



BSI Standards Publication

## Mobile elevating work platforms — Design, calculations, safety requirements and test methods

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# National foreword

This British Standard is the UK implementation of ISO 16368:2024.

The UK participation in its preparation was entrusted to Technical Committee MHE/12/1, Lifting Platforms - Mobile elevating work platforms.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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**International  
Standard**

**ISO 16368**

**Mobile elevating work platforms —  
Design, calculations, safety  
requirements and test methods**

*Plates-formes élévatrices mobiles de personnel — Conception,  
calculs, exigences de sécurité et méthodes d'essai*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at [www.iso.org/patents](http://www.iso.org/patents). ISO shall not be held responsible for identifying any or all such patent rights.

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 214, *Elevating work platforms*.

This third edition cancels and replaces the second edition (ISO 16368:2010), which has been technically revised.

The main changes are as follows:

- all requirements from ISO 16653-1 have been integrated into this document;
- in the Scope, additional details have been added included intended use and objectives;
- the normative references have been updated;
- in [Clause 3](#), seven new definitions have been added to support their use in the text;
- [Clause 4](#) has been updated to include a new figure for the rated load of tools and materials; [Table 1](#) and [Figure 3](#) have been revised to show load-sensing and enhanced stability examples separately and to include more working configurations; verification methods have been removed from each clause and placed in new [Table 7](#) in [Clause 5](#); access system requirements have been revised to include [Table 4](#) and [Table 5](#);
- in [Clause 6](#), the contents of [Annex F](#) have been merged into [6.2.1](#) and the previous [Annex F](#) has been deleted.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

This document is a type-C standard as stated in ISO 12100:2010.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

- machine manufacturers (small, medium and large enterprises);
- health and safety bodies (regulators, accident prevention organisations, market surveillance, etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

- machine users/employers (small, medium and large enterprises);
- machine users/employees (e.g. trade unions, organizations for people with disabilities);
- service providers, e.g. for maintenance (small, medium and large enterprises);
- consumers (in the case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered, are indicated in the Scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

The objective of this document is to establish rules for safeguarding persons and objects against the risk of an accident associated with the operation of mobile elevating work platforms (MEWPs). MEWPs are assemblies of one or more sub-assemblies produced by one or more manufacturers. A MEWP is the product of activities that include design, production, and testing, as well as the provision of information on the MEWP itself.

This document does not repeat all the general technical rules applicable to every electrical, mechanical, or structural component. Its safety requirements have been developed on the basis that MEWPs are periodically maintained according to given instructions, working conditions, frequency of use and national or other regulations. It is assumed that MEWPs are checked for function before start of work, whether used daily or seldom used, and are not put into operation unless all the required control and safety devices are available and in working order. Where, for clarity, an example of a safety measure is given in the text, it is not intended as the only possible solution. Any other solution leading to the same risk reduction is permissible if an equivalent level of safety is achieved.

[Annex A](#) explains the choice of Beaufort Scale 6 as the maximum wind speed.

[Annex B](#) specifies additional requirements for wireless controls and control systems.

[Annex C](#) provides, in addition to those found in the body of this document, appropriate extracts from DIN 15020 (all parts) to avoid the unexplained inconsistencies in coefficients of utilization for wire ropes found in other standards for lifting devices.

[Annex D](#) provides a worked example of the provisions given in [Annex C](#).

[Annex E](#) gives kerb test calculations.

[Annex F](#) presents the list of significant hazards dealt with by this document.



# Mobile elevating work platforms — Design, calculations, safety requirements and test methods

## 1 Scope

This document specifies safety requirements and protective/risk reduction measures, and the means for their verification, for all types and sizes of mobile elevating work platforms (MEWPs) intended for moving a person(s) along with their necessary tools and materials at an elevated work location.

This document also applies to MEWPs designed for applications requiring special access to specific work areas. These MEWPs can be either self-propelled or manually propelled and are used to elevate personnel to a level at which they can place, install, or retrieve objects or material on a routine basis. To facilitate operator access to the work area, the retraction of a portion of the MEWP's work platform guardrail system(s) can be necessary.

This document is intended to serve as a guide for manufacturers and remanufacturers of MEWPs to achieve the following objectives:

- elimination or reduction of accidents and personal injuries;
- establishment of criteria for design, manufacture, remanufacture, rebuild/recondition, testing and performance;
- establishment and understanding by manufacturers and remanufacturers of their responsibilities.

The design and manufacturing requirements of this document apply to all MEWPs manufactured or remanufactured on or after the effective date, but it is not applicable to rebuilt or reconditioned MEWPs.

It identifies the hazards arising from the use of MEWPs and describes methods for the elimination or reduction of these hazards.

This document is not applicable to

- a) permanently installed personnel-lifting appliances serving defined levels,
- b) firefighting and fire rescue appliances (see for example, EN 1777),
- c) unguided work cages suspended from lifting appliances (see for example, EN 1808),
- d) elevating operator position on rail-dependent storage and retrieval equipment (see for example, EN 528),
- e) tail lifts (see for example, EN 1756-1:2001+A1:2008, EN 1756-2:2004+A1:2009),
- f) mast-climbing work platforms (see ISO 16369),
- g) fairground equipment,
- h) lifting tables with a lifting height of less than 2 m (see for example, EN 1570-1:2011+A1:2014),
- i) builder's hoists for persons and materials,
- j) aircraft ground-support equipment (see for example, EN-1915-1:2013, EN-1915-2:2001+A1:2009),
- k) digger derricks,
- l) elevating operator positions on industrial trucks (see for example, ISO 3691-3),

- m) elevating operator positions on cranes,
- n) certain requirements for insulating aerial devices on a chassis for use in live work on electrical installations (see Note 1),
- o) multi-purpose elevating platform powered industrial trucks (MPEPs) controlled by a single stand-up riding operator and intended to be used for manually picking and transporting small items at height,
- p) powered industrial trucks used to pick and place stock or inventory.

NOTE 1 For requirements for use near live electrical installations, see ISO 16653-2. For requirements for use on live electrical installations, see IEC 61057.

It does not cover hazards arising from:

- use in potentially explosive atmospheres,
- use of compressed gases for load-bearing components,
- derailment and runaway of rail-mounted MEWPs,
- work on live electrical systems (see Note 2 and Note 3).

NOTE 2 Hazards arising from work on live electrical systems are addressed in IEC 61057.

NOTE 3 For MEWPs that employ aerial devices used for live working, this document is to be used in conjunction with IEC 61057, taking into consideration the potential exceptions from this document that are specified in IEC 61057.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 3864 (all parts), *Graphical symbols — Safety colours and safety signs*

ISO 4305, *Mobile cranes — Determination of stability*

ISO 7000, *Graphical symbols for use on equipment — Registered symbols*

ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13849-1, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13850, *Safety of machinery — Emergency stop function — Principles for design*

ISO 13854, *Safety of machinery — Minimum gaps to avoid crushing of parts of the human body*

ISO 18893:—<sup>1)</sup>, *Mobile elevating work platforms — Safety principles, inspection, maintenance, and operation*

ISO 20332, *Cranes — Proof of competence of steel structures*

ISO 21455, *Mobile elevating work platforms — Operator's controls — Actuation, displacement, location and method of operation*

IEC 60068-2-64, *Environmental testing — Part 2-64: Tests — Test Fh: Vibration, broadband random and guidance*

IEC 60204-1, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60204-32:2023, *Safety of machinery — Electrical equipment of machines — Part 32: Requirements for hoisting machines*

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1) Under preparation. Stage at the time of publication: ISO/FDIS 18893:2024.

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 61310-1, *Safety of machinery — Indication, marking and actuation — Part 1: Requirements for visual, acoustic and tactile signals*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1

##### **access position**

position(s) to provide access to and from the *work platform* (3.58)

Note 1 to entry: The access position, *lowered travel position* (3.21), *stowed position* (3.51) and *transport position* (3.52) can be identical.

#### 3.2

##### **aerial device**

device, extensible, articulating or both, which is primarily designed and used to position personnel

Note 1 to entry: This does not include the *chassis* (3.5). When an aerial device is mounted on a mobile *chassis* (3.5) it becomes a component of a MEWP. This device can also be used to handle material, if designed and equipped for that purpose.

#### 3.3

##### **anchorage**

designated point of attachment utilized with a personal fall protection system

#### 3.4

##### **chain drive system**

system that comprises one or more chains running on chain sprockets or over chain pulleys, as well as any associated chain sprockets, chain pulleys and compensating pulleys

#### 3.5

##### **chassis**

base of a MEWP

Note 1 to entry: See [Figure 1](#).

Note 2 to entry: The chassis can be pulled, pushed, self-propelled, etc.

#### 3.6

##### **ductile materials**

materials that have a minimum elongation at fracture of 10 % in a gauge length of 51 mm of a standard tensile test specimen

#### 3.7

##### **elevated travel position**

configuration(s) of the MEWP for travel outside of the *lowered travel position* (3.21)

#### 3.8

##### **extending structure**

structure which is connected to the *chassis* (3.5) and supports the *work platform* (3.58) and which allows movement of the *work platform* (3.58) to its required position

Note 1 to entry: See [Figure 1](#).

**3.9**

**fall arrest system**

personal fall protection system designed to arrest the fall of an *operator* (3.36) or *occupant(s)* (3.35)

**3.10**

**fall restraint system**

personal fall protection system that restrains or prevents an *operator* (3.36) or *occupant(s)* (3.35) from reaching a fall hazard

**3.11**

**finite element analysis**

FEA

computerized method of idealizing a real model for the purposes of performing structural analysis

**3.12**

**folding guardrails**

guardrails capable of being reduced in height

Note 1 to entry: For facilitating MEWP movement under obstructions and ease of transport.

**3.13**

**handhold**

device for single hand placement that aids body support and balance

**3.14**

**handrail**

device for hand placement that aids body support and balance and permits hand movement on the device

Note 1 to entry: A handrail can be part of a guardrail.

**3.15**

**indoor use**

operation in areas shielded from wind so that there is no wind force acting on the MEWP being operated

**3.16**

**instability**

condition of a MEWP in which the sum of the moments which tend to overturn the MEWP exceeds the sum of the moments which tend to resist overturning

**3.17**

**installer**

entity that installs an *aerial device* (3.2) on a *chassis* (3.5)

Note 1 to entry: The installer can also be the *responsible entity* (3.43).

**3.18**

**load cycle**

cycle starting from an *access position* (3.1) and completed by the carrying out of work and return to the same *access position* (3.1)

**3.19**

**load-sensing system**

system of monitoring the vertical load and vertical forces on the *work platform* (3.58)

**3.20**

**lowering**, noun

operations, other than travelling, for moving the *work platform* (3.58) to a lower level

Note 1 to entry: See [Figure 1](#).

### 3.21

#### **lowered travel position**

configuration(s) of the MEWP, as defined by the *responsible entity* (3.43), for travel up to maximum travel speed

Note 1 to entry: The lowered travel position, *access position* (3.1), *stowed position* (3.51), and *transport position* (3.52) can be identical.

