

Strength and stability of structures

Aluminium structures



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Foreword

The Ministry of the Environment publishes the recommendations for strength and stability related to the design of aluminium structures in the National Building Code of Finland. The instruction contains a compilation of all the National Annexes concerning the design of aluminium structures.

The beginning of each National Annex presents those clauses in the standard where national choice is permitted, and where such a choice has been made.

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Contents

1. Scope	4
2. Design of structures	
2.1 Execution documents	4
2.2 Content of structural designs	4
2.3 Execution classes	5
2.4 Durability and design working life	5
3. Execution	
3.1 Execution planning	6
3.2 Construction products	6
3.3 Fabricated products	7
3.4 Tolerances for aluminium structures	7
4. Execution supervision and Conformity of structures	
4.1 Execution supervision	7
4.1.1 Fire protection supervision	8
4.2 Conformity of structures	8
5. References	8
6. National Annexes to Eurocodes SFS-EN 1999	
National Annex to standard SFS-EN 1999-1-1 Part 1-1: General structural rules	10
National Annex to standard SFS-EN 1999-1-2 Part 1-2: Structural fire design	15
National Annex to standard SFS-EN 1999-1-3 Part 1-3: Structures susceptible to fatigue	17
National Annex to standard SFS-EN 1999-1-4 Part 1-4: Cold-formed structural sheeting	20
National Annex to standard SFS-EN 1999-1-5 Part 1-5: Shell structures	22

1. Scope

These instructions provide additional information when applying the Ministry of Environment Decree on load-bearing structures in the design and execution of aluminium structures. A solution pursuant to these instructions is considered to meet the requirements set for load-bearing structures.

These instructions are applied when aluminium structures are designed pursuant to standards SFS-EN 1999 and their National Annexes, and executed pursuant to standard SFS-EN 1090-3.

2. Design of structures

2.1 Execution documents

Usually, the execution documents include, at a minimum, the following:

- a) construction drawings
- b) requirements pursuant to standard SFS-EN 1090-3, such as the execution classes, tolerance classes, degrees of prefabrication and the information required in Tables A.1 and A.2 of Annex A to standard SFS-EN 1090-3
- c) other documents to be adhered to or references to other documents
- d) if necessary, structural aluminium work not covered by SFS-EN 1090-3.

2.2 Contents of structural designs

Usually, the structural designs for aluminium structures present, at a minimum, the following to the extent applicable to the design task:

- a) consequence class
- b) the planned service life of the structure
- c) the R/E/I/M fire resistance class for the fully fabricated components
- d) the adopted characteristic loads and category of use
- e) complete information on the dimensions and location of the structures
- f) execution class
- g) the class of the allowed deviation pursuant to standard SFS-EN 1090-3 and special project-specific tolerances
- h) identifying information for the materials and supplies
- i) technical specifications required for designing the fireproofing (e.g. critical temperature during standard fire) or plans concerning operational fire design or other fire design plans
- j) fire protection method
- k) weld class
- l) degree of utilisation for welds and, if necessary, welds intended for special inspection

- m) the effective a- dimensions of welds required for the calculations and butt weld thicknesses regardless of the welding process and, if necessary, the effective lengths of tack welds l_{eff} and the lengths of butt welds
- n) the information required for determining the surface treatment
- o) any possible other methods (in addition to tightening) used for preventing the loosening of bolts
- p) special requirements concerning manufacture, such as the hole creation method, weld grinding, allowed hardness values, allowed bending radii for cold bending, unless these are presented separately elsewhere in the execution specification. Special requirements refer to matters that affect the resistance of the structure or that are otherwise required on the basis of planning.

The following are also presented for factory-made construction components (included in manufacturing or installation drawings):

- q) the information required for the assessment of the qualification and design of the fabricated product
- r) the CE labelling method adopted for the fabricated products (M1, M2, M3a or M3b)
- s) the weight and centroid location for the fabricated product
- t) lifting points
- u) handling, support and lifting instructions if necessary.

2.3 Execution classes

The requirements set for the execution of aluminium structures are divided into four execution classes. The execution classes are presented in standard SFS-EN 1090-3, and the instructions for selecting the execution class are given in standard SFS-EN 1999-1-1.

The execution class is selected on the basis of the consequences classes (CC1, CC2 and CC3) given in the National Annex to standard SFS-EN 1990 and the risk factors related to the implementation.

2.4 Durability and design working life

In order to achieve the planned service life, the exposure caused by the environmental conditions is defined. The exposure is used to determine the requirements such as the aluminium alloy to be used, the possible method of protection and the inspection and maintenance activities required by it.

3. Execution

3.1 Execution planning

The work plans for the execution of aluminium structures are drawn up on the basis of the execution documents in adherence with standard SFS-EN 1090-3.

Usually, the work plans for the execution of aluminium structures present, at a minimum, the following to the extent applicable to the design task:

- the required execution drawings
- installation plan pursuant to standard SFS-EN 1090-3
- a fireproofing plan that normally presents the following, at a minimum:
 - the product name and possible product approval identifier of the fireproofing agent
 - the component-specific design value for the fireproofing (e.g. the thickness of the fireproofing plate or insulation)
 - instructions for the periodic condition inspection of the fireproofing, which are appended to the operating and maintenance instructions of the building
- quality documents pursuant to standard SFS-EN 1090-3.

3.2 Construction products

The characteristics of the building products, materials and supplies used in aluminium structures are demonstrated by means of the CE label if they are covered by the scope of the harmonised product standard or if the manufacturer has acquired the European Technical Approval/Assessment for its product. Otherwise, they are demonstrated according to the Act on the Type Approval of Certain Construction Products (954/2012).

The characteristics of the following products are central in terms of the reliability of the aluminium structures:

- aluminium profiles and sheets
- sheetings
- screws and bolt assemblies
- welding consumables
- fireproofing products
- fabricated aluminium products and elements with aluminium frames

When using materials and supplies presented in the reference standards presented in standard SFS-EN 1090-3 that have no harmonised product standard, their material properties are usually demonstrated with material certificates pursuant to the requirements of standard SFS-EN 1090-3.

3.3 Fabricated products

If a harmonised product standard does not exist for a fabricated aluminium product, and the manufacturer has not present a European Technical Approval/Assessment (ETA), and the suitability of the building product has not been demonstrated with a voluntary product approval procedure pursuant to Act 954/2012 on the Type Approval of Certain Construction Products, the suitability of the fabricated product is demonstrated on a per-site basis by using the quality documents pursuant to the requirements of standard SFS-EN 1090-3.

3.4 Tolerances for aluminium structures

The tolerances for aluminium structures are given in standard SFS-EN 1090-3. However, in case A of Table G3 in the standard, the following are used as permitted deviations:

$$\Delta < \frac{d}{200} \quad \text{when } \frac{d}{t} \leq 50$$
$$\Delta < \frac{d^2}{10000t} \quad \text{when } 50 < \frac{d}{t} \leq 100$$
$$\Delta < \frac{d}{100} \quad \text{when } \frac{d}{t} > 100$$

4. Execution supervision and the conformity of structures

4.1 Execution supervision

The inspections related to the supervision of the execution of aluminium structures are drawn up within the scope required by the execution documents in adherence with standard SFS-EN 1