Mobile access and working towers made of prefabricated elements — Materials, dimensions, design loads, safety and performance requirements

The European Standard EN 1004:2004 has the status of a British Standard

ICS 91.220

National foreword

This British Standard is the official English language version of EN 1004:2004. It supersedes BS 1139-3:1994 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee B/514, Access and support equipment, to Subcommittee B/514/24, Access towers, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

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English version

Mobile access and working towers made of prefabricated elements - Materials, dimensions, design loads, safety and performance requirements

Échafaudages roulants de service en éléments préfabriqués - Matériaux, dimensions, charges de calcul et exigences de sécurité

Fahrbare Arbeitsbühnen aus vorgefertigten Bauteilen - Werkstoffe, Maße, Lastannahmen und sicherheitstechnische Anforderungen

This European Standard was approved by CEN on 12 November 2004.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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Contents

Foreword

This document (EN 1004:2004) has been prepared by Technical Committee CEN/TC 53 "Temporary works equipment", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2005, and conflicting national standards shall be withdrawn at the latest by June 2005.

This document supersedes HD 1004:1992.

The development of mobile access and working towers system is from two roots:

— scaffold manufacturers placed prefabricated unanchored scaffolds on four legs and castors and

— ladder manufacturers began to construct mobile access towers with light-weight ladders using aluminium frames and castors.

Taking this into account, CEN/TC53 decided in 1980 to standardize the manufacture of mobile access and working towers in parallel with the European standardization of prefabricated service and working scaffolds EN 12810-2 and EN 12811-3.

For materials, this document refers only to valid documents. However, a large stock of equipment made of materials conforming to documents no longer valid is in use. This document does not cover this equipment.

During discussion of the draft it was noted that the average height of people is increasing and that consideration will have to be given in later editions to altering vertical dimensions.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This document applies to the design of mobile access and working towers made of prefabricated elements with a height from 2,5 m to 12,0 m (indoors) and from 2,5 m to 8,0 m (outdoors).

This document:

- gives guidelines for the choice of the main dimensions and stabilizing methods;
- gives safety and performance requirements; and
- gives some information on complete towers.

NOTE In this document "indoors" means that the towers is not be exposed to wind, and "outdoors" means that the towers may be exposed to wind.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 74, *Couplers, loose spigots and base-plates for use in working scaffolds and falsework made of steel tubes – Requirements and test procedures*

EN 1298, *Mobile access and working towers – Rules and guidelines for the preparation of an instruction manual*

EN 1991-2-4, *Eurocode 1: Basis of design and actions on structures- Part 2-4: Actions on structures - Wind actions*

EN 1993-1-1:2005, *Eurocode 3: Design of steel structures – Part 1-1: General rules and rules for buildings*

EN 1995-1-1, *Eurocode 5 : Design of timber structures – Part 1-1 : General rules and rules for building*

EN 1999-1-1, *Eurocode 9: Design of aluminium structures – Part 1-1: General rules - General rules and rules for buildings*

EN 12810-2, *Façade scaffolds made of prefabricated components – Part 2: Particular methods of structural design*

EN 12811-2, *Temporary works equipment – Part 2: Information on materials.*

EN 12811-3, *Temporary works equipment – Part 3: Load testing*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
mobile access and working towers
scaffold structures which:

— are capable of being used free-standing;

— have one or more working platforms;

— are assembled using prefabricated components;

— have the dimensions fixed by the design;

— have normally four legs with at least four castors;

— are stable, by supports on the ground and if necessary by support to a vertical construction by wall strut

3.2
height (H)
distance from the ground to the upper surface of the top platform

3.3
castor wheel
swivelling wheel secured to the base of a member to enable the tower to be moved

3.4
adjustable leg
incorporated into the structure only for plumbing a tower when situated on uneven or sloping ground. An adjustable leg may be fitted with either a castor wheel or a base plate

3.5
platform component
unit of platform that supports a load on its own

3.6
bracing member
means used to stiffen the structure

3.7
outrigger
component that increases the effective base dimensions of a tower, with provision for the attachment of a castor

3.8
stabilizer
component that increases the effective base dimensions of a tower, without provisions for the attachment of a castor

3.9
ballast
weights placed at the base of the tower to increase its resistance to overturning

3.10
wall strut
means for providing compressive restraint to prevent a tower overturning. It is normally a horizontal tubular member, one end of which is coupled to the tower, while the other end rests against a wall or other structure

3.11
stairway
means of access intended for persons carrying tools or materials

3.12
stairladder
means of access intended for persons not carrying tools or materials

3.13
inclined ladder
means of access intended for persons not carrying tools or materials with an inclination from 60° to 75°

3.14
vertical ladder
means of access intended for persons not carrying tools or materials with an inclination of 90°

3.15
platform
one or more platform components forming a working area

3.16
length (*L*)
greater of the two plane dimensions at the platform level (see Figure 1)

3.17
width (*W*)
lesser of the two plane dimensions at the platform level (see Figure 1)

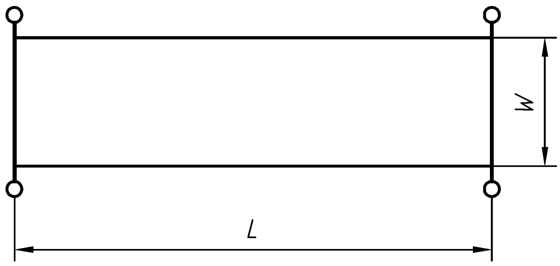


Figure 1 —Width (*W*) and length (*L*)

4 Classification

4.1 Load classes

The classes of uniformly distributed load are given in Table 1.

Table 1 — Classes of uniformly distributed load

Load class	Uniformly distributed load q kN/m^2
2	1,50
3	2,00

4.2 Access classes

Four options for access to the platform are described in 7.6.