### 3.22

#### **mobile elevating work platform**

MEWP

machine/device intended for moving a person(s), along with their necessary tools and material to an elevated work location, consisting of at least a *work platform* (3.58) with controls, an *extending structure* (3.8) and a *chassis* (3.5)

### 3.23

#### **group A MEWP**

MEWPs on which the vertical projection of the centre of the *work platform* (3.58) area, in all work platform configurations at the maximum chassis inclination specified by the manufacturer, is always inside the tipping lines

### 3.24

#### **group B MEWP**

MEWPs not in group A

### 3.25

#### **type 1 MEWP**

MEWP for which travelling is only allowed when in the *stowed position* (3.51)

### 3.26

#### **type 2 MEWP**

MEWP for which travelling with the *work platform* (3.58) in the *elevated travel position* (3.7) is controlled from a point on the *chassis* (3.5)

Note 1 to entry: Type 2 MEWPs and type 3 MEWPs can be combined.

### 3.27

#### **type 3 MEWP**

MEWP for which travelling with the *work platform* (3.58) in the *elevated travel position* (3.7) is controlled from a point on the *work platform* (3.58)

Note 1 to entry: Type 2 MEWPs and type 3 MEWPs can be combined.

### 3.28

#### **pedestrian-controlled MEWP**

MEWP whose controls for powered travel can be operated by a person walking close to the MEWP

### 3.29

#### **rail-mounted MEWP**

MEWP whose travel is guided by rails

### 3.30

#### **self-propelled MEWP**

MEWP whose travel is powered by an internal power source

### 3.31

#### **totally manually operated MEWP**

MEWP whose movement is powered only by manual effort

### 3.32

#### **vehicle-mounted MEWP**

MEWP whose *aerial device* (3.2) is designed for and installed on a vehicle *chassis* (3.5)

**3.33**

**moment-sensing system**

system monitoring the moment acting about the tipping line tending to overturn the MEWP

**3.34**

**non-ductile materials**

brittle materials

materials that are not classified as *ductile materials* (3.6)

**3.35**

**occupant(s)**

person(s) in the *work platform* (3.58) other than *operator* (3.36)

**3.36**

**operator**

person who controls the operation of a MEWP

**3.37**

**oscillating axle**

supporting structure which allows mainly vertical movement of the end wheel assemblies independently or in relation to each other

**3.38**

**outdoor use**

use of a MEWP in an environment that can be exposed to wind

**3.39**

**raising, noun**

operation, other than travelling, that moves the *work platform* (3.58) to a higher level

Note 1 to entry: See [Figure 1](#).

**3.40**

**rated load**

load for which the MEWP has been designed in normal operation, comprising persons, tools and materials, acting vertically on the *work platform* (3.58)

Note 1 to entry: A MEWP can have more than one rated load.

**3.41**

**rebuild/recondition**

overhaul or repair of a MEWP, accomplishing work beyond the scope of maintenance, utilizing replacement parts and components, in order to restore the MEWP to the original standard(s)

**3.42**

**remanufacture**

modification of a MEWP, either by the original manufacturer or *responsible entity* (3.43), so that the MEWP will comply with one or more standards in effect on the date the remanufacture is completed

**3.43**

**responsible entity**

person or entity with responsibility for the design, specification, procurement, fabrication, manufacture, assembly, provision of information and testing of a MEWP sub-assembly or ready-for-use MEWP

Note 1 to entry: Depending on national regulations or local practice, this term can refer to one or more of the following entities: manufacturer, installer, custodian, dealer, or entity placing the product on the market.

**3.44**

**retractable guardrail**

guardrail where a portion is capable of being locked in a retracted position without reducing overall height

Note 1 to entry: For accessing a work area.

### 3.45

#### **rotation**

circular movement of the *work platform* (3.58) about a vertical axis local to the *work platform* (3.58)

Note 1 to entry: See [Figure 1](#).

### 3.46

#### **secondary work platform**

additional platform attached to the *work platform* (3.58) or the *extending structure* (3.8), and able to be moved separately

### 3.47

#### **slab**

substantially level surface of asphalt, concrete, or equivalent supporting material

### 3.48

#### **slewing**, noun

circular movement of the *extending structure* (3.8) about a vertical axis

Note 1 to entry: See [Figure 1](#).

### 3.49

#### **stability**

condition of a MEWP in which the sum of the moments which tend to overturn the unit is less than or equal to the sum of the moments tending to resist overturning

### 3.50

#### **stabilising device**

device or system used to stabilise a MEWP by supporting and/or levelling the complete MEWP or the *extending structure* (3.8)

Note 1 to entry: See [Figure 1](#).

EXAMPLE Outrigger, jack, suspension-locking device, extending axle, torsion bar.

### 3.51

#### **stowed position**

configuration of the MEWP as defined by the *responsible entity* (3.43), in which the *extending structure* (3.8) is lowered and retracted, and *stabilising devices* (3.50) are retracted

Note 1 to entry: The stowed position, *access position* (3.1), *lowered travel position* (3.21) and *transport position* (3.52) can be identical.

### 3.52

#### **transport position**

configuration of the MEWP prescribed by the *responsible entity* (3.43) in which the MEWP is to be transported

Note 1 to entry: The transport position, *access position* (3.1), *lowered travel position* (3.21) and *stowed position* (3.51) can be identical.

### 3.53

#### **travelling**

movement of the *chassis* (3.5) except when the MEWP is being transported

Note 1 to entry: See [Figure 1](#).

### 3.54

#### **type test**

test on a representative model of a new design, or a model incorporating significant changes to an existing design, carried out by or on behalf of the *responsible entity* (3.43) or their authorized representative

**3.55**

**wireless control**

means by which an operator's commands are transmitted without any physical connection for at least part of the distance between a control console and the MEWP system

**3.56**

**wire rope drive system**

system that comprises one or more wire ropes running on rope drums and on or over rope pulleys, as well as any associated rope drums, rope pulleys and compensating pulleys

**3.57**

**working envelope**

space in which the *work platform* ([3.58](#)) is designed to work within the specified loads and forces, under normal operation conditions

Note 1 to entry: A MEWP can have more than one working envelope.

**3.58**

**work platform**

component of the MEWP intended for carrying a person(s) along with their necessary tools and materials

EXAMPLE Cage, bucket, basket.

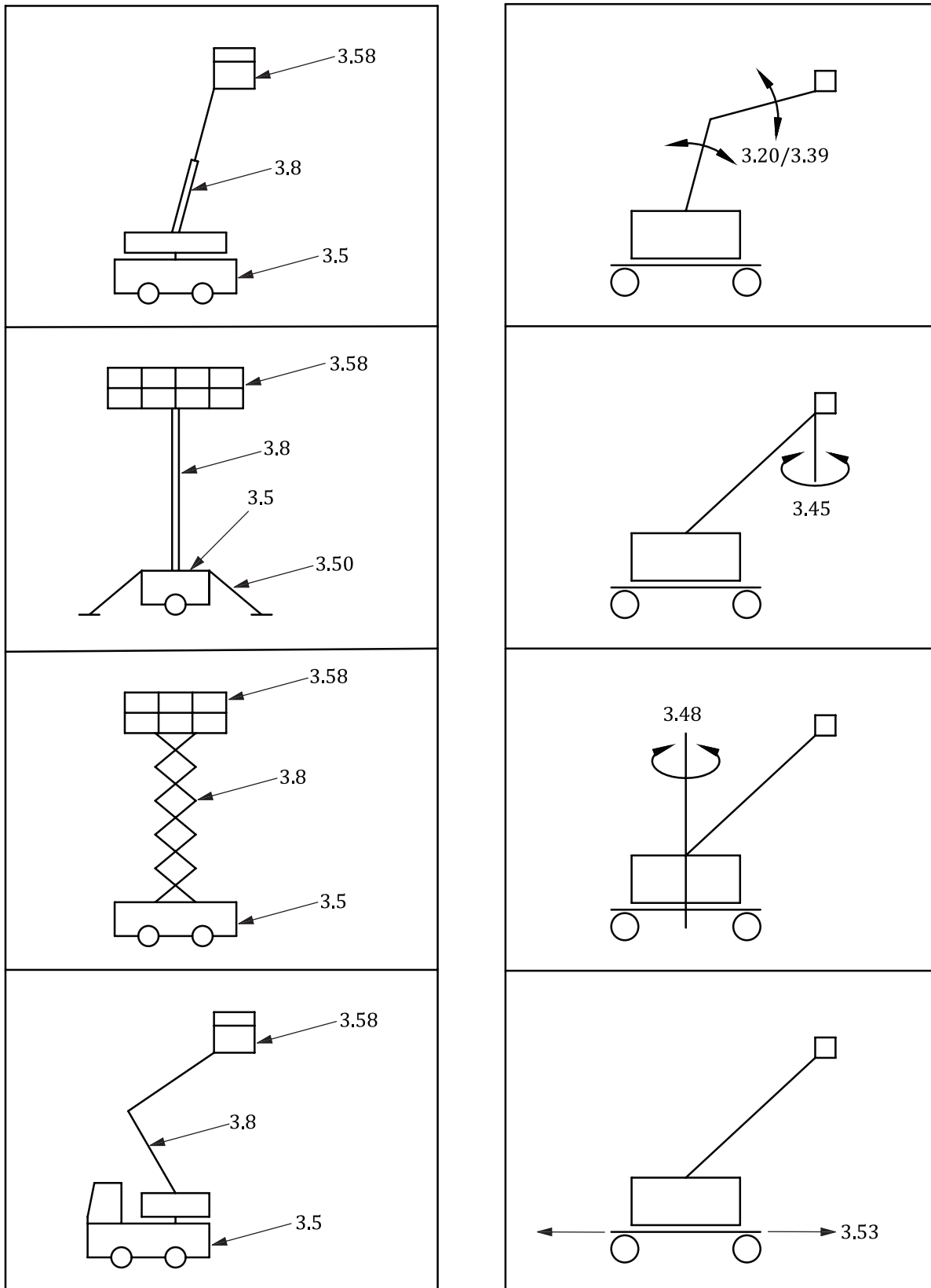


Figure 1 — Illustration of key terms

## 4 Safety requirements and/or protective/risk reduction measures

### 4.1 General

**4.1.1** MEWPs shall comply with the safety requirements and/or protective/risk reduction measures of [Clause 4](#).

**4.1.2** In addition, the MEWP shall be designed in accordance with the principles of ISO 12100 for relevant but not significant hazards, which are not dealt with by this document.

**4.1.3** Verification methods of safety requirements in [Clause 4](#) can be found in [Table 7](#). Where necessary, specific verification methods are provided for individual subclauses.

NOTE National or local requirements can be more stringent.

### 4.2 Stability and structural calculations

#### 4.2.1 Calculations and rated load

**4.2.1.1** The responsible entity shall perform:

- a) stability calculations, to identify the various positions of the MEWP and combinations of loads and forces which together create conditions of minimum stability;
- b) structural calculations, to evaluate the individual loads and forces in their positions, directions and combinations which produce the most unfavourable stresses in the components.

**4.2.1.2** The rated load, equivalent to a mass,  $m$ , shall be determined from:

$$m = (n \times m_p) + m_e$$

where

$m_p$  is 80 kg (mass of a person);

$m_e$  is  $\geq 40$  kg, representing the mass of tools and materials;

$n$  is the permitted number of persons on the work platform.

