ²)
B	leg length of angle, i.e. breadth
C	length of individual angle between stitch bolts
D	bolt, solid round or tube diameter; depth of section
E	modulus of elasticity of steel
F	leg load
j	reduction factor
K	effective slenderness factor
	NOTE $K\lambda$ is effective slenderness and $K\lambda$ is effective slenderness ratio.
L	length
L_d	system length of diagonal member
L_h	system length of horizontal member
N	the design buckling resistance of a member
P_1	compressive force in horizontal of K brace
P_2	tensile force in horizontal of K brace
Q_u	ultimate resistance of bolt
r_{vv}	radius of gyration about axis vv
r_{xx}	radius of gyration about axis xx
r_{yy}	radius of gyration about axis yy
t	thickness of angle leg, thickness of tube wall
x	distance from centre line of bolt to end of member
y	distance from centre line of bolt to edge of member
z	spacing between bolts
a	imperfection factor
β	ratio of effective to gross area
λ	slenderness ratio, i.e. system length divided by radius of gyration
Λ	relative slenderness (λ/λ_1)
Λ_{eff}	effective slenderness (non-dimensional parameter incorporating K)
σ_b	specified minimum yield strength of bolt steel
σ_r	reference stress of member
σ_t	specified minimum tensile strength of bolt
σ_y	specified minimum yield strength of steel member
σ_u	specified minimum tensile strength of steel member
χ	reduction factor for relevant buckling mode

4 Axes of members

For the purposes of this part of BS 8100 the axes of members are shown in Figure 2.

5 Structural configurations, system length and effective slenderness

5.1 General

There are a number of different configurations that are commonly used in lattice towers and masts. Each requires separate consideration. Some popular arrangements are dealt with in 5.2 and 5.3.

In order to determine the buckling resistance of a lattice member it is necessary first to derive the appropriate geometric length of the member between intersection points providing restraint, defined as the "system" length. The relevant slenderness ratio based on the system length and appropriate radius of gyration is calculated and the effective slenderness determined appropriate to the end conditions of the member (see 5.5).

5.2 Leg members

5.2.1 Single members

Single angles, tubular sections or solid rounds may be used for leg sections. The capacity of the leg will be dependent on the pattern and connections of bracings used to stabilize the leg. For legs or chords with axial compression load braced symmetrically in two normal planes or planes 60° apart, for example in the case of triangular structures, the slenderness should be determined from the system length between nodes, i.e. intersections of bracings.

Effective slenderness factors are given in Table 2.

When this bracing is staggered in two normal planes or planes 60° apart in the case of triangular structures, the system length should be taken as the length between nodes on one face. Modified effective slenderness parameters are given for angle legs in Table 2 to allow for their torsional instability in such cases.

NOTE A maximum effective slenderness ratio of 120 for leg members is good practice.

5.2.2 Compound members

Compound members for legs may be built up with two angles in cruciform section and then taken as fully composite if welded continuously [see Figure 3a)]. When intermittently connected [see Figure 3b)] the possible additional deformations due to shear should be taken into account by modifying the slenderness ratio, λ , in accordance with the following:

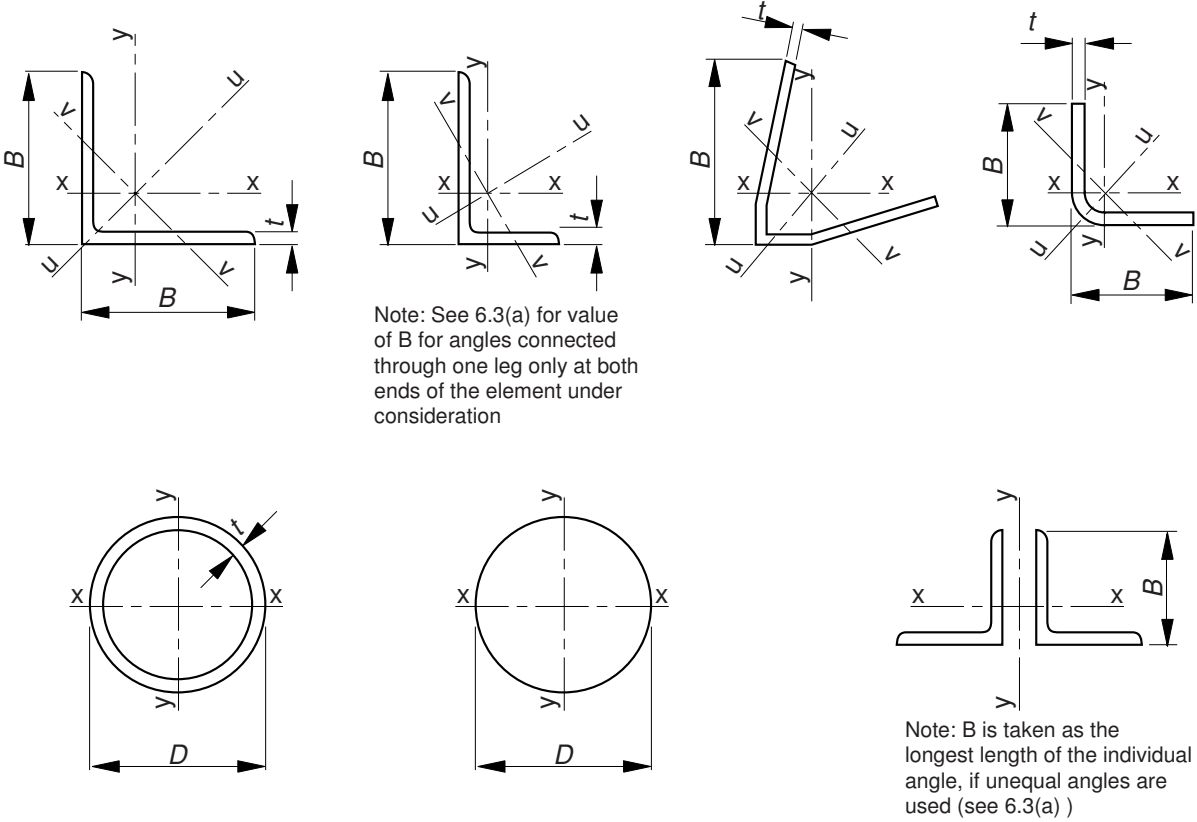
$$\lambda^2 = \lambda_0^2 + \lambda_1^2$$

where

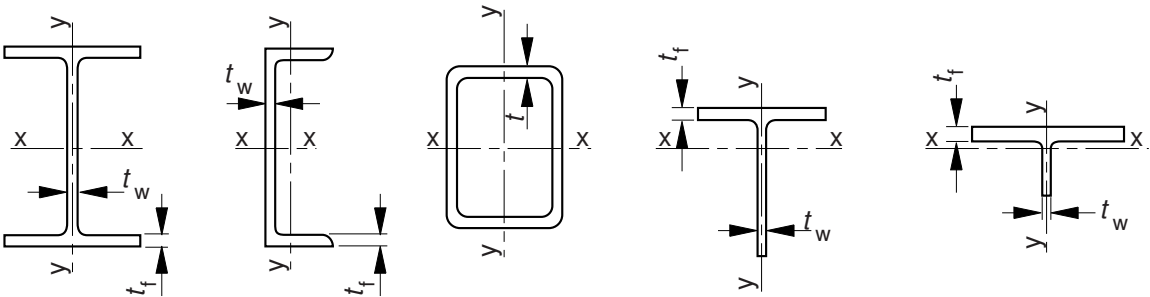
- λ_0 is the slenderness ratio of the full member;
- λ_1 is the slenderness ratio of one component angle (C/r_{vv}).

NOTE It is good practice to have $\lambda_0 \geq \lambda_1$ and $\lambda_1 \leq 50$

A method for determining the size of battens is given in annex A.