5 Designation

The following data are required for the designation of all prefabricated mobile access and working towers:

a) class of uniformly distributed load (see 4.1);

b) maximum height outdoors/indoors;

c) access classes (see 4.2).

EXAMPLE

Tower EN 1004 2 8/12 A B X X

class 2

maximum height
outdoors 8 m
indoors 12 m

access through
stairway and stairladder

6 Materials

Materials shall fulfil the requirements given in documents where design data are provided. Information for the most commonly used materials are given in EN 12811-2.

Steel shall be protected by one of the methods given in EN 12811-2, Clause 8 or zinc coated with an average thickness of 15 µm.

7 General requirements

7.1 General

The following subclauses specify the minimum requirements for the mobile access and working tower including platforms.

It shall be possible to fix platforms for erection and dismantling purposes with vertical distances between platforms not exceeding 2,10 m

7.2 Dimensions

The minimum width, *W*, of the platform shall be 0,60 m and the minimum length, *L*, shall be 1,00 m.

The minimum clear height between platforms “H” shall be in accordance with Table 2.

Table 2 — Clear height classes

Clear height class	Minimum clear height H in m
H_1	1,85
H_2	1,90

7.3 Apertures within platforms

The aperture shall be as small as practicable, and it shall have a minimum clear opening of:

0,40 m wide x 0,60 m long

Apertures in platforms shall not exceed 25 mm in width. This does not apply to apertures like hand holes in hatches.

Access to a working platform through an aperture in a platform shall be provided with means to prevent falling through.

7.4 Side protection

7.4.1 General

For allowable dimensions see Figure 2.

Dimensions in millimetres unless otherwise stated

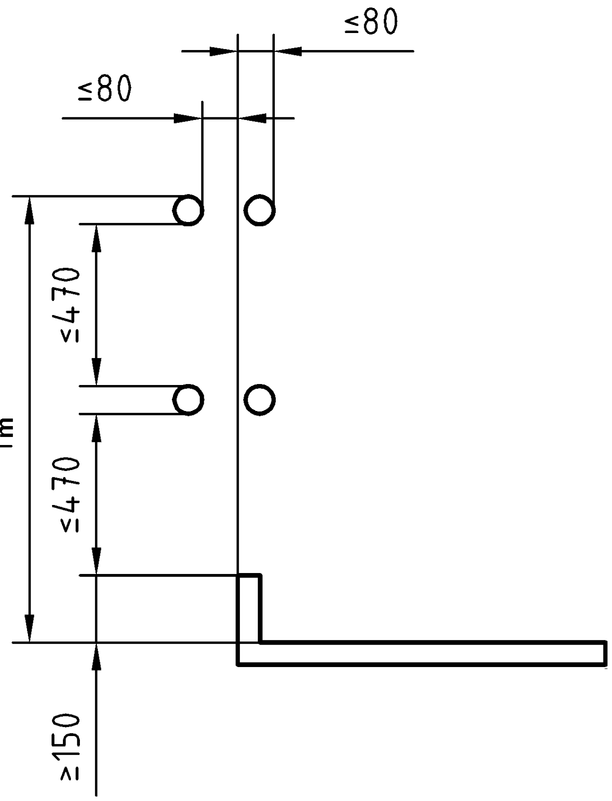


Figure 2 — Side protection dimensions

Side protection components shall be incapable of removal except by direct intentional action.

It shall be possible to erect protection at platform edges comprising:

a) at least one principal guardrail and intermediate side protection;

b) toe-board;

7.4.2 Principal guardrail

The principal guardrail shall be fixed so that its top surface is 1 m or more above the adjacent level of the working area everywhere (minimum height 950 mm).[1)]

1) See A-deviation.

7.4.3 Intermediate side protection

Intermediate side protection shall be fixed between the principal guardrail and the toe-board.

Intermediate side protection may consist of:

- one or more intermediate guardrails, or
- a frame, or
- a frame of which the principal guardrail forms the top edge, or
- a fencing structure.

Openings in the side protection shall be so dimensioned so that a sphere with a diameter of 470 mm will not pass through them.

7.4.4 Toe-board

It shall be possible to fix a solid toe-board such that its top edge is at least 150 mm above the adjacent platform level.

7.5 Castor wheels

7.5.1 General

Castor wheels shall be fixed to the tower in such a way that they cannot be accidentally detached.

7.5.2 Brakes

All castors shall have wheel brakes. They shall have swivel brakes unless by their design they are not eccentric when locked.

The brake mechanism shall be designed in such a way that it can only be unlocked by a deliberate action. The brake mechanism shall effectively prevent any rotation of the wheel when a horizontal force of 0,30 kN is applied through the vertical swivel axis of the castor as close as possible above the castor housing and in the rolling direction of the castor. The full value of the specified service load per castor wheel is to be applied when testing the castor brakes. A minimum of five control tests shall be carried out.

7.5.3 Test loads

The vertical service load per wheel given by the manufacturer of the MAT (Mobile Access Tower) shall be verified by a minimum of 5 tests.

The test load shall be three times the service load per castor wheel derived from the most unfavourable load combination from Table 4.

When the brakes are locked, an initial vertical load of 0,50 kN shall be applied. The plate of the fork shall be taken as the origin for measurements of vertical displacement d_c and the residual deformation d_r.

The load shall be increased to the maximum test load, maintained for one minute and the vertical deformation d_c shall be measured. The load shall be returned to 0,50 kN. After 30 min the residual deformation d_r shall be measured.

The test shall meet both of the following requirements:

— residual deformation d_r after 30 min shall not be more than 1,5 mm;

— total deformation d_c shall not be more than 15 mm.

The service load is verified if all five tests meet the test requirements.

