BRITISH STANDARD

BS EN
12813:2004

Temporary works equipment — Load bearing towers of prefabricated components — Particular methods of structural design

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ICS 91.220

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National foreword

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Equipements temporaires de chantiers - Tours d'étaiement en composants préfabriqués - Méthodes particulières de calcul des structures

Temporäre Konstruktionen für Bauwerke - Stützentürme aus vorgefertigten Bauteilen - Besondere Bemessungsverfahren

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Foreword

This document (EN 12813:2004) has been prepared by Technical Committee CEN/TC 053 “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of an identical text or by endorsement, at the latest by December 2004, and conflicting national standards shall be withdrawn at the latest by December 2004.

Annex A is informative, annex B is normative.

This document includes a bibliography.

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Introduction

This European Standard is intended to provide information for those who specify load bearing towers made from prefabricated components and for the designer who has to prepare a scheme for their use.

This European Standard will be of interest to those who wish to develop particular items, or groups of items for load bearing towers of prefabricated components.

This European Standard describes how to establish structural data for load bearing towers made from prefabricated components.

Most of the figures illustrating the standard are of a particular type of tower but the procedures described are applicable to all towers.

There is a requirement for a global test to demonstrate that the modelling adopted in the analysis is sufficiently accurate and on the conservative side.

For materials this standard refers only to valid European Standards. However a large stock of equipment made of materials conforming to standards no longer valid is in use. This standard does not cover the use of this equipment.

NOTE This European Standard does not give information on site activities nor about safety requirements, for which reference should be made to E.C. directives, and national documents.

1 Scope

This European Standard describes methods for establishing structural data for stiffness and resistance by calculation supported by tests for load bearing towers made of prefabricated components of steel or aluminium alloy. The vertical load capacity is established, both with or without horizontal loads and with the top restrained or free.

This European Standard specifies two methods of analysis, by first order theory, or by second order theory.

NOTE For definitions and requirements relating to structures and materials of the structure, specifications and loads, see EN 12812.

The European Standard is not intended for towers constructed with tubes and couplers: it is expected that they will be designed in accordance with EN 12812.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

ENV 1993-1-1, *Eurocode 3 —- Design of steel structures — Part 1-1: General rules and rules for buildings.*

ENV 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 12811-3:2002, *Temporary works equipment - Part 3: Load testing*.

EN 12812:2004, *Falsework — Performance requirements and general design*.

3 Terms and definitions

For the purposes of this European Standard, the terms an definitions of EN 12812 and the following apply.

3.1
base plate
plate used for spreading the load in a standard over a greater area

3.2
base jack
base plate which has means of vertical adjustment

NOTE It is intended to be positioned at the base of an upright. It usually incorporates a base plate.

3.3
bracing
component or components to increase stiffness and to provide greater vertical and lateral strength

NOTE In the horizontal plane this may comprise frames, platforms, or rigid linkages between the uprights. In the vertical plane the usual methods include closed frames, with or without gussets, open frames, ladder frames with open access, rigid assemblies between horizontal members and uprights, and diagonals.

3.4
fork head
"U" shaped component for holding a beam

NOTE It is intended to be positioned at the top of an upright for locating and supporting a horizontal beam.

3.5
frame
component which has at least one horizontal element permanently fixed to at least one upright element

3.6
fully triangulated load bearing tower
tower in which a diagonal member is attached to each panel including either braced or unbraced jacks (see Figures 1a, 1b, 2)

NOTE A panel is bounded by two adjacent vertical and two adjacent horizontal members. The diagonals are considered to create full triangulation to each vertical plane, if they are attached within 200 mm of each node point.

3.7
head jack
screw device both able to adjust height and to release the tower from the loading.

NOTE It is intended to be positioned at the top of an upright. It usually incorporates a fork head.

3.8
horizontal member
component forming a horizontal connection between two uprights.

NOTE An upright may either be the vertical linear element of frames, or vertical components of a modular system.

3.9
load bearing tower
tower with three or more uprights made of prefabricated steel or aluminium alloy components

NOTE The components are principally linear members or frames.