**4.2.1.3** All MEWPs shall have at least one rated load  $\geq 120$  kg.

**4.2.1.4** For group B MEWPs with multiple rated loads, it is permissible to have rated loads  $\geq 80$  kg and  $< 120$  kg if fitted with both a load-sensing system and a moment-sensing system.

#### 4.2.2 Loads and forces acting on MEWP structure

##### 4.2.2.1 General

The following loads and forces shall be taken into account:

- a) forces created by rated load and structural masses ([4.2.2.2](#));
- b) wind forces ([4.2.2.3](#));
- c) manual forces ([4.2.2.4](#));

d) special loads and forces (see [4.2.2.5](#)).

#### 4.2.2.2 Forces created by rated load and structural masses

##### 4.2.2.2.1 Gravitational and dynamic forces

**4.2.2.2.1.1** Gravitational forces created by the rated load and structural masses shall be taken to act vertically downwards at the component centres of mass. These forces shall be calculated by multiplying the component masses by  $1,0 g$ .

NOTE The factor  $g$  represents the acceleration due to gravity ( $9,81 \text{ m/s}^2$ ).

**4.2.2.2.1.2** Dynamic forces created by acceleration and deceleration of rated load and structural masses shall be represented by forces acting in the line of motion of the component centres of mass.

**4.2.2.2.1.3** Dynamic forces created by extension or retraction of the extending structure shall be calculated by multiplying the structural masses by  $0,1 g$ . Values lower than  $0,1 g$  may be used, provided they have been verified by measurement of the effects of acceleration and deceleration.

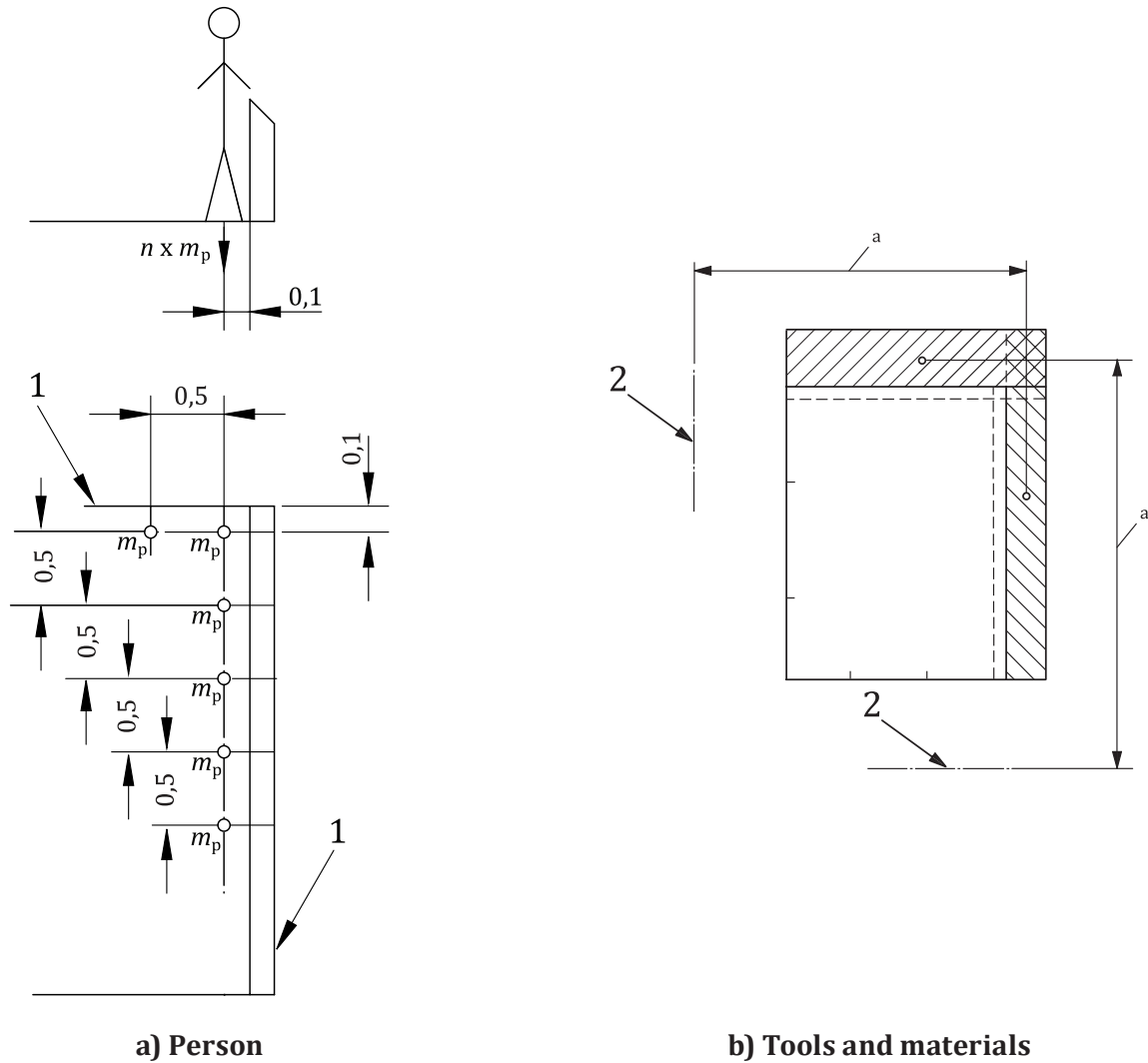
**4.2.2.2.1.4** Dynamic forces created by travelling movements of type 2 and type 3 MEWPs shall be calculated by multiplying the structural masses by  $z$  times  $g$ . Factor  $z \cdot g$  represents the acceleration/deceleration of the MEWP due to travel and its angular acceleration/deceleration due to travel over ground obstacles such as that which occurs during the kerb test (see [5.1.4.2.2.2](#)). Factor  $z$  shall be a minimum of  $0,1$  unless determined by calculation or testing (see [Annex E](#) for an example of the calculation of  $z$ ).

##### 4.2.2.2.2 Load distribution on work platform

**4.2.2.2.2.1** The mass of each person is assumed to act as a point load on the work platform and any platform extension at a horizontal distance of  $0,1 \text{ m}$  from the upper inside edge of the top rail. The distance between the point loads shall be  $0,5 \text{ m}$  [see [Figure 2](#) a) as an example].

**4.2.2.2.2.2** Tools and materials are assumed to act as an evenly distributed load on  $25 \%$  of the floor of the work platform. If the resulting pressure exceeds  $3 \text{ kN/m}^2$ , the value of  $25 \%$  may be increased to give a pressure of  $3 \text{ kN/m}^2$  [see [Figure 2](#) b) as an example].

**4.2.2.2.2.3** All these loads are assumed to be located in the positions giving the worst-case results.



**Key**

- 1 edge of work platform
- 2 tipping line
- a Max.

**Figure 2 — Rated load**

### 4.2.2.3 Wind forces

#### 4.2.2.3.1 MEWPs designed for outdoor use

**4.2.2.3.1.1** All MEWPs designated for outdoor use are regarded as being affected by wind at a pressure of 100 N/m<sup>2</sup>, derived from a wind speed of 12,5 m/s (Beaufort scale 6, see [Annex A](#)).

**4.2.2.3.1.2** It is permissible to use data from computational fluid dynamics (CFD) modelling or physical testing to meet this requirement. The CFD analysis shall include a summary of the boundary conditions applied. Physical testing shall include the modelling and dimensional similarity parameters used.

**4.2.2.3.1.3** Wind forces are assumed to act horizontally at the centre of surface of the parts of the MEWP, persons and tools and materials on the work platform.

#### 4.2.2.3.2 Shape factors applied to surfaces exposed to wind

4.2.2.3.2.1 The following shape factors are applicable to surfaces exposed to wind:

- a) L-, U-, T-, I-sections: 1,6;
- b) box sections: 1,4;
- c) large flat areas: 1,2;
- d) circular sections, according to size: (values in accordance with ISO 4302:2016, 5.4);
- e) persons directly exposed: 1,0.

4.2.2.3.2.2 For additional shape factors and shielded structural areas, the requirements of ISO 4302 shall apply. For shielded persons, see [4.2.2.3.3](#).

#### 4.2.2.3.3 Surface area of persons on a work platform exposed to wind

4.2.2.3.3.1 The full surface area of one person shall be 0,7 m<sup>2</sup> (0,4 m average width × 1,75 m height) with the centre of area 1,0 m above the work platform floor.

4.2.2.3.3.2 The exposed surface area of one person standing on a work platform behind an imperforate (not perforated) section of fencing 1,1 m high shall be 0,35 m<sup>2</sup>, with the centre of area 1,45 m above the work platform floor.

4.2.2.3.3.3 The number of persons directly exposed to the wind shall be calculated as follows:

- a) the length of the side of the work platform exposed to the wind, rounded to the nearest 0,5 m, divided by 0,5 m;
- b) the number of persons allowed on the work platform, if less than the number calculated in a).

4.2.2.3.3.4 If the number of persons allowed on the work platform is greater than for a) above, a shape factor of 0,6 shall be applied to the extra number of persons.

#### 4.2.2.3.4 Tools and materials on work platform exposed to wind

The wind force ( $W$ ) on exposed tools and materials on the work platform shall be calculated as 0,03  $g$  multiplied by their mass acting horizontally at a height of 0,5 m above the work platform floor:

$$W = 0,03 g \times m_e$$

where  $m_e$  is the mass of tools and materials.

#### 4.2.2.4 Manual forces

The minimum value for a manual force,  $F_m$ , shall be taken as 200 N for MEWPs designed to carry only one person, and 400 N for MEWPs designed to carry more than one person. Manual forces are to be applied at a height of 1,1 m above the work platform floor. Any greater force permitted shall be specified by the responsible entity.

#### 4.2.2.5 Special loads and forces

If a MEWP is designed for use with special working methods or conditions, such as

- a) objects carried on the outside of the work platform,

- b) person(s) getting on or off the work platform at height,
- c) wind forces on large objects carried on the work platform,
- d) wind speeds greater than 12,5 m/s,
- e) forces imposed by winches or other material handling devices,
- f) a combination of forces,

the resulting loads and forces shall be taken into consideration as a modification to the rated load, structural load, wind load, and/or manual forces, as appropriate.

### 4.2.3 Stability calculations

#### 4.2.3.1 Forces created by rated load and structural masses

**4.2.3.1.1** Forces created by rated load and structural masses, causing overturning or stabilising moments, shall be multiplied by a factor of 1,0 *g*, and calculated as acting vertically downwards.

**4.2.3.1.2** In the case of movement of the extending structure these forces shall be multiplied by a factor of 0,1 *g* and applied as additional forces acting in the direction of movement creating the greatest overturning moment. Manufacturers may use factors lower than 0,1 *g* provided they have been proved by measurement of the effects of acceleration and deceleration.

**4.2.3.1.3** For the travelling movements of MEWP of type 2 and type 3 the factor of 0,1 *g* shall be replaced by a factor *z* representing the forces produced by acceleration and deceleration, or during the kerb and depression tests (see [5.1.4.2.2](#)). This factor shall be determined by calculation or tests (see [Annex E](#) for a calculation example).