7.5.4 Wheels

Wheels shall be of punctureless type.

7.6 Access to platforms

7.6.1 General

The access type is classified by a letter A, B, C or D as follows:

— Access type A: Stairway;

— Access type B: Stairladder;

— Access type C: Inclined ladder;

— Access type D: Vertical ladder.

Where a range of access types is provided, a combined classification is used.

EXAMPLES

Type AXCX means that stairways and inclined ladders can be provided.

Type ABCD means that all four types of access can be provided.

NOTE The X in the designation means that those types of access are not provided.

7.6.2 General requirements

Access to the platforms in an assembled tower shall be within the main structural supports and shall:

- be secured against unintentional loosening;
- not rest on the ground;
- have a distance from the ground to the first step or rung of 400 mm maximum (if the first step is a platform, 600 mm is allowable);
- have steps/rungs with constant spacing and a slip resistant surface.

7.6.3 Requirements for stairway and stairladder

7.6.3.1 General

The outside of stair flights shall be provided with a handrail which runs approximately parallel to the stairs. Where a flight of stairs is provided in a continuous dog-leg style, a handrail shall be also be provided on the inside. When flights of stairs are interrupted by platforms at ≤ 2,1 m intervals, the inside handrail may be omitted.

Flights of stairs in a continuous dog-leg style shall have landings. Each of these stairs shall have a minimum of one landing and this shall have a minimum length of 300 mm.

The minimum clear height for access measured between the steps and the supporting structure of the stairway or stairladder above shall not be less than 1,75 m.

7.6.3.2 Requirements for stairway class A (see Figure 3)

- Inclination	35 ° ≤ α ≤ 55 °;
- vertical step rise	190 mm ≤ t ≤ 250 mm;
- Minimum step depth	*d* = 125 mm;
- Minimum clear width	400 mm;
- Horizontal gap between steps	0 ≤ *g* ≤ 50 mm;

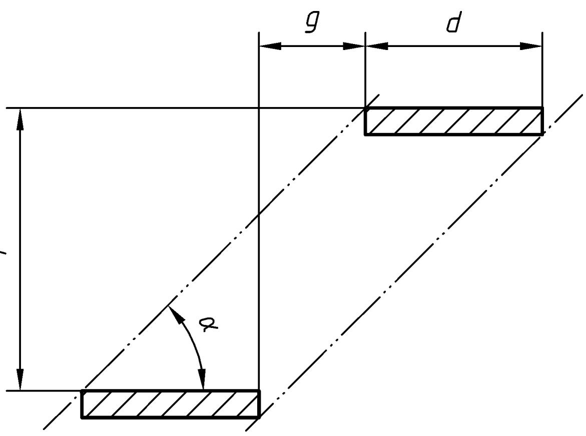


Figure 3 — Dimensions of stairway

7.6.3.3 Requirements for stairladder class B (see Figure 4)

- Inclination — $35\,° \leq \alpha \leq 55\,°$;
- Vertical step rise — 150 mm $\leq t \leq$ 250 mm;
- Minimum step depth — d = 80 mm;
- Minimum clear width — 280 mm;
- Horizontal gap between steps — $0 \leq g \leq$ 160 mm.

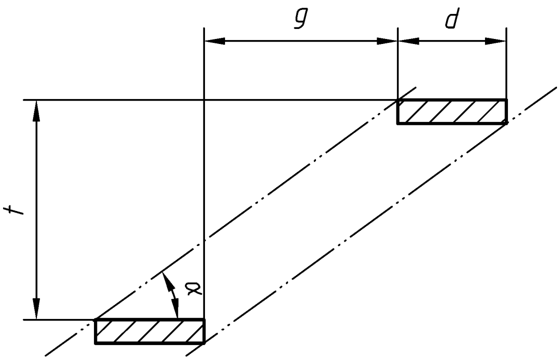


Figure 4 — Dimensions of stairladder

7.6.3.4 Requirements of inclined ladder class C (see Figure 5)

- Inclination — $60\,° \leq \alpha \leq 75\,°$;
- Step spacing — 230 mm $\leq t \leq$ 300 mm;
- Step depth — d > 80 mm;
- Rung spacing — 230 mm $\leq t \leq$ 300 mm;
- Rung depth — 20 mm $\leq d \leq$ 80 mm;
- Minimum clear width — 280 mm;
- Maximum vertical distance between different platforms — 4,2 m;
- Maximum distance between the ground and the first platform — 4,6 m.

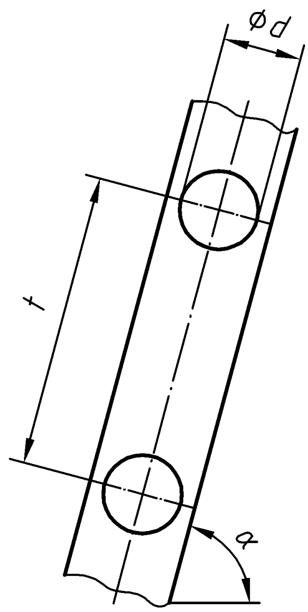
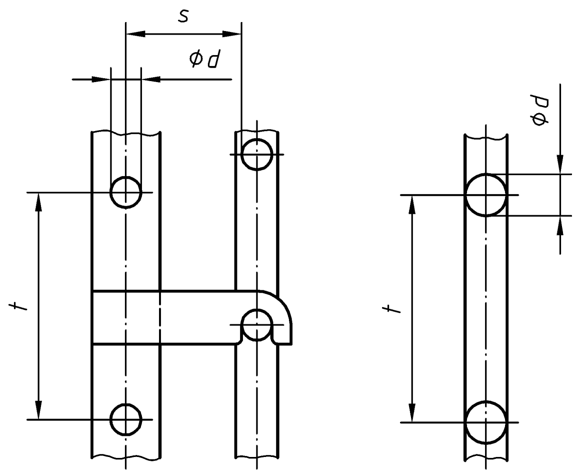


Figure 5 — Dimensions of inclined ladder

7.6.3.5 Requirements of vertical ladder class D (see Figure 6)

From the front edge of the step or from the centre of the rung to any obstacle behind the stairway/ladder there shall be a horizontal distance of s = 150 mm minimum (see Figure 6).