3.10
loading beam
horizontal member positioned above the primary beams onto which the vertical imposed test load is centrally applied

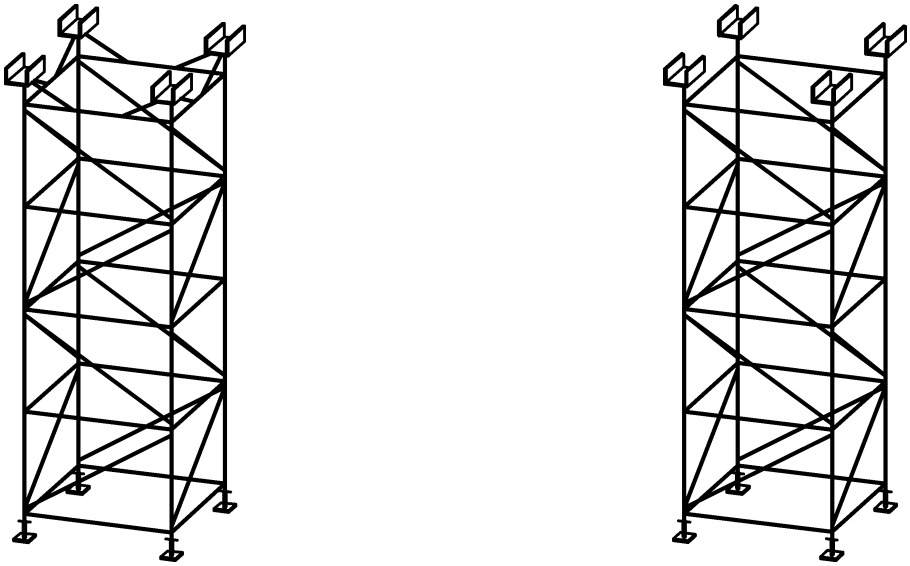
3.11
not fully triangulated load bearing tower
tower in which not all vertical planes are fully triangulated (see Figures 3a, 3b)

3.12
prefabricated component
discrete part of a tower with permanently fixed connection devices which pre-determine dimensions

3.13
primary beam
lowest horizontal beam distributing load at the top of a tower

3.14
storey
part of the tower comprised between two consecutive horizontal planes

3.15
upright
vertical load bearing element



a) with braced head jacks

b) with unbraced jacks

Figure 1 — Examples of fully triangulated towers

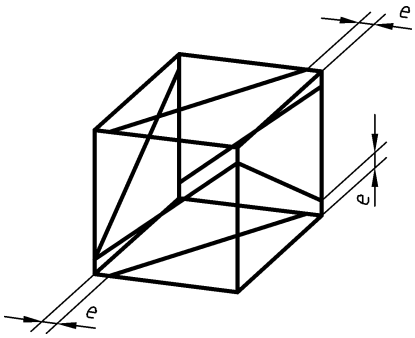
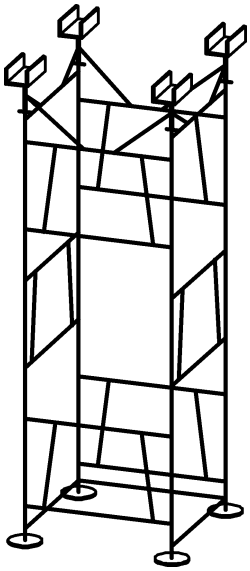
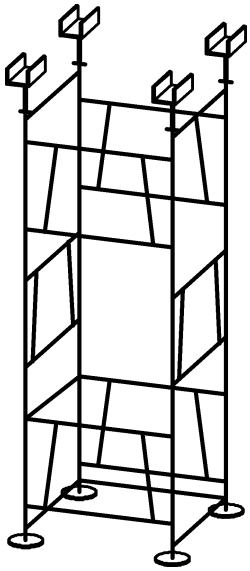


Figure 2 — Eccentricity "e" of the diagonals to members



a) with braced head jacks



b) with unbraced jacks

Figure 3 — Examples of not fully triangulated towers

4 Symbols

Table 1 — Symbols

Number	Symbol	Denomination	Unit
1	A	Cross-sectional area	mm²
2	d	Horizontal displacement	mm
3	e	Eccentricity	mm
4	E	Longitudinal modulus of elasticity	N/mm²
5	F	External load applied to the structure	N
6	F_H	Horizontal load applied to the structure	N
7	F_{Hd}	Design value of the horizontal load	N
8	F_v	Vertical load applied to the structure	N
9	F_{vd}	Design value of the vertical load	N
10	F_{cr}	Buckling load of a face	N
11	$f_{y\ nom}$	Nominal yield stress	N/mm²
12	H, h	Height	m
13	L	Length	m
14	n	Number of uprights in a tower	
15	R_d	Design value of resistance	N/mm²
16	S_d	Design value of the effects of actions	N/mm²
17	γ_F	Partial factor for the actions	
18	γ_M	Partial factor for resistance	
19	α_{cr}	The lowest elastic buckling load factor to be applied to the design loads	

5 General information needed for structural analysis of a load bearing tower made in prefabricated components

See EN 12812:2004, for information about :

- materials, clause 5, (and also EN 12811-2)
- thickness of material, 7.2
- partial factors, 9.2.2
- imperfections and boundary conditions, 9.3
- classes, clause4, 9.1.2
- differential settlement and thermal conditions 8.3.2
- actions, clause 8.