**4.2.3.1.4** The maximum allowable chassis inclination shall be increased by 0,5° (as shown in [Figure 3](#)) to allow for inaccuracy in setting up the MEWP.

#### 4.2.3.2 Wind forces

Wind forces shall be multiplied by a factor of 1,1 and taken to be acting horizontally.

#### 4.2.3.3 Manual forces

Manual forces applied by persons on the work platform shall be multiplied by a factor of 1,1 and taken to be acting in the direction creating the greatest overturning moment (see [Figure 3](#) for examples).

#### 4.2.3.4 Special loads and forces

Special loads and forces, as determined by the responsible entity, shall be included in the calculation.

#### 4.2.3.5 Calculation of overturning and stabilising moments

**4.2.3.5.1** The MEWP shall be taken to be operating in the most adverse stability situation with respect to the combination of chassis inclination, structural configuration, position, structural motions and vehicle travel motion.

**4.2.3.5.2** The maximum overturning and corresponding stabilising moments shall be calculated about the least favourable tipping lines. Tipping lines shall be determined in accordance with ISO 4305; however, for solid and foam-filled tyres, the tipping lines may be taken at a point on the tyre ground contact at a distance of 25 % from the outside edge of the ground contact width.

**4.2.3.5.3** All forces shall be taken to act in their allowable direction that will produce the least stable outcome. Forces that can act simultaneously shall be considered in their least favourable combinations.

**4.2.3.5.4** When the load has a stabilising effect, additional stability calculations shall be made assuming the least favourable load combination on the work platform.

NOTE For examples, see [Table 1](#) and [Figure 3](#).

**4.2.3.5.5** In each case, the calculated stabilising moment shall be greater than the calculated overturning moment.

**4.2.3.5.6** The calculation shall include the following factors:

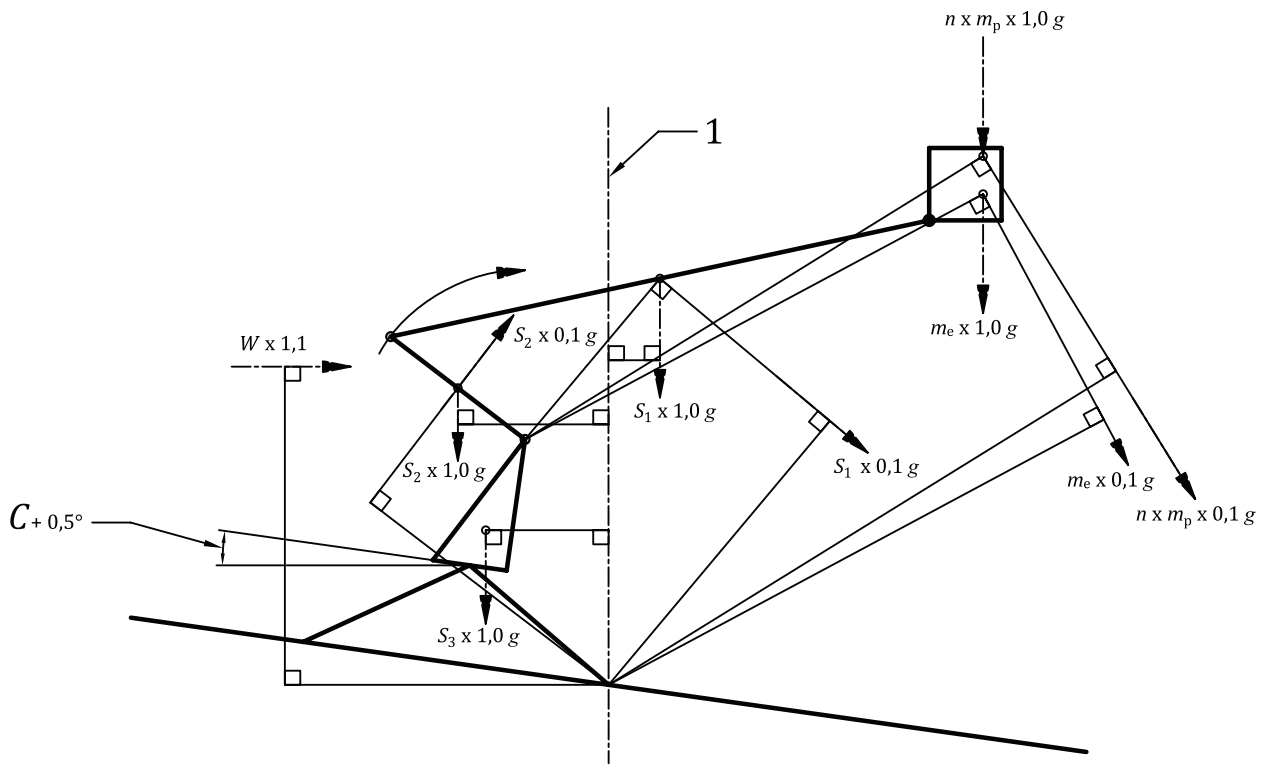
- a) tolerances in the manufacture of the components;
- b) clearances that allow movement in the connections of the extending structure;
- c) elastic deformations due to the effects of forces;
- d) failure of any one tyre in the case of MEWPs supported by pneumatic tyres in the working position, unless the MEWP is equipped with stabilising devices that eliminate the dependence on tyres for stability or with a tyre pressure monitoring system (TPMS) that warns the operator before the tyre pressure has dropped below 75 % of the inflation pressure specified by the MEWP manufacturer;
- e) performance characteristics (accuracy) of the load-sensing system, moment-sensing system, and position control, which can be affected by, for example,
  - peaks caused by short-term dynamic effects,
  - hysteresis,
  - chassis inclination of the MEWP,
  - ambient temperature,
  - different positions and distribution of load on the work platform (see [4.2.2.2.2](#)),
  - accuracy of the system.

**4.2.3.5.7** When using the criteria for enhanced stability in [4.4.1.5](#), the rated load shall be replaced by 150 % of the rated load.

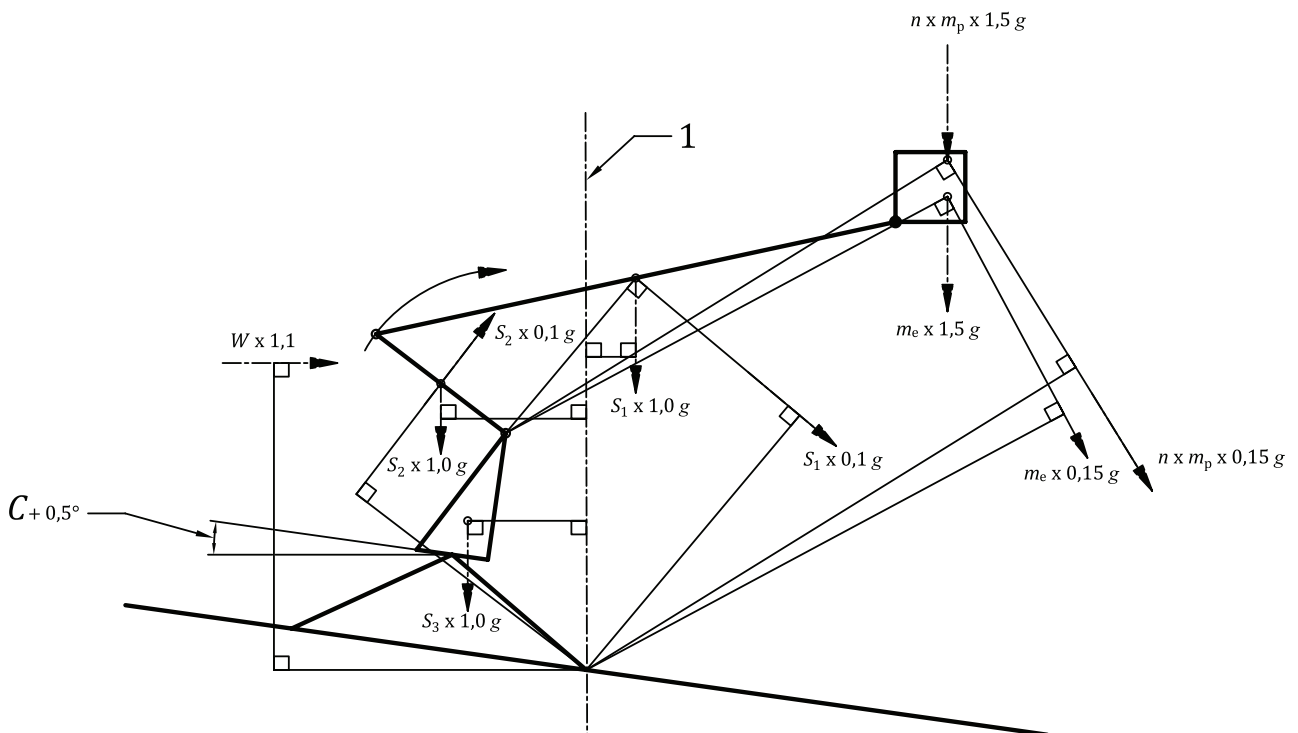
**4.2.3.5.8** The determination of elastic deformations shall be obtained by experiment or by calculation.