Commonly used sections



Other sections

Figure 2 — Dimensions and axes of sections

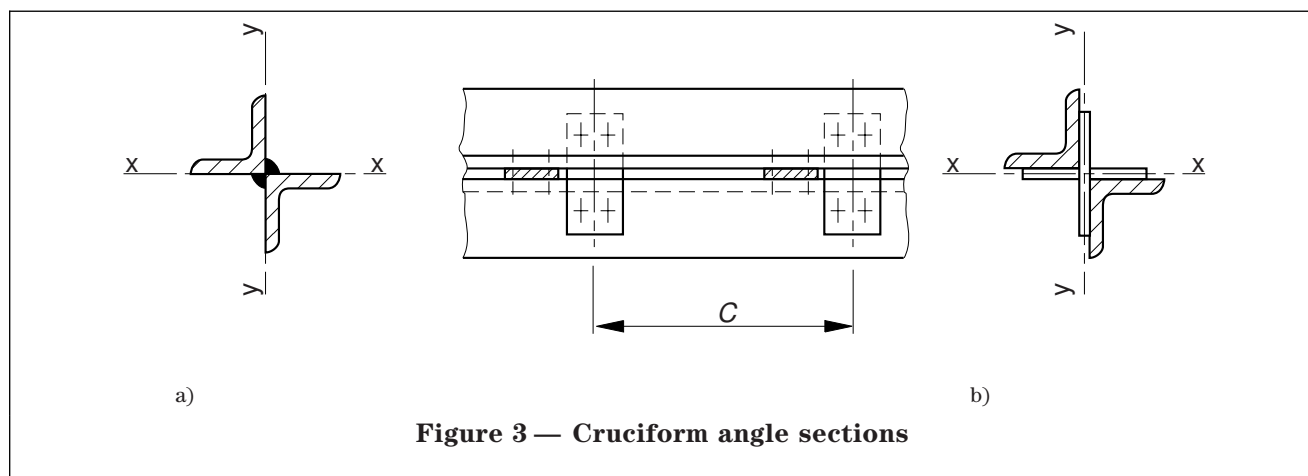


Figure 3 — Cruciform angle sections

5.3 Primary bracing members

5.3.1 General

Typical primary bracing patterns are shown in Figure 4.

Secondary bracings can be used to subdivide the primary bracing or main leg members as shown, for example, in Figures 4 and 5.

NOTE A maximum effectiveness slenderness ratio of 180 for primary bracing members is good practice.

5.3.2 Single lattice

A single lattice is commonly used where the loads are light and the length relatively short, as for instance near the top of towers or in light guyed masts [see Figure 4a) and g)]. The slenderness ratio, λ , should be taken as:

$$\begin{aligned}\lambda &= L_d/r_{vv} && \text{for angles;} \\ \lambda &= L_d/r_{xx} && \text{for tubes or solid rounds.}\end{aligned}$$

5.3.3 Cross bracing systems

5.3.3.1 Cross bracing without secondary members

Provided that:

- the load is equally split into tension and compression; and
- both members are continuous [see Figure 4b)]; and
- the members are adequately connected where they cross, then the centre of the connection may be considered as a point of restraint both transverse to and in the plane of the bracing and the critical system length becomes length L_{d2} on the minimum axis. The slenderness ratio, λ , should be taken as:

$$\begin{aligned}\lambda &= L_{d2}/r_{vv} && \text{for angles;} \\ \lambda &= L_{d2}/r_{xx} && \text{for tubes.}\end{aligned}$$

NOTE Where either member is not continuous, the centre of the connection may only be considered as a restraint in the transverse direction if the detailing of the centre connection is such that the effective lateral stiffness of both members is maintained through the connection and the longitudinal axial stiffness is similar in both members.

When the load is not equally split into tension and compression and provided both members are continuous, the compression members should be checked for the worst compressive load. In addition, it should be checked that the sum of the load carrying capacities of both members in compression is at least equal to the algebraic sum of the loads in the two members. For the calculations of these load carrying capacities, the system length is the whole length L_d and the radius of gyration is that about the rectangular axis parallel to the plane of the bracing. The value of the slenderness ratio, λ , should be taken as one of the following:

$$\begin{aligned}\lambda &= L_d/r_{xx} \quad \text{or} \quad \lambda = L_d/r_{yy} && \text{for angles;} \\ \lambda &= L_d/r_{xx} && \text{for tubes or solid rounds.}\end{aligned}$$