6 Analysis methods for the design resistance of a tower

6.1 Cases to be analysed

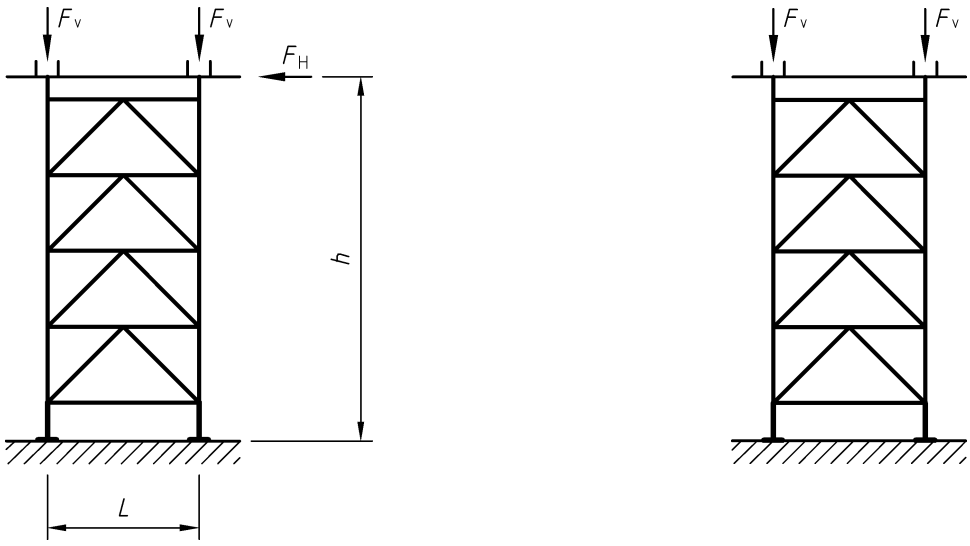
A tower shall be analysed with the following three sets of loads, and with base and head Jacks fully extended, unless design resistance for smaller extensions has to be established.

Case 1 A tower unrestrained at the top subjected to vertical loading:

Case 1a, Figure 4a) with horizontal loading

Case 1b, Figure 4b) without horizontal loading

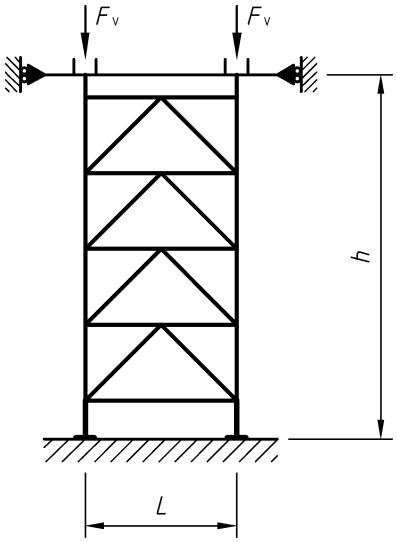
Case 2 A tower with the top restrained , subjected to vertical loading (see Figures 4a), 4b), and 5).



a) with horizontal loading b) without horizontal loading

For explanations of symbols see clause 4

Figure 4 — Typical loading conditions for a tower free at the top

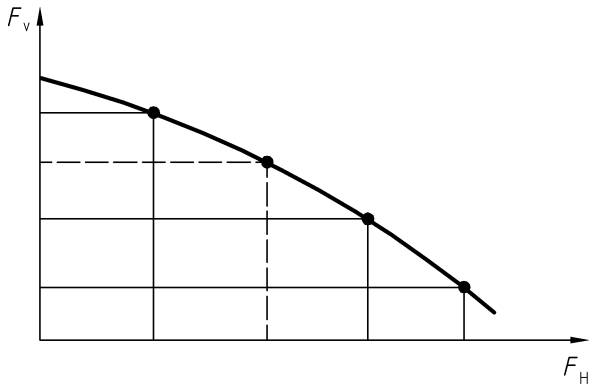


For explanations of symbols see clause 4

Figure 5 — Typical loading conditions for a tower restrained at the top

6.2 Curve to be established for case 1a

For case 1a), a curve shall be produced showing the combination of maximum resistances to vertical and horizontal loads, see Figure 6.