**Table 1 — Examples of load and force directions and combinations for stability calculations**  
(see [Figure 3](#))

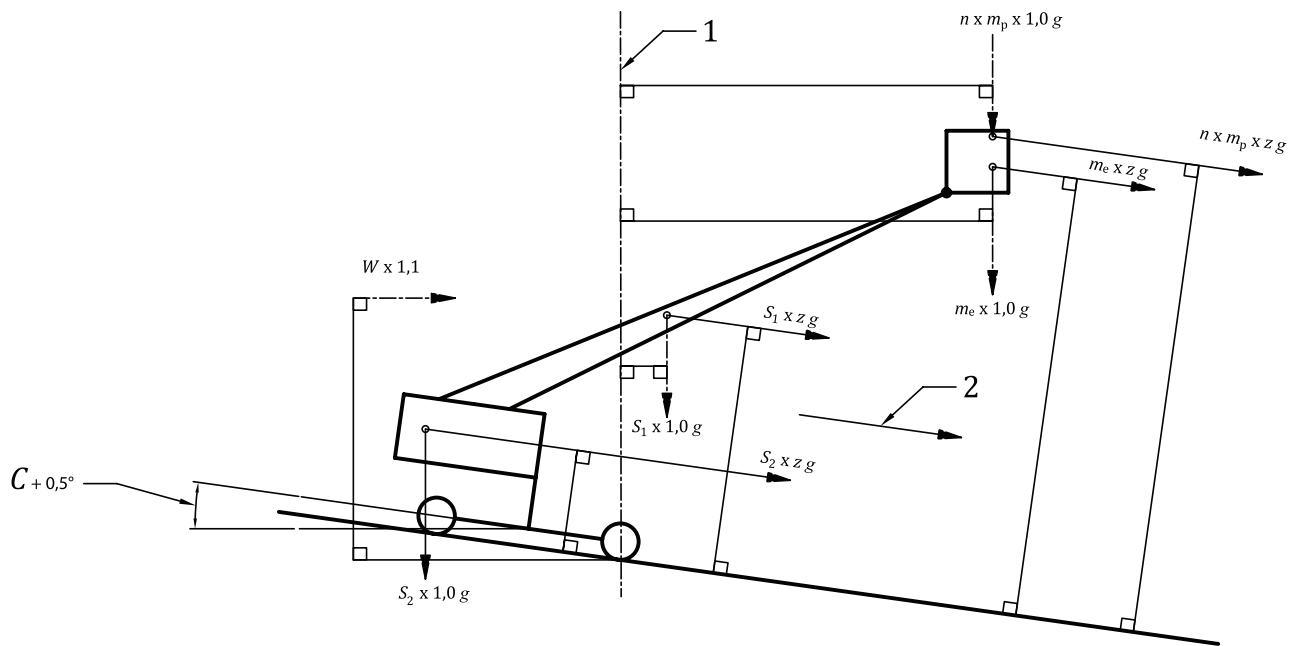
|                                                                             |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                             | 80 kg up to rated load |                    |                    |                       | Structural force<br>$S_n$ |                    | Manual force<br>$F_m$ | Wind force<br>$W$ |
|-----------------------------------------------------------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|------------------------|--------------------|--------------------|-----------------------|---------------------------|--------------------|-----------------------|-------------------|
| Working configuration                                                       | Figure example | Load-sensing                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Enhanced stability criteria | x 1,0                  | x 1,5 <sup>a</sup> | x 0,1 <sup>c</sup> | x 0,15 <sup>b,d</sup> | x 1,0                     | x 0,1 <sup>c</sup> | x 1,1                 | x 1,1             |
| Raising (lowering)                                                          | 3a             | X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -                           | V                      | -                  | A                  | -                     | V                         | A                  | -                     | H                 |
| Raising (lowering)                                                          | 3b             | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | X                           | -                      | V                  | -                  | A                     | V                         | A                  | -                     | H                 |
| Traveling                                                                   | 3c             | X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -                           | V                      | -                  | S                  | -                     | V                         | S                  | -                     | H                 |
| Traveling                                                                   | 3d             | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | X                           | -                      | V                  | -                  | S                     | V                         | S                  | -                     | H                 |
| Traveling                                                                   | 3e             | X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -                           | V                      | -                  | S                  | -                     | V                         | S                  | -                     | H                 |
| Traveling                                                                   | 3f             | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | X                           | -                      | V                  | -                  | S                     | V                         | S                  | -                     | H                 |
| Forward stability, stationary on slope                                      | 3g             | X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -                           | V                      | -                  | -                  | -                     | V                         | -                  | A                     | H                 |
| Forward stability, stationary on slope                                      | 3h             | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | X                           | -                      | V                  | -                  | -                     | V                         | -                  | A                     | H                 |
| Backward stability, stationary on slope                                     | 3i             | X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | X                           | V                      | -                  | -                  | -                     | V                         | -                  | A                     | H                 |
| Limited reach, forward stability, stationary on a slope, raising (lowering) | 3j             | X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -                           | V                      | -                  | A                  | -                     | V                         | A                  | -                     | H                 |
| Limited reach, forward stability, stationary on a slope, raising (lowering) | 3k             | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | X                           | -                      | V                  | -                  | A                     | V                         | A                  | -                     | H                 |
| Stationary, on slope                                                        | 3l             | X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -                           | V                      | -                  | -                  | -                     | V                         | -                  | A                     | H                 |
| Stationary, on slope                                                        | 3m             | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | X                           | -                      | V                  | -                  | -                     | V                         | -                  | A                     | H                 |
| Stationary, on level ground                                                 | 3n             | X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | X                           | V                      | V                  | -                  | -                     | V                         | -                  | A                     | H                 |
| Underbridge, stationary on slope                                            | 3o             | X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | -                           | V                      | -                  | -                  | -                     | V                         | -                  | A                     | H                 |
| Underbridge, stationary on slope                                            | 3p             | -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | X                           | -                      | V                  | -                  | -                     | V                         | -                  | A                     | H                 |
| V – vertical<br>H – horizontal<br>A – angular<br>S – at slope angle         |                | <sup>a</sup> 1,5 instead of 1,0 to be applied if enhanced stability criteria are applicable according to <a href="#">4.4.1.5</a> .<br><sup>b</sup> 0,15 instead of 0,1 to be applied if enhanced stability criteria are applicable according to <a href="#">4.4.1.5</a> .<br><sup>c</sup> z (see <a href="#">4.2.2.2.1.4</a> ) instead of 0,1 to be applied when traveling on slope [example in <a href="#">Figure 3</a> c), d), e) and f)].<br><sup>d</sup> z (see <a href="#">4.2.2.2.1.4</a> ) instead of 0,15 to be applied when traveling on slope [example in <a href="#">Figure 3</a> d) and f)]. |                             |                        |                    |                    |                       |                           |                    |                       |                   |



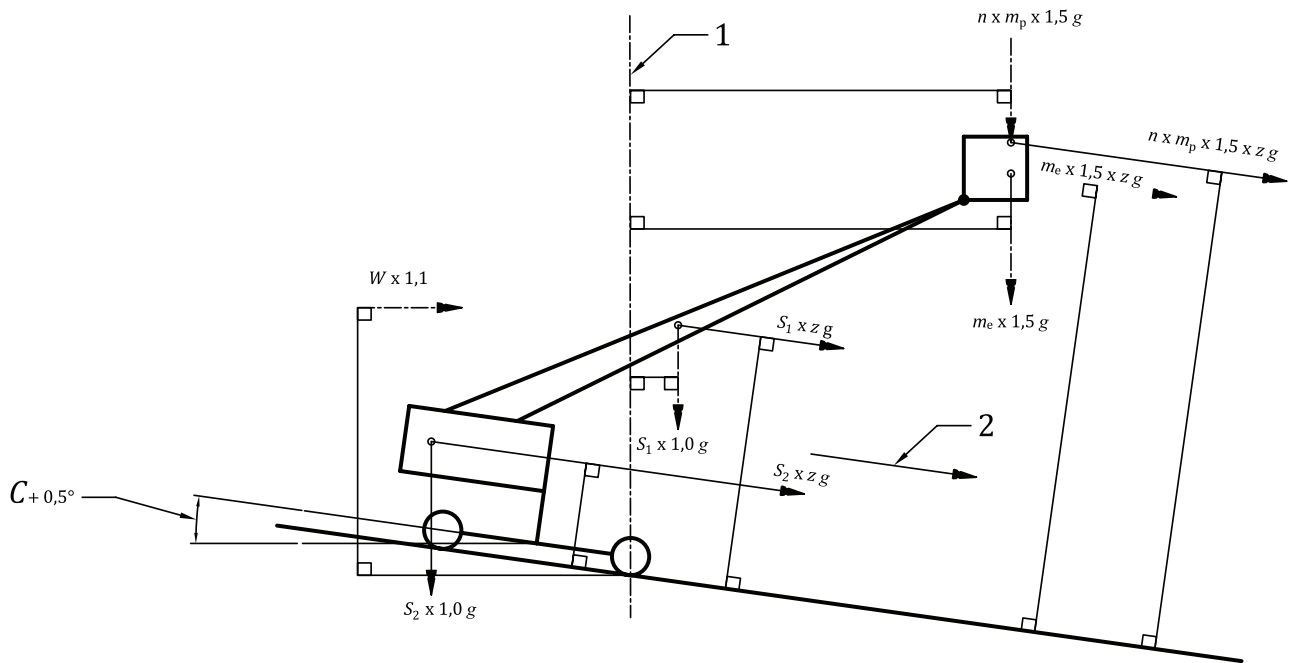
a) Raising (lowering) applying load-sensing



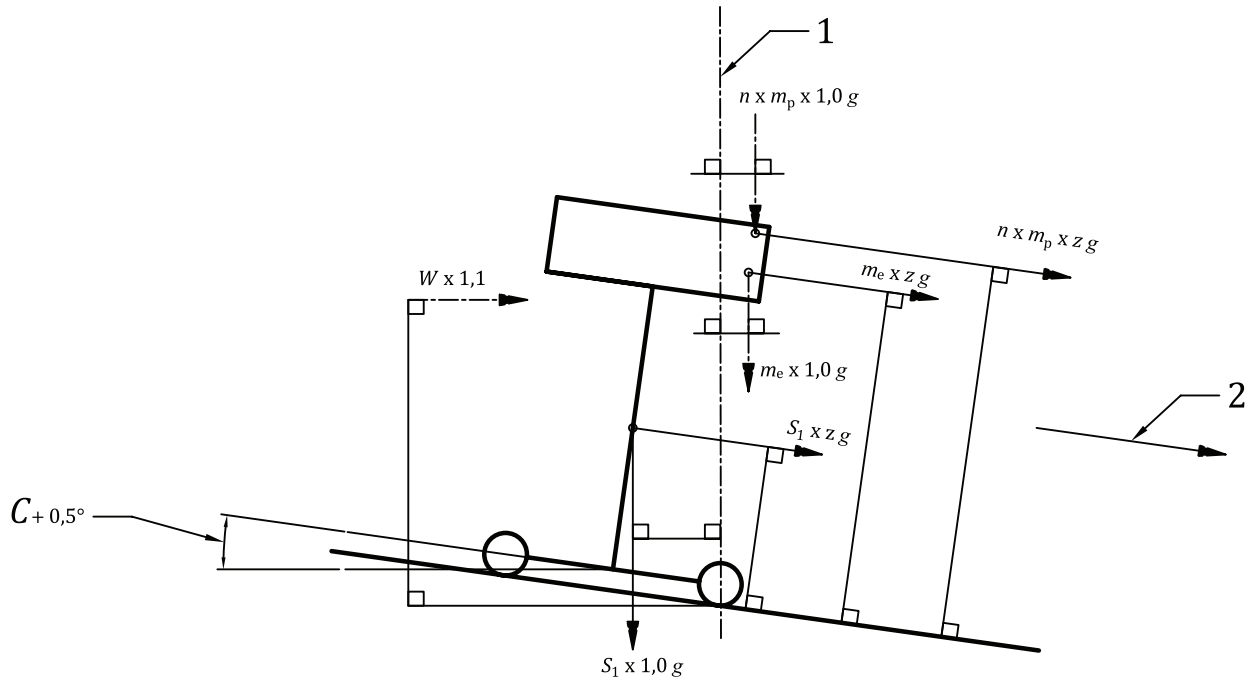
b) Raising (lowering) applying enhanced stability criteria