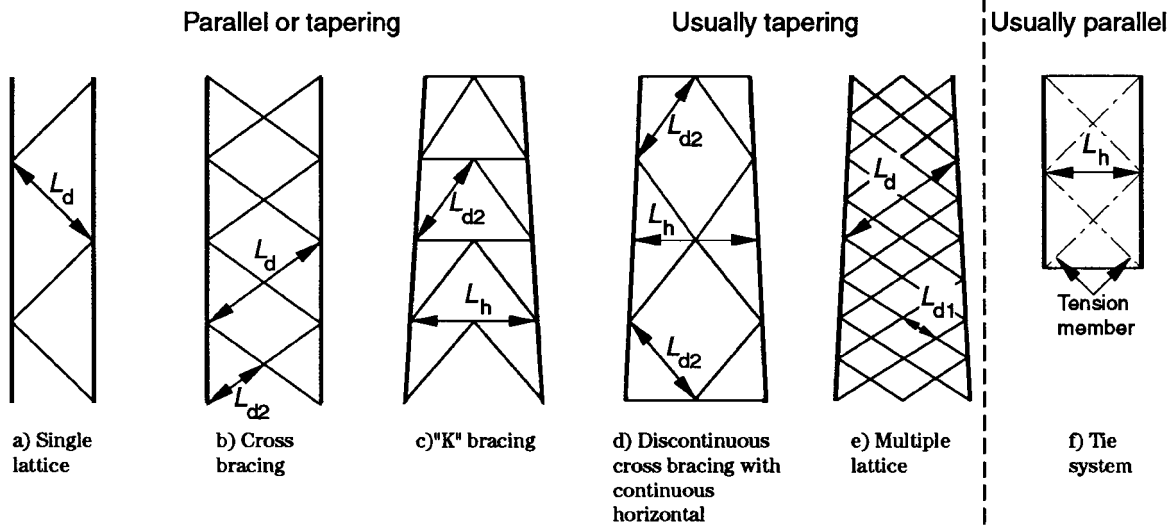
5.3.3.2 Cross bracing with secondary members

Where secondary members are inserted [see Figure 4h) and Figure 5a) and b)], they reduce the system length of the bracing member on the minimum axis to L_{d1} . The slenderness ratio, λ , should be taken as:

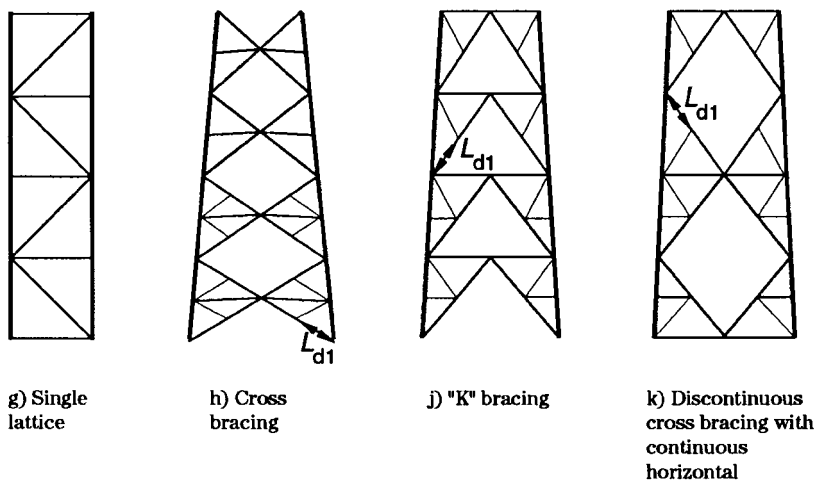
$$\begin{aligned}\lambda &= L_{d1}/r_{vv} && \text{for angles;} \\ \lambda &= L_{d1}/r_{xx} && \text{for tubes or solid rounds} \\ &&& \text{(normally not critical).}\end{aligned}$$

Buckling should also be checked over the system length L_{d2} on the rectangular axis for buckling transverse to the bracing and, when the load is not equally split into tension and compression, over the system length L_d for the algebraic sum of the loads (see 5.3.3.1).

Typical primary bracing patterns



Typical primary bracing patterns using secondary members
(see also figure 5)



NOTE 1 The members in the system should be designed to carry the total shear as shown.

NOTE 2 If relevant, checks should be made to ensure that the ineffective member can provide an adequate basis for incorporating secondary bracing

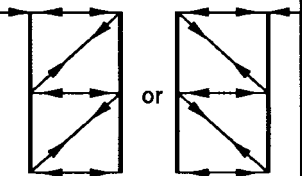


Figure 4 — Typical bracing patterns