Key

F_V Vertical load
F_H Horizontal load

Figure 6 — Typical curve relating maximum vertical and horizontal loading

6.3 Examination methods

6.3.1 Analysis by second order theory

This method can be used with a bi-dimensional model or with a tri-dimensional model for all structural systems.

For steel, this will be in accordance with ENV 1993-1-1. For aluminium alloy, this will be in accordance with ENV 1999-1-1.

Detail tests shall be carried out in accordance with the principal requirements of EN 12810-2.

In order to find the load bearing capacity of tower the structural analysis performed by using a second order approach shall be interrupted when the first plastic hinge takes place in some element because of the internal forces.

6.3.2 Analysis by first order theory

This method may only be used with towers assembled from frames and those made with modular system components.

NOTE In a fully triangulated modular system, connections may be considered as hingesde.

The results of analysis by first order theory for a given configuration of a tower will be multiplied by factors based on the ratio $\alpha_{cr} = \frac{F_{vd}}{F_{Cr}}$, where F_{vd} is the design value of compression and F_{cr} the buckling load determined by a buckling analysis (see annex A).

These factors will be found in the relevant Eurocodes for steel and for aluminium alloy.

6.4 Detail tests and global tests

6.4.1 Before commencing testing it shall be verified: that the materials and fabrication are those stated by the manufacturer, that the dimensions of components are within the tolerances given on the manufacturing drawings and that the welding conforms to the manufacturing drawing.

6.4.2 The test results shall be adjusted to take account of the actual material properties, which shall be established, see clause 10 of EN 12811-3:2002

When there are three or more test results, they shall be analysed statistically in accordance with EN 12811-3 (see EN 12810-2 for detail tests).

6.4.3 For the purpose of checking the modelling there shall be a comparison using the global test specified in annex B between the results obtained by calculation and by test for one representative structure, generally a four or five storey tower under simultaneous vertical and horizontal loading.

In case of a first order analysis including the buckling analysis the purpose of the test is the comparison of the theoretical and experimental critical load and slenderness of the tower ; in the case of a second order analysis, the purpose of the test is the comparison of the curves of load *F* and horizontal displacement, *d*, at various levels of the tower.

The result for the calculated and experimental results shall be such that no calculated value is greater than the corresponding experimental value.

7 Documentation relating to the test

The test report shall be in accordance with clause 9 of EN 12811-3:2002.

8 Documentation to be provided

8.1 General

In addition to 8.2 and 8.3, general information about the equipment shall be made available. This shall include:

a) the supplier's name;

b) the manufacturer's name, if different;

c) the name of the equipment;

d) the supplier's trade mark, where available;

e) reference to this European Standard.

8.2 Information for the user

The user shall be provided with the following:

a) an instruction manual giving information on:

- strength, height and load bearing capacity so that each configuration of tower can be used safely;
- how towers can be erected and dismantled safely;
- which components there are;
- the weight of components.

b) Data for each configuration examined:

- dimensions;
- instructions to enable the tower to be assembled on site to correspond exactly with the configuration analysed including actions and combinations of actions.

8.3 Information for the falsework designer

8.3.1 The structural data established from the calculation shall be made available in a form suitable for the falsework designer. In addition, the test report and a statement of whether first or second order theory was used shall be made available.

8.3.2 All information made available to the user see 8.2, shall also be made available for the falsework designer.

Annex A
(informative)

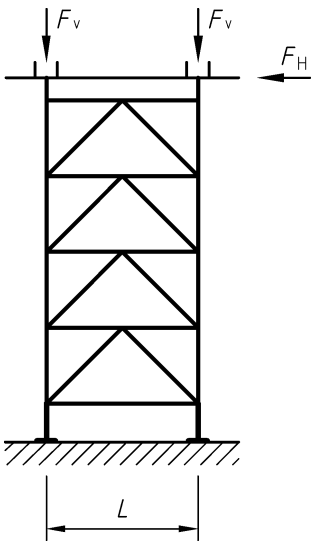
Procedure for analysis by first order theory of a fully triangulated load bearing tower

A.1 Example chosen

This annex gives for analysis, by first order theory, the example of a square steel tower unrestrained at the top, subjected to vertical forces F_V and to horizontal forces F_H (Figure A.1) (6.1, case 1a, Figure 4a), for a type equipment, with given extensions of the jacks at the top and at the bottom.