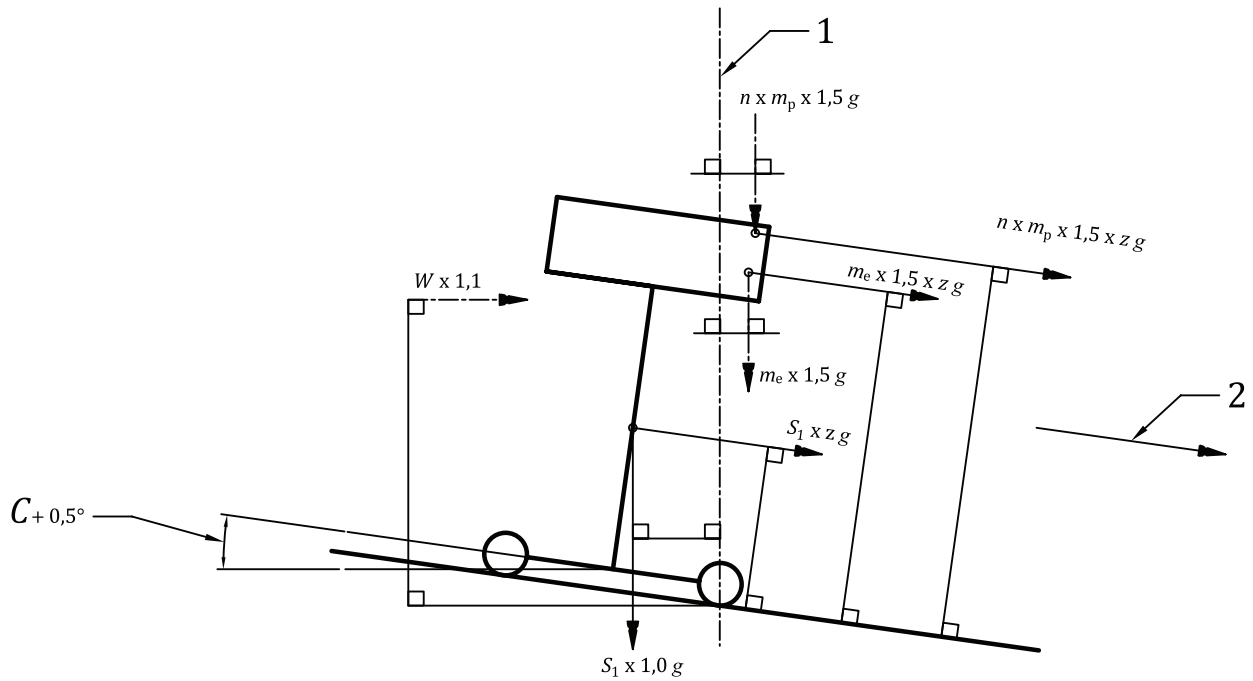
c) Traveling applying load-sensing



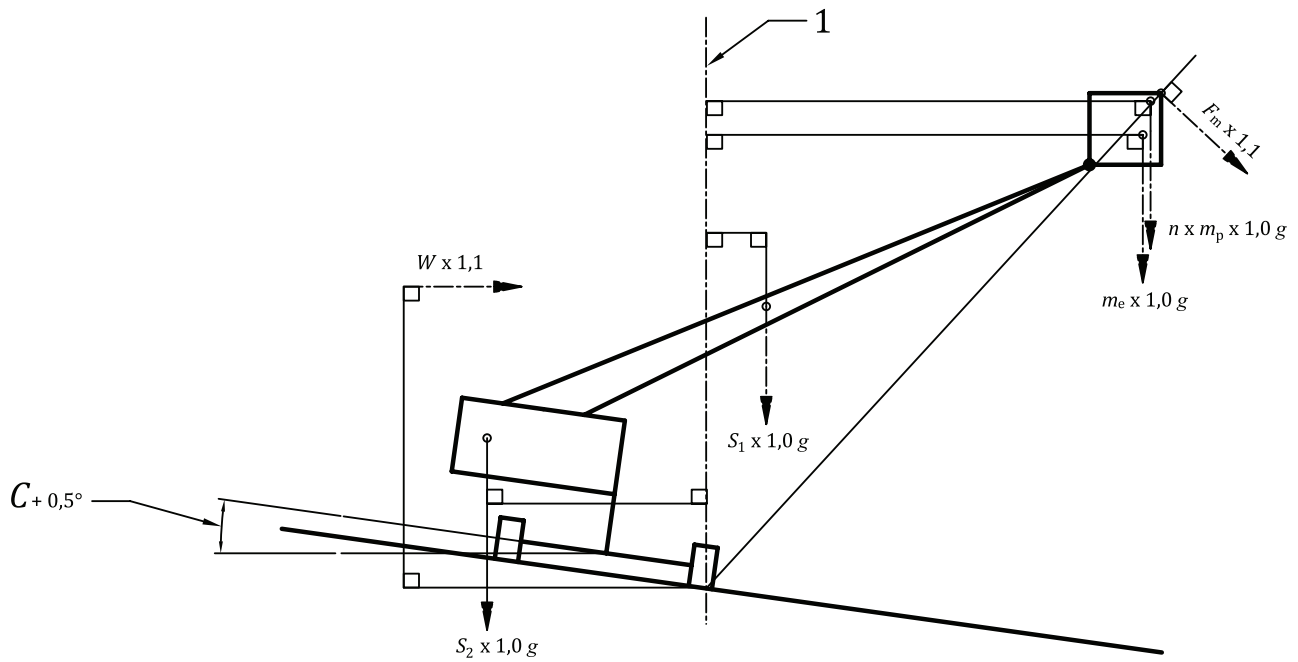
d) Traveling applying enhanced stability criteria



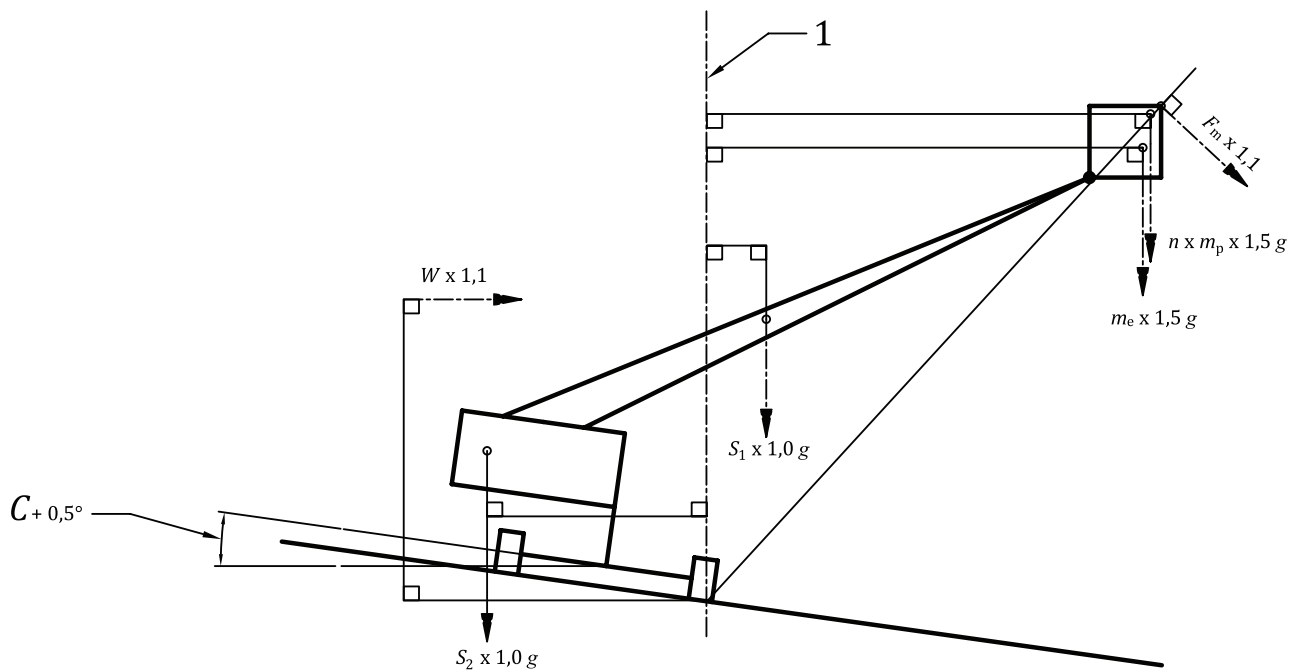
e) Traveling applying load-sensing



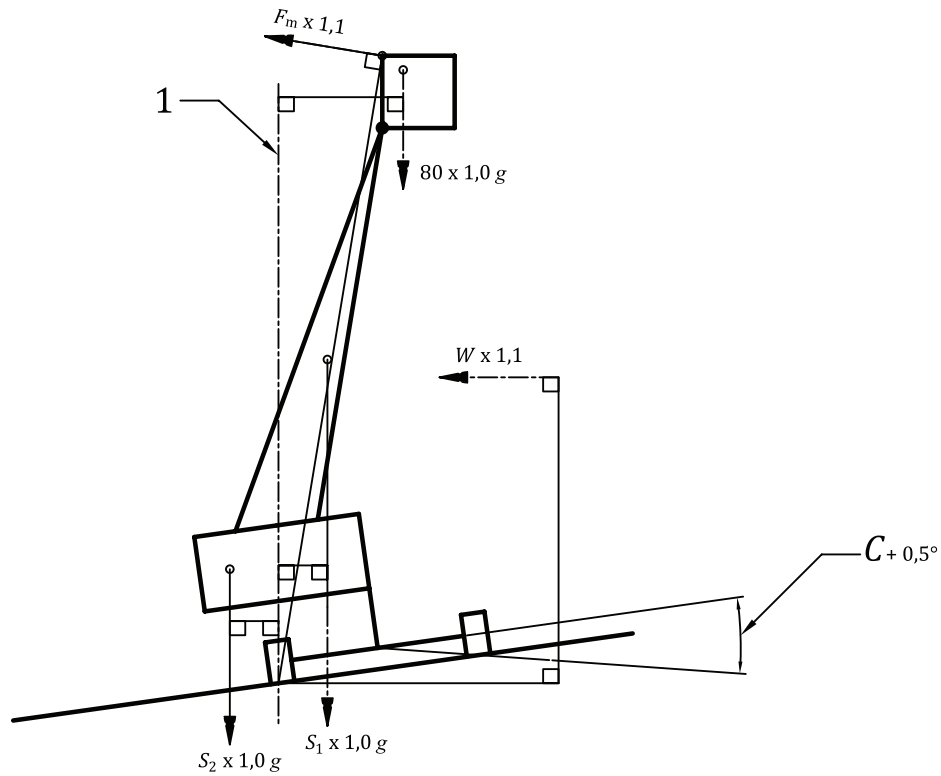
f) Traveling applying enhanced stability criteria