- Rung spacing	230 mm ≤ t ≤ 300 mm;
- Rung depth or diameter	20 mm ≤ d ≤ 51 mm;
- Minimum clear width	280 mm;
- Maximum vertical distance between different platforms	4,2 m;
- Maximum distance between the ground and the first platform	4,6 m.



a) Separate ladder **b) Integral ladder**

Figure 6 — Dimensions of vertical ladder

7.7 Means for stabilizing

7.7.1 Stabilizers and outriggers

The stabilizers and outriggers of a tower shall be purpose designed as component of the main structure and shall provide means of adjustment to ensure contact with the ground.

The method of fixing the stabilizer or outrigger to the tower shall have adequate strength and shall be such that the reaction loads in the stabilizer or outrigger are transferred to the tower without slip, rotation, or other movement of the stabilizer or outrigger.

7.7.2 Ballast

If ballast is necessary, it shall be securely positioned and made of rigid materials such as steel or concrete, but excluding liquids or granular materials.

7.8 Connections

7.8.1 General

Each connection device shall be effective, easy to monitor and the components shall be easy to assemble. The securing of components forming part of the structure of the scaffold and side protection components shall make them incapable of removal except by direct intentional action.

7.8.2 Vertical spigot and socket connection

When assembled, the horizontal movement (slack or play) between upper and lower components shall not exceed 4 mm or a movement away from the centre line of 2 mm.

In all cases it shall not be possible to disconnect an upper component laterally until the upper component has been lifted more than 80 mm.

When the spigot and socket connection acts over a distance less than 150 mm, the connection shall be provided with a positive locking device, such as a cross pin, to prevent the upper component from being lifted unintentionally.

The captive locking device shall be placed in such a way that its positive action can be monitored visually.

7.8.3 Other vertical connections

There shall be equivalent provisions related to 7.8.2 to limit the risk of accidental disconnections.

NOTE Other strength requirements can impose further limitations on the arrangement of connections.

7.9 Platform components

Components of platforms shall be durable and shall have a slip-resistant surface. It shall be possible to secure these components so that overturning or removal by wind is not possible.

7.10 Erection and dismantling

The tower shall remain stable and resist all loads imposed on the components also during erection and dismantling.

8 Requirements for structural design

8.1 General

A tower structure shall be able to resist the combination of loads, taking from one line from each of the five groups given in Table 4, in their worst combinations.

All loads are taken to be static loads.

Eccentricities of castor wheels shall be taken into account.

Adjustable legs shall be extended to their maximum extension.

Platforms shall be assessed with respect to self-weight and the most unfavourable service load according to Table 6.

8.2 Actions on the complete structure including its parts

8.2.1 Verticals loads

8.2.1.1 Tower nominal self-weight as given by the manufacturer

The self-weight of the tower including all parts and ballast (if applicable) shall be taken into account.

8.2.1.2 Uniformly distributed load on the topmost platform

— class 2 : 1,5 kN/m²;

— class 3 : 2,0 kN/m².

8.2.1.3 Load resulting from an inclination of 1 %

Vertical loads to be taken into consideration are:

- nominal self-weight as given (see 8.2.1.1);
- vertical service loads as given (see 8.2.1.2).

8.2.1.4 Minimum vertical service load on the structure, equally distributed on 4 legs

P = 5,0 kN ;

NOTE P can be larger than 5,0 KN in accordance with the uniformly distributed loads as given in Table 4.

8.2.2. Horizontal loads

8.2.2.1 Horizontal service load on the topmost platform

On the level of the platforms with length *L* :

— $L \leq 4{,}0$ m 0,3 kN;

— $L > 4{,}0$ m 2 x 0,3 kN.

8.2.2.2 Horizontal design loads on all components to simulate wind

0,1 kN/m² multiplied by the appropriate shape factors, see 2.4 of ENV 1991-2-4.

The wind area shall include at all working levels the fully equipped side protection (included toe-boards).

Shelter factors for more than one member being upwind may be taken into consideration as follows:

The reference area A for more than one solid members is shown in Equation (1)

$$A = [1 + \eta + (n-2)\,\eta^2] \times A_1 \quad (1)$$

where

A_1 is the reference area of one member (the highest one if there are different areas);

$n \geq 2$ is the number of single members;

η is the shelter factor as a function of (x / h) (see Table 3).

where

x is the space between the walls (the greatest one if there are different spaces);

h 100 % of the height of the walls, if the walls are open
200 % of the height of the walls, if the walls are decked on top or at bottom.

Table 3 — Shelter factor η for solidity φ = 1

Spacing x / h	2	3	4	5	6,3	8	10	12,5	16	20	25
η	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0

8.3 Actions on parts of the structure

8.3.1 Loads on platforms

Platforms and supporting structure shall be designed for concentrated loads in the most unfavourable position on a platform area of:

— 0,50m x 0,50m 1,5 kN;

— 0,20m x 0,20m 1,0 kN.

In addition uniformly distributed load shall also be considered (see 8.2.1.2).

The above requirements may be fulfilled separately.

8.3.2 Load on side protection

8.3.2.1 Downward load

Any principal guardrail or intermediate guardrail, regardless of its method of support, shall be able to resist a point load of 1,25 kN. This also applies to any other side protection component, such as a fencing structure, which has a potential foothold of 50 mm wide or greater.