A.2 Determination of the buckling load, F_{cr} for one face of the tower

The buckling critical load is determined under vertical loading with a bi-dimensional buckling analysis,see Figure A.2 for the arrangement.



For explanation of symbols, see clause 4.

Figure A.1

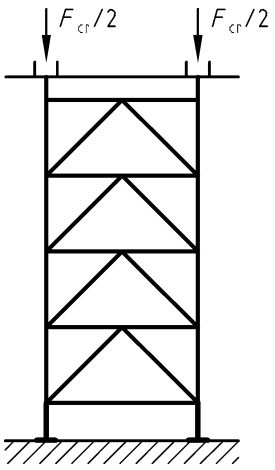


Figure A.2

A.3 Structural analysis by first order theory

The tower is considered with simultaneously applied vertical design loading, $F_{vd,}$ and horizontal design loading , $F_{Hd.}$

The modelling is the same as in the buckling analysis.

Stresses obtained should be multiplied by amplification factors which are given in relevant Eurocodes, for steel and for aluminium alloy. It should be verified that for the most unfavourable components S_d does not exceed Rd

$$S_d \leq R_d = \frac{f_{y\ nom}}{\gamma_M} \quad \text{(class B1)}$$

$$S_d \leq R_d = \frac{f_{y\ nom}}{\gamma_M \times 1.15} \quad \text{(class B2)}$$

where:

$f_{y\ nom}$ = yield stress
γ_M = partial factor of material
R_d = design value of resistance
S_d = design value of the effects of actions

Values of a series of different combinations of horizontal and vertical loadings and different jack extensions can then be determined.Several calculations should be carried with different combinations of vertical and horizontal loading. These values should be used to produce a curve relating maximum vertical and horizontal loading, see 6.2

An explanation of classes B1 and B2 is given in EN 12812:2004 clauses 8.3.2 and 9.1.2

Annex B
(normative)

Global test procedure

B.1 Introduction

This annex specifies the equipment and methods used for global tests specified in 6.4 together with some recommendations.

B.2 Apparatus

B.2.1 The apparatus specified in B.2.2 to B.2.4 is needed to perform the tests specified in clause B.6. Precise details will depend on the tower under test and the laboratory conditions.

B.2.2 Equipment shall be provided to record the:

a) loading;

b) and corresponding deformation at successive stages.

Both should preferably record the data automatically.

B.2.3 Equipment shall be provided to apply the load at the rate specified in B.5.2 .

B.2.4 Pads made of Douglas fir plywood or equivalent timber, with sides 50 mm longer than the baseplates they will support. The thickness shall be between 15 mm and 20 mm.

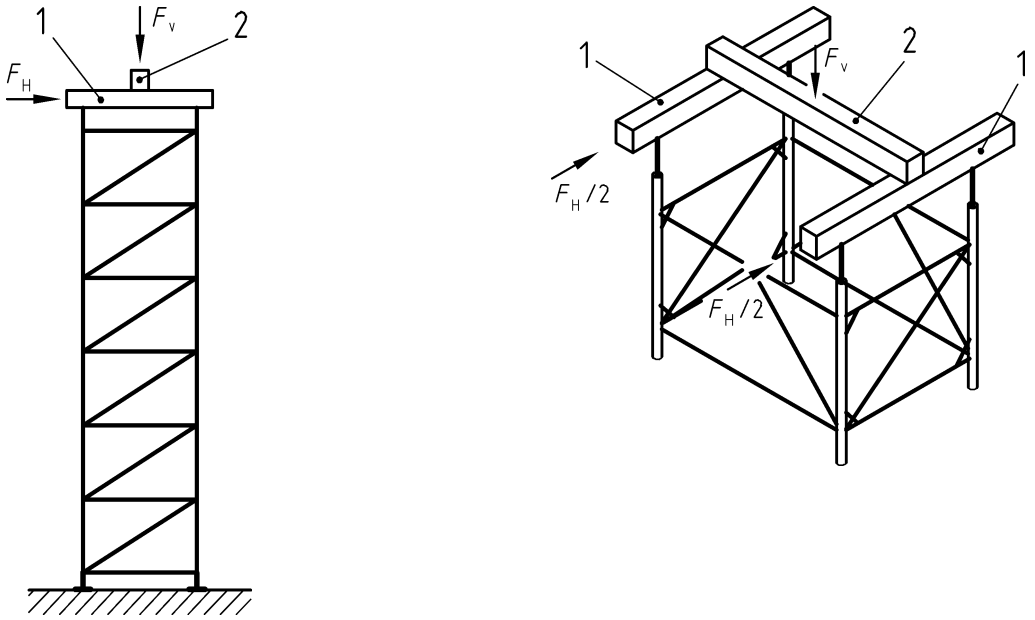
B.3 Choice of components

The components used to construct a test tower shall be representative of those in general use and not specially selected.