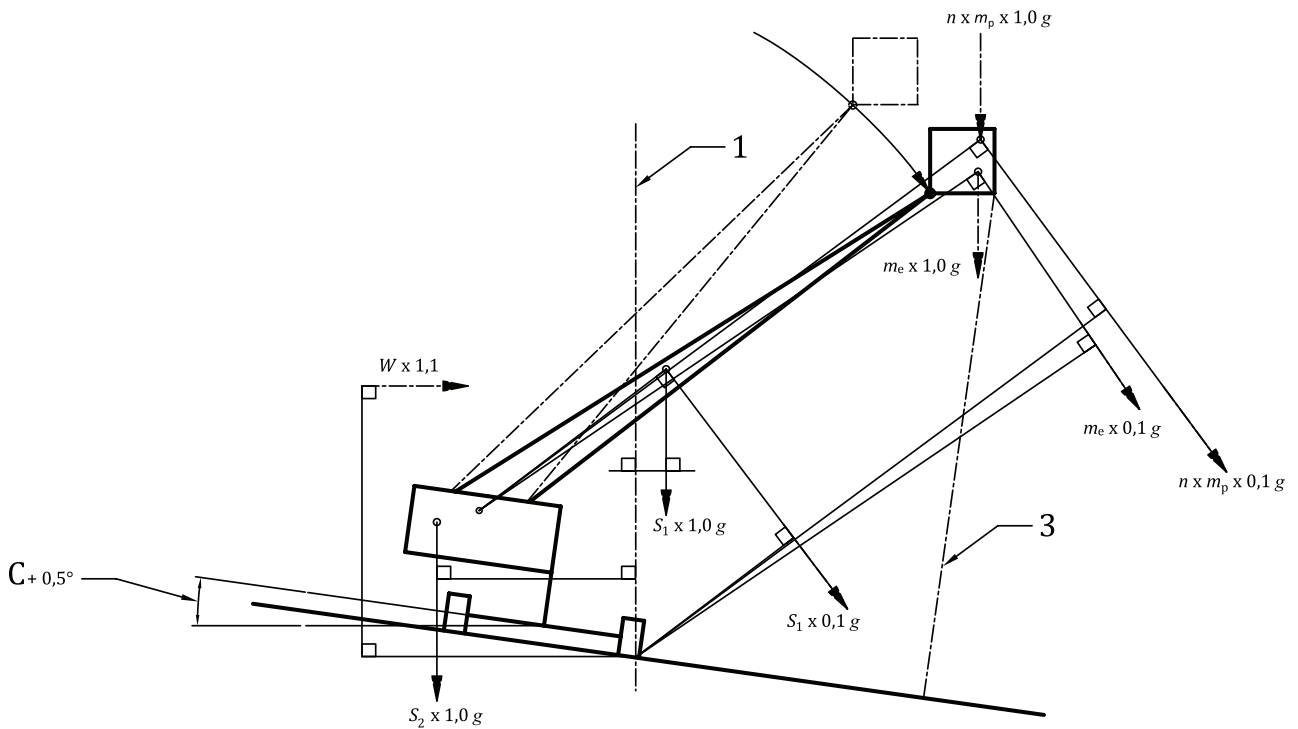
g) Forward stability, stationary on slope applying load-sensing



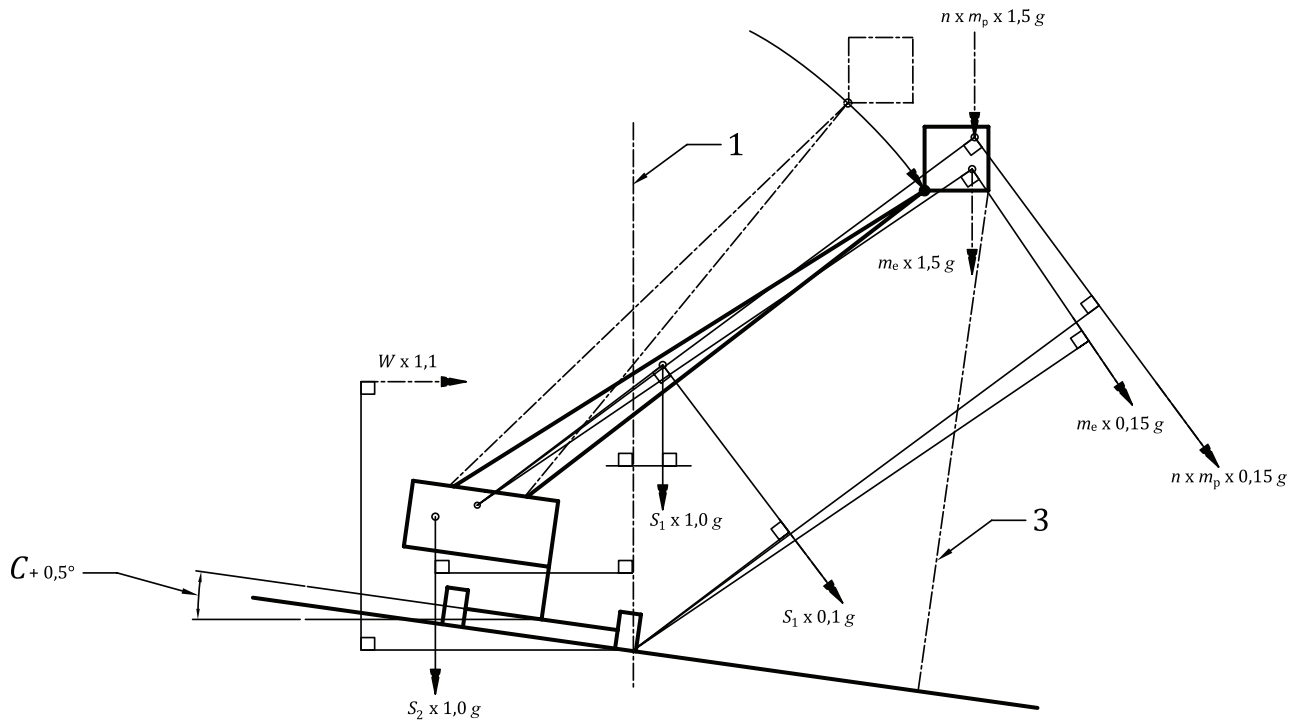
h) Forward stability, stationary on slope applying enhanced stability criteria



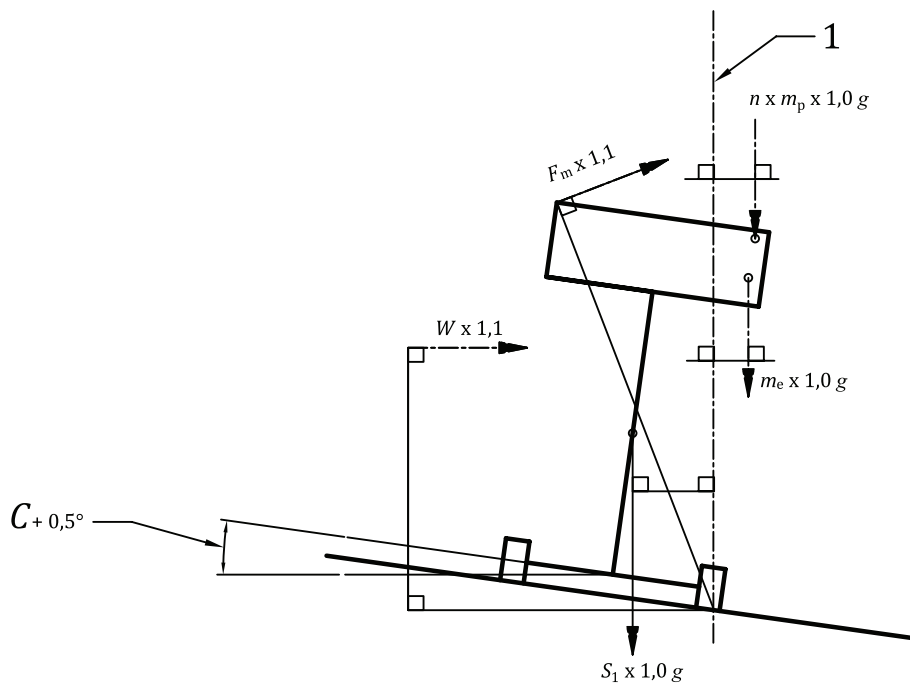
**i) Backward stability, stationary on slope applying load-sensing and enhanced stability criteria**



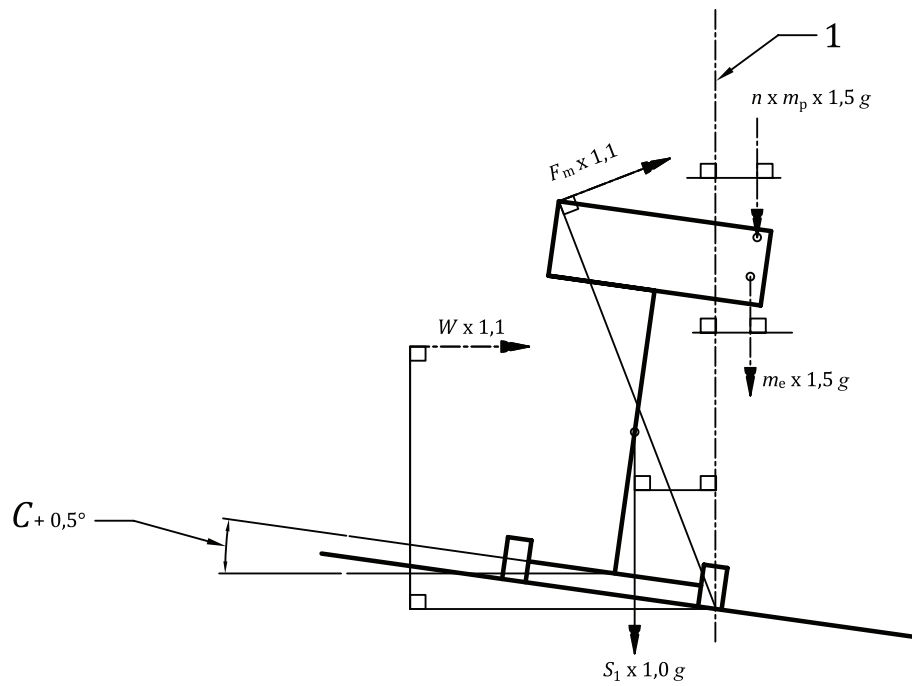
**j) Limited reach, forward stability stationary on slope, raising (lowering) applying load-sensing**



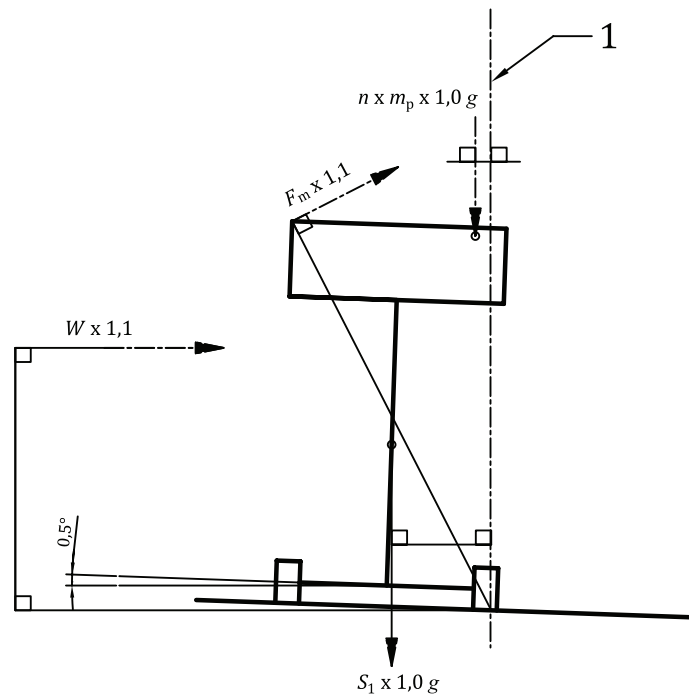
k) Limited reach, forward stability stationary on slope, raising (lowering) applying enhanced stability criteria