This load shall be considered as an accidental load and applied in the most unfavourable position in a downward direction within a sector of ± 10° from the vertical.

8.3.2.2 Horizontal load

All components of the side protection, except toe-boards, shall be able to of resist a horizontal load of 0,3 kN in each case in the most unfavourable position. This load may be distributed over an area of 300 mm x 300 mm, for example when applied to the grid of a fencing structure. For toe-boards, the horizontal load is 0,15 kN.

Table 4 — Service loads on the whole structure

Group	**Line**	**Kind of load**	**Value of loads**	**Subclause**
1		Self-weight including ballast if applicable	as given	8.2.1.1
2		Vertical service load on the topmost platform		
	2.1	Uniformly distributed load		8.2.1.2
	2.1.1	for class 2	1,5 kN/m²	
	2.1.2	for class 3	2,0 kN/m²	
	2.2	minimum service load on structure	5,0 kN/4 legs	8.2.1.4
3		Horizontal service load on the topmost platform		8.2.2.1
	3.1	$L \leq 4{,}0$ m [a]	0,3 kN	
	3.2	$L > 4{,}0$ m [a]	2 x 0,3 kN	
4		Horizontal design loads to simulate wind		8.2.2.2
5		Loads resulting from an inclined position of 1 %		8.2.1.3

[a] L = length of the platform.

Table 5 — Design loads on parts of the structure

Line	Element	Kind of load	Value of loads	Subclause
1	platform			
1.1		Uniformly distributed on the whole area		8.2.1.2
1.1.1		class 2	1,5 kN/m²	
1.1.2		class 3	2,0 kN/m²	
1.2		Concentrated on an area of 500 mm x 500mm in the most unfavourable position on the platform If the width of the decking component is less than 500 mm, the load shall not be reduced.	1,5 kN	8.3.1
1.3		Concentrated on an area of 200 mm x 200 mm in the most unfavourable position on the platform	1,0 kN	8.3.1
2	guardrail			
2.1		a point load on the guardrail in the most unfavourable position	1,25 kN	8.3.2.1
2.2		a point load on the guardrail in the most unfavourable position	0,3 kN	8.3.2.2
3	toe-board	a point load on the toe-board in the most unfavourable position	0,15 kN	8.3.2.2

8.4 Deflections

8.4.1 Elastic deflection of platform components

When subjected to the concentrated loads specified in Table 5, line 1.2, the elastic deflection of any platform component shall not exceed 0,01 of the span of that platform component.

In addition, in the case of platform components with spans of 2,5 m or greater, when the appropriate concentrated load is applied, the maximum difference in levels between adjacent loaded and unloaded platform components shall not exceed 25 mm.

8.4.2 Elastic deflection of side protection

When subjected to the load specified in Table 5, line 2.2, the maximum deflection of any principle or intermediate guardrail, regardless of its span, shall not exceed 35 mm. When subjected to the load specified in Table 5; line 3, the maximum deflection of any toe-board, regardless of its span shall not exceed 35 mm. These are measured with reference to the supports at the points where they are connected.

9 Instruction manual

For each type of prefabricated equipment the manufacturer shall produce an instruction manual for use on site. The instruction manual shall include at least the data according to EN 1298.

10 Marking

10.1 Components

Each purpose designed component shall be marked with:

a) a symbol or letters to identify the MAT system and its manufacturer;

b) the year of manufacture, using the last two digits. Alternatively a code for tracing the year of manufacturer may be used.

Marking shall be so arranged that it will remain legible for the life of the component. The size of the lettering may take account of the size of the component.

10.2 Manufacturers plate

A manufacturer's plate showing the information below shall be displayed and visible from the ground level on all mobile access and working towers:

a) manufacturer's mark;

b) designation;

c) "Instructions for erection and use to be followed carefully" in the respective language.

11 Structural design

11.1 Basic design principle

11.1.1 Introduction

Mobile access and working towers shall be designed for load bearing capacity, serviceability and resistance to overturning. Unless otherwise stated in this clause, the documents for structural engineering shall be applied.

The strength of joints and connections (e.g. welded joints, compressed connections, hollow type rivet connections) shall be verified.

Concepts relate to the limit state method.

Full scale or detail testing may be undertaken in accordance with EN 12811-3 to supplement calculation.

11.1.2 Structural design of components

11.1.2.1 Steel

The structural design shall be in accordance with EN 1993-1-1 taking into account EN 12811-2.

11.1.2.2 Aluminium

The structural design shall be in accordance with EN 1999-1-1 taking into account EN 12811-2.

11.1.2.3 Timber

The structural design shall be in accordance with EN 1995-1-1 taking into account EN 12811-2.

11.1.2.4 Other materials

Appropriate documents shall be applied for the structural design. If European documents do not exist, International documents may be applied.

11.1.3 Limit states

The limit states are classified into:

— ultimate limit states;

— serviceability limit states.

At ultimate limit state the design value for the effect of actions, that is the design value of an internal force or moment, E_d, shall not exceed the design value of the corresponding resistance, R_d, in accordance with the expression

$$E_d \leq R_d$$

The design value, E_d, for the effect of actions is calculated from the characteristic values of the actions specified in 8.2 and 8.3 by multiplying each by the corresponding partial safety factor, γ_F .

The design value of the resistance, R_d, is calculated from the characteristic resistance values specified in 11.3 by dividing by a partial safety factor, γ_M.

At serviceability limit state the design value for the effect of actions specified in the serviceability criterion, E_d, shall not exceed the limiting design value of the relevant serviceability criterion, C_d.

$$E_d \leq C_d$$

11.2 Structural analysis

11.2.1 Choice of a model

The models adopted shall be sufficiently accurate to predict the structural behaviour level taking into account the imperfections given in 11.2.2.

The analysis carried out by checking separate planar systems shall consider the interaction.

11.2.2 Imperfections

11.2.2.1 General

The effects of practical imperfections, including residual stresses and geometrical imperfections, such as out of vertical, out of straight and unavoidable minor eccentricities shall be taken into account by suitable equivalent geometrical imperfections.

The method of application shall be in accordance with the respective specifications of the relevant design documents, for example, for steel EN 1993-1-1, for aluminium EN 1999-1-1. Deviating from these specifications, the assumptions concerning imperfections in global frame analysis shall comply with 11.2.2.2.

The equivalent geometric imperfections need not be geometrically compatible.

11.2.2.2 Inclinations between vertical components

Frame imperfections by angular deviations at the joints between vertical components shall be taken into account.

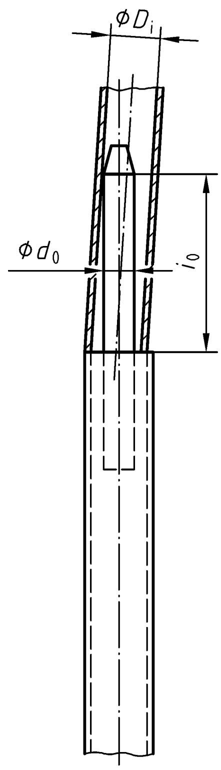


Figure 7 — Angle of inclination between vertical components

For a joint in a tubular standard, the angle of inclination, ψ, between a pair of tubular components connected by a spigot permanently fixed to one of the components (see Figure 7) may be calculated from Equation (2):

$$\tan\psi = \frac{D_i - d_0}{\ell_0} \text{ but not less than } \tan\psi = 0{,}01 \qquad (2)$$

where

D_i is the nominal inner diameter of the tubular component;

D_0 is the nominal outer diameter of the spigot;

ℓ_0 is the nominal overlap length.

NOTE This does not cover the use of loose spigots where the inclination is likely to be twice or much or the use of expanding joint pints, where it can be much less.

In the case of a closed frame of prefabricated tower, the value of tan ψ in the plane of the frame may be taken to 0,01 if the overlap length is at least 150 mm and to 0,02 if the overlap length is less, but in minimum 80 mm.

The requirements of 11.2.3.1 also apply.

11.2.3 Rigidity assumptions

11.2.3.1 Joints between tubular members

The joints between tubular members may be assumed to be rigid connections if the spigot is permanently fixed to one document and if:

— the overlapping length of the spigot is at least 150 mm and

— the play between the nominal inner diameter of the tube and the nominal outer diameter of the spigot is not greater than 4 mm.

or

— the overlapping length of the spigot is at least 80 mm and

— the play between the nominal inner diameter of the tube and the nominal outer diameter of the spigot is not greater than 2 mm.

This assumption applies to tubular members with external diameters not exceeding 60 mm.

If one of these requirements is not met, for example if spigots according to EN 74 are used, the joints shall be modelled as an ideal hinge. Alternatively, a detailed check on the spigot and the standard may be made (see 11.3.3.2).

11.2.3.2 Connecting devices

The realistic load-deformation behaviour of the connecting devices shall be incorporated in the model for the analysis. Alternatively joints may be modelled by assumptions which are on the safe side.

NOTE ENV 1993-2 and EN 12811-3 give some information on semi-rigid connections.

For the determination of the relevant parameters for semi-rigid connecting devices in prefabricated towers, see EN 12810-2.

Where the connections to standards are made by prefabricated joints, for example in a modular system, the design moment-rotation characteristic of ledger-to-standard or transom-to-standard connections shall be determined.

11.2.4 Resistance

11.2.4.1 General

The characteristic values of the resistances shall be calculated using the characteristic values of the mechanical properties (for example the yield strength $f_{y,k}$), which are given in EN 12811-2 or may be taken from relevant documents.

For steel or aluminium members the resistances shall be determined in accordance with 5.4 of EN 1993-1-1:2005 or 5.3 of EN 1999-1-1 respectively.

11.2.4.2 Connecting devices

To establish the characteristic values of resistances for:

a) connections covered by the scope of structural engineering regulations: see relevant design documents;

b) semi-rigid connection devices for prefabricated towers: see EN 12810-2 and EN 12811-3;

c) other connection devices which do not comply with a document: test shall be carried out. See e.g. EN 12810-2.

11.3 Verification

11.3.1 General

For the determination of internal forces and moments, elastic methods shall be used. For example for steel see ENV 1993-1-1:1993, 5.2.1.3.

The influence of the deflections on the internal forces and moments shall be taken into account; the equilibrium of the displayed system shall be calculated by the use of a second-order analysis or by the use of a first-order analysis with amplification factors.

11.3.2 Partial safety factors

11.3.2.1 Partial safety factors for actions, γ_F

Except when stated otherwise, the partial safety factor, γ_F, shall be taken as follows:

a) ultimate limit state

γ_F = 1,5 for all permanent and variable loads;

γ_F = 1,0 for accidental loads;

b) serviceability limit state

γ_F = 1,0.

11.3.2.2 Partial safety factors for material resistances, γ_M

For the calculation of the design values of the resistance of steel or aluminium components the partial safety factor, γ_M, shall be taken as 1,1. For components of other materials the partial safety factor, γ_M, shall be taken from relevant documents.

For the serviceability limit state, γ_M, shall be taken as 1,0.

11.3.3 Ultimate limit state

11.3.3.1 General

At ultimate limit state it shall be verified, that the design values of the effects of actions do not exceed the design values of the corresponding resistances.