NOTE In some cases only prototype components will be available.

B.4 Assembly of test tower

B.4.1 The base below the tower shall be rigid and horizontal. It shall comprise either a smooth concrete slab (a concrete floor) or a rigid framework of steel beams, see Figures B.1 a) and B.1 b).



a) Assembly for test of the whole tower

b) Beams for loading

Key
1 primary beam
2 loading beam

For explanation of symbols, see clause 4

Figure B.1 — Example of load bearing tower with several stories

B.4.2 Assemble the tower, attaching the components and tightening with torques in accordance with the supplier's instructions.

B.4.3 Place the primary beams across pairs of forkheads parallel to the vertical plane in which the structural system is stiffest. In case of doubt, repeat the test with the primary beams in the other direction.

NOTE The stiffest horizontal plane will usually be the plane of the frames in frame and brace systems or the plane of the smallest plan dimension between uprights in other rectangular towers. A different arrangement may be necessary for towers that have more or less than four uprights.

B.4.4 Position and wedge the beams centrally over the spigots of the forkheads. Provide a facility at the bottom of these primary beams for application of any horizontal loads needed, or for stabilisation if the tower is to be restrained in position.

B.4.5 Where the tower has head plates with devices for locating or fixing primary beams centrally in the forkheads, use the appropriate primary beams in the test assembly.

B.4.6 Place a loading beam to span at right angles between the primary beams. Connect the primary and loading beams together to prevent relative movement in plan.

NOTE This ensures that the test results will not be influenced by the top moving out of square.

B.4.7 When the assembly is complete, the vertical load point shall be adjusted so that its centroid is vertically in line with the centroid of the top of the tower.

The forkheads shall be adjusted to a common level and to the extension chosen in the calculation.

NOTE More than one load point may be used provided that it is ensured that the same loading is applied to all uprights of the tower.

B.5 Test procedure

B.5.1 Determine the mass of all test apparatus so that the loading recorded can be adjusted to give the actual failure load. The mass of the test apparatus includes any primary beams, loading beams or tendons. Determine the mass by weighing or by calculation from the dimensions and densities. Do not take the self-weight of the tower into account when making the subsequent adjustment.

B.5.2 Apply a preliminary load to eliminate any secondary effects that may be caused by imperfections such as slackness at joints or a lack of local flatness at the supports. This preliminary load shall not exceed 5% of the anticipated failure load and may be applied vertically, horizontally or at an angle as appropriate. Record the magnitude and direction of the load. Take the position of the tower after this application of the load as the reference point for all further measurements of deformation.

Apply the load progressively in a single sequence until the maximum attainable load is reached, or until the deformation of a component or the tower is such that in practical conditions failure would be said to have occurred.

If the load is applied continuously calculate the rate of loading in Newtons per minute by dividing the anticipated value of the load at failure by 5.

If the load is increased in steps, sustain the test load at a constant value at each step until movement ceases before recording the displacement.

NOTE Test load increments should normally be about 10 % of the failure load ; when failure appears to be imminent, smaller increments are likely to be more appropriate.

B.6 Data to be recorded

Record at each stage:

a) the vertical load applied to the loading beam at each point,

b) the vertical displacements of the load point(s) relative to the baseplates,

c) the horizontal displacements of the forkheads relative to the baseplates,

d) the applied load at each step.

Where the load is applied continuously, an automatic graphical record should be made.

B.7 Additional requirements when a horizontal load is also applied

B.7.1 Apply a point load horizontally at the level of the forkhead.

B.7.2 Apply the horizontal load by a method based on tendons or kentledge.

Apply the horizontal load using a method that will ensure that the load applied is constant. For example, a cable may be attached at the level of the forkhead and passed over a pulley at this height so that kentledge may be used.

Bibliography

EN 12810-1, *Façade scaffolds made of prefabricated components — Part 1: Product specifications*.

EN 12811-1, *Temporary works equipment - Part 1: Scaffolds Performance requirements and general design*.

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