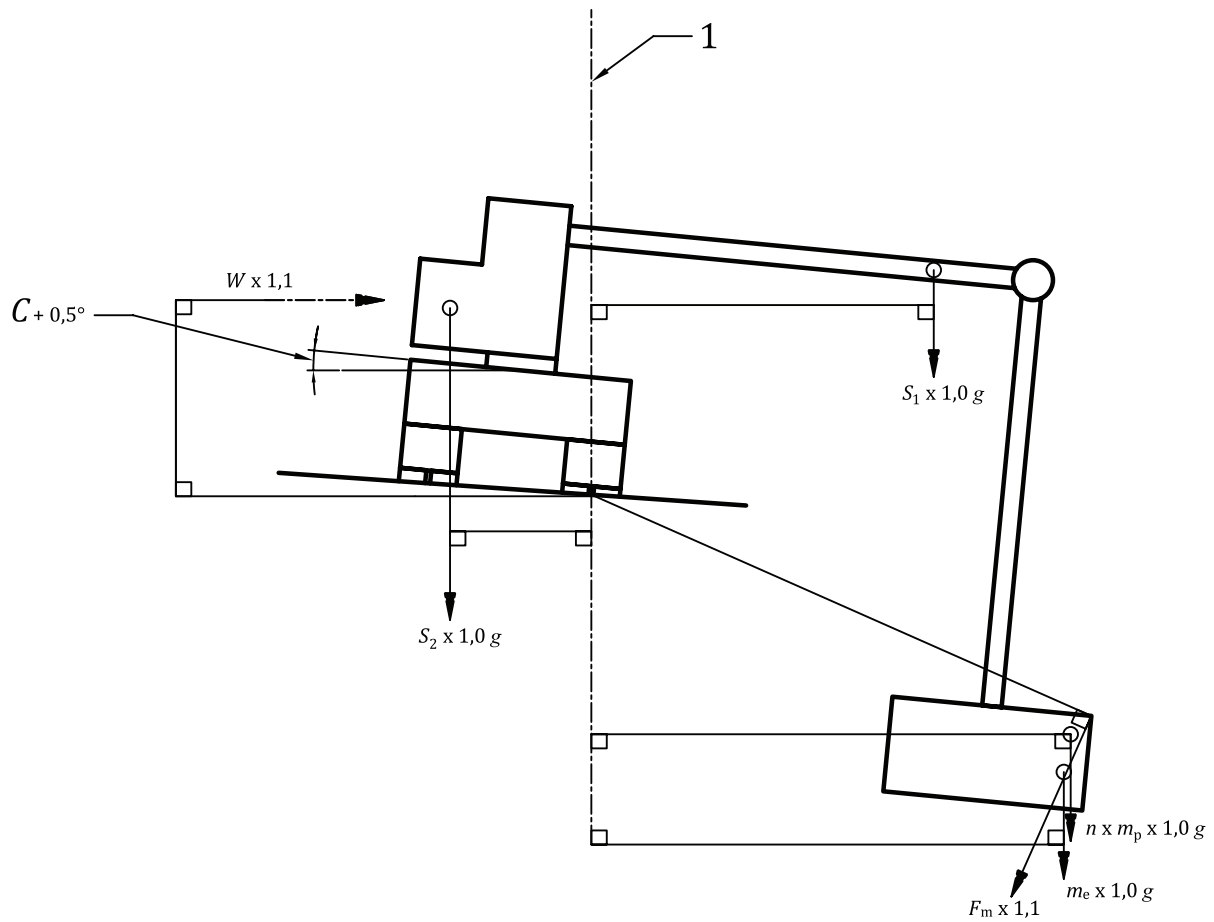
l) Stationary on slope, applying load-sensing



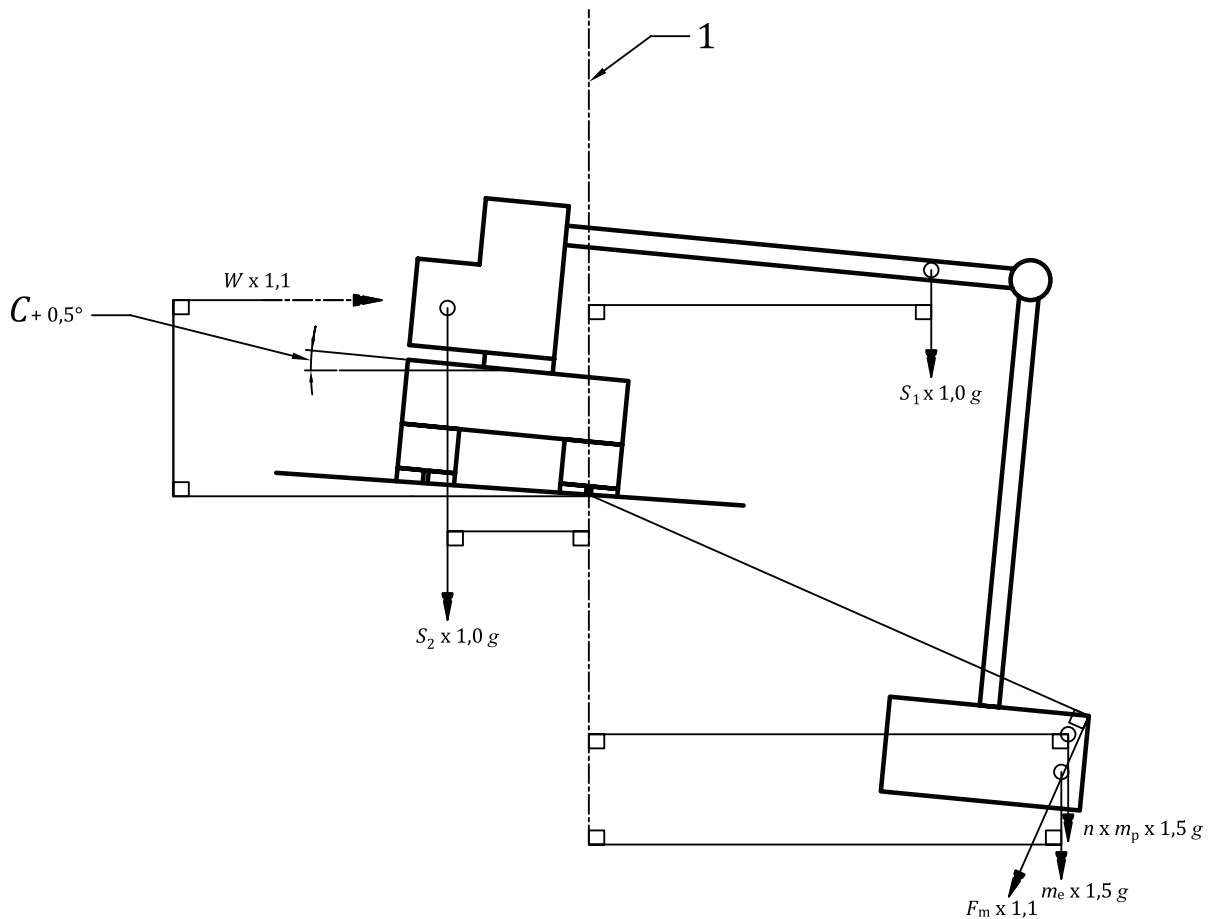
m) Stationary, on slope applying enhanced stability criteria



n) Stationary, on level ground applying load-sensing and enhanced stability criteria



**o) Underbridge, stationary on slope applying load-sensing**



**p) Underbridge, stationary on slope applying enhanced stability criteria**

**Key**

- 1 tipping line
- 2 direction of travel
- 3 limited reach
- C maximum chassis inclination

**Figure 3 — Example of load and force directions and combinations**

#### 4.2.4 Structural calculations

##### 4.2.4.1 General

**4.2.4.1.1** Structural calculations shall conform with the laws and principles of applied mechanics and strength of materials. If special formulas are used, the sources shall be given, or otherwise the formulas shall be developed from first principles, so that their validity can be checked.

**4.2.4.1.2** Requirements given in [4.2.2](#), [4.2.3.1](#), [4.2.3.2](#), [4.2.3.3](#), [4.2.3.4](#) and [4.2.3.5.6](#) shall be considered for the determination of loads and forces to be used in the calculations.

**4.2.4.1.3** Except where otherwise stated, the individual loads and forces shall be taken to act in the positions, directions and combinations that produce the least favourable conditions.

#### 4.2.4.2 Analysis

##### 4.2.4.2.1 General stress analysis

**4.2.4.2.1.1** The general stress analysis shall be used to analyse failure by yielding, buckling, and fracturing. This analysis shall be made for all load-bearing components and joints.

**4.2.4.2.1.2** The required information on stresses or safety factors shall be included in the analysis. Details of the main dimensions, cross-sections and materials for the individual components and joints shall be stated.

**4.2.4.2.1.3** Finite element analysis (FEA) may be used to meet the requirements of [4.2.4.2](#). The FEA model shall be specified and include an explanation of the loading areas, load types, constraint areas and constraint types.

**4.2.4.2.1.4** Stress analysis shall be performed by one of the stress analysis methods described in [4.2.4.2.2](#). When using criteria for the enhanced overload method in [4.4.1.6](#), the rated load shall be replaced by 150 % of the rated load.

##### 4.2.4.2.2 Stress analysis methods

###### 4.2.4.2.2.1 Permissible stress method

Stresses imposed by the load and force combinations defined in [4.2.4.1](#) shall not exceed 66,7 % of either the minimum yield strength or the buckling strength of the ductile materials. When using the criteria for enhanced overload methods in [4.4.1.6](#), stresses imposed by the load and force combinations defined in [4.2.4.1](#) shall not exceed 50 % of either the minimum yield strength or the column strength of the ductile materials. Structural elements made of non-ductile materials shall have a design stress of no more than 20 % of the minimum ultimate strength of the material.

###### 4.2.4.2.2.2 Limit state method

Using the limited state method:

- a) Loads can be considered to be either regular or occasional:
  - regular loads are either rated load or structural masses and occur frequently under normal operation;
  - occasional loads occur infrequently, are usually neglected in fatigue assessment and are either loads due to in-service wind or due to manual force.
- b) These loads are combined into two load combinations:
  - load combination A is comprised of only regular loads;
  - load combination B is comprised of both regular and occasional loads.
- c) The static strength of the structure shall be assessed for both load combination A and B. The loads and forces defined in [4.2](#) shall thereby be multiplied by the partial safety factors  $\gamma_p$  given in [Table 2](#).

**Table 2 — Partial safety factors**

| Clause                  | Loading             | Partial safety factors $\gamma_p$ |                    |
|-------------------------|---------------------|-----------------------------------|--------------------|
|                         |                     | Load combination A                | Load combination B |
| <a href="#">4.2.1.2</a> | Rated load          | 1,34                              | 1,22               |
| <a href="#">4.2.2.2</a> | Structural masses   | 1,22                              | 1,16               |
| <a href="#">4.2.2.3</a> | Wind forces (loads) | -                                 | 1,22               |
| <a href="#">4.2.2.4</a> | Manual force        | -                                 | 1,22               |