11.3.3.2 Tubular members

For the combination of actions, the interaction Equation (3) may be used:

$$\frac{M}{M_{pl,V,d}} \leq \cos\left[\frac{\pi}{2}\frac{N}{N_{pl,V,d}}\right] \tag{3}$$

where

$$N_{pl,V,d} = \frac{N_{pl,k}}{\gamma_M}\sqrt{1-\left(\frac{V}{V_{pl,k}/\gamma_M}\right)^2}$$

is the design value of the resistant axial force with respect to the acting shear force V;

$$M_{pl,V,d} = \frac{M_{pl,k}}{\gamma_M}\sqrt{1-\left(\frac{V}{V_{pl,k}/\gamma_M}\right)^2}$$

is the design value of the resistant bending moment with respect to the acting shear force V

and

$N_{pl,k}$ is the characteristic plastic resistance of the axial force *N*;

$M_{pl,k}$ is the characteristic plastic resistance of the bending moment *M*;

$V_{pl,k}$ is the characteristic plastic resistance of the shear force *V*;

M is the design value of the actual bending moment;

N is the design value of the actual axial force;

V is the design value of the actual shear force.

For the value of the partial safety factor, γ_M, see 11.3.2.2.

11.3.3.3 Joints between tubular members

When the requirements of a rigid connection between tubular members according to 11.2.3.1 are met, the spigot only needs to be verified for the design bending moment at the joint.

When the overlap is less than 150 mm - respectively 80 mm - and the joint is not treated as an ideal hinge, see 11.2.3.1, the detailed structural design check shall include the bending stresses, shear stresses and local bearing stresses.

11.3.3.4 Side protection

Components of the side protection shall withstand the accidental load specified in 8.3.2.1 without failing or disconnecting. A displacement from the original line of more than 300 mm at any point is to be taken as failure. Where necessary the displacement may be calculated by assuming a plastic hinge, which transfers the plastic bending resistance of the component.

11.3.4 Serviceability limit state

It shall be verified that the deflection requirements specified in 8.4 are met.

11.4 Positional stability

11.4.1 General

The structure as a whole shall be stable in all conditions. This applies to overturning of free-standing towers.

Overturning may be resisted by self-weight, added ballast, stabilizers and outriggers or combinations of these.

11.4.2 Load cases

11.4.2.1 General

Following load cases shall apply. Both load directions (parallel and perpendicular to the tower) shall be evaluated for each load case.

NOTE When a tower which requires stabilizers or outriggers is used against a wall, wall struts may be used to provide stability. There should be a minimum of one wall strut on each vertical of the tower close to the wall. The wall struts should always be fitted at a level equal to or higher than the upper attachment point of the stabilizer or outrigger.

11.4.2.2 Load case 1

11.4.2.1.1 Safety factor

The safety factor against overturning shall be S ≥ 1,5.

11.4.2.2.2 Vertical loads

- Self-weight
- vertical service load on a position of 100 mm from the most unfavourable edge of the top platform. The vertical service load to be taken into account is:
  - for platform length $L \leq 4$ m : 0,75 kN;
  - for platform length $L > 4$ m : 2 x 0,75 kN.

11.4.2.2.3 Horizontal loads

- Horizontal service load on the top platform. The horizontal service load to be taken into account is:
  - for platform length $L \leq 4$ m : 0,3 kN;
  - for platform length $L > 4$ m : 2 x 0,3 kN.
- Wind load 0,1 kN/m² on structure (see 8.2.2.2) and persons:
  - for platform length $L \leq 4$ m : 1 person;
  - for platform length $L > 4$ m : 2 persons.

For the wind load on persons:

- projected area of one person : 0,7 m²;
- shape factor of : 1,0;
- centre of area : 1 m above the top platform level.

The horizontal service load and the wind load shall not be combined. Only the most unfavourable of these horizontal loads shall be taken into account.

11.4.2.2.4 Additional loads

Loads resulting from an inclined position of 1 %.

11.4.2.3 Load case 2

The safety factor against overturning shall be S ≥ 1,3.

11.4.2.3.1 Vertical loads

— self weight.

11.4.2.3.2 Horizontal loads

— wind load 0,1 kN/m² on structure (see 8.2.2.2).

11.4.2.3.3 Additional loads

Loads resulting from an inclined position of 1 %.

12 Tests

Being part of the structural design additional stiffness tests of a complete tower shall be made. These tests shall be carried out in accordance with Annex A.

13 Assessment

An assessment shall be carried out by a person or an organization different from the designing person and organization. On completion of a successful assessment a statement to that effect shall be given by the assessor. This statement shall identify the reference number of all examinations and the tests report shall include:

— identification of the particular set of components examined;

— identification of the evaluated configuration;

— structural data for components and connections as resistances and stiffnesses evaluated by tests.

Annex A
(normative)

Stiffness test on complete tower structure

A.1 General requirements (see Figures A.1 and A.2)

The object of the test is to ensure that towers do not exceed the maximum permitted displacement when erected to their maximum platform height and subjected to horizontal loads. This includes elastic stiffness, plus any take up of slack or play in the structure.

A.2 Test structure

The tests shall be carried out on complete tower structures with a minimum height of 6,0 m. The tower shall be built in accordance with the manufacturers manual instructions. When the self weight of the structure is insufficient to prevent overturning during the test, sufficient ballast may be added to the base to prevent this.

If the maximum platform height, in accordance with the manufacturer's instructions, is less than 6,0 m the test structure shall be erected to at least 6,0 m height with additional components as prescribed by the manufacturer. This extra height will enable D_1 to be measured. The stiffness may not be adversely affected by doing this. Tests shall be carried out in the arrangement envisaged by the manufacturer, which is:

- either: with or without stabilizers;
- or: with or without outriggers.

As the stiffness of the tower is not affected by ballast only one test is necessary, where ballast is the only means of stability.

Adjustable legs, if fitted, shall be extended to 50 % of their maximum extension. Castor wheels shall be turned in their most unfavourable orientation and shall be locked.

As adjustable legs are normally fitted to level the tower, this represents a working condition.

A.3 Test method

The horizontal test load shall be 500 N.

It shall be applied at the first convenient node point above 6,0 m level. It may be adjusted to give equivalent moment above the base level of the tower because of this.

The load shall be applied perpendicular to one face of the tower and acting through the centroid. The load shall be applied in one direction and then the opposite direction, and the total displacement D_1 (in mm) shall be measured at the exact height of 6,0 m (see Figure A.1).

This test shall be repeated at 90° to the first face (see Figure A.1).

A.4 Result of test (see Figure A.2)

The total displacement measured as described in the above test shall be correlated by linear calculation to give a value of displacement D_2 for the maximum permitted platform height of the tower, with or without stabilizers, outriggers or ballast. This total displacement D_2 shall not exceed 200 mm and may limit the maximum platform height.

The maximum height of platform, limited by stiffness, is given in Equation (A.1):

$$h_1 = \frac{6 \times D_2}{D_1} = \frac{6 \times 200}{D_1} m \tag{A.1}$$

NOTE The measured value, D_1, enables the limit of height to be calculated. For example:

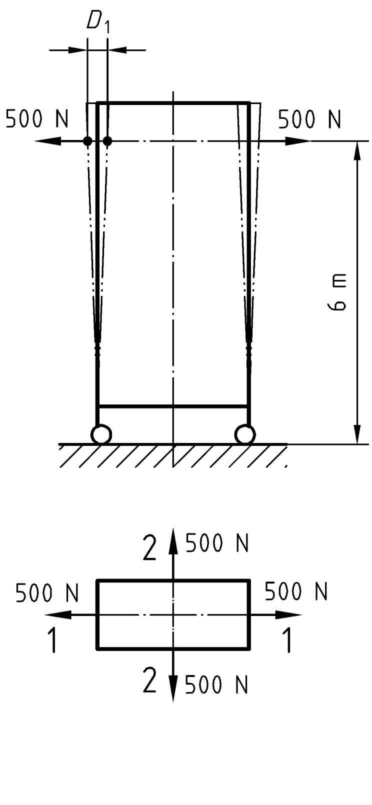
a) if the measured value D_1 is 100 mm, then Equation (A.2) applies:

$$h_1 = \frac{6m \times 200}{100} \tag{A.2}$$

the maximum permitted platform height h_1 = 12 m.

b) if the measured value D_1 is 300 mm, then the maximum permitted platform height h_1 = 4 m.

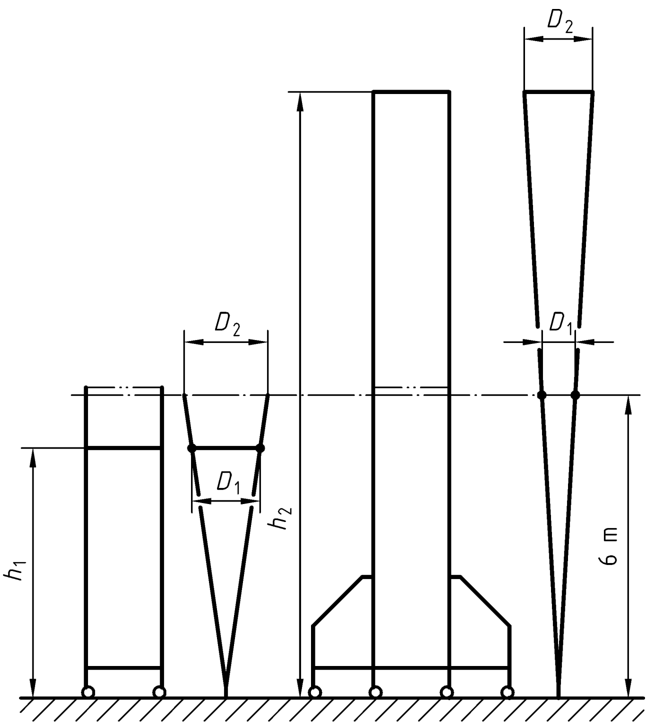
The linear formula is not precisely correct but over the range of towers that this document covers, calculations and practical tests have shown that a linear relationship is acceptable.



Key

1 first test in two opposite directions
2 second test in two opposite directions

Figure A.1 — Horizontal loads for stiffness tests on a complete tower structure



Key

h_1 maximum permitted height without stabilizers or outriggers
h_2 maximum permitted height with stabilizers or outriggers
D_1 measured total displacement on the test height of 6,0 m
D_2 maximum permitted total displacement on the maximum permitted platform height

Figure A.2 — Measured and permitted displacements of towers

Annex B
(informative)

National A-deviations

A-deviation: National deviation due to regulations, the alteration of which is for time being outside the competence of the CEN member.

This document does not fall under the Directive of the EC. In the relevant CEN countries these A-deviation are valid instead of the provisions of the document until they have been removed.

Austrian national legislative deviation

According to §8 (1) – Guardrails, of Bauarbeiterschutzverordnung (BauV) 1994, in the version of Bundesgesetzblatt 313/2002 shall be observed:

Principe guardrails shall be fixed so that its top surface is at minimum height 1,00 m above from the adjacent level of the working area everywhere. This requirement refers to 7.4.2 of this document.

Bibliography

[1] EN 39, *Loose steel tubes for tube and coupler scaffolds – Technical delivery conditions*

[2] EN 1993-2, *Eurocode 3: Design of steel structures – Part 2: Steel bridges*

[3] EN 10240, *Internal and/or external protective coatings for steel tubes – Specification for hot dip galvanized coatings applied in automatic plants*

[4] EN 12810-1, *Façade scaffolds made of prefabricated components – Part 1: Product specifications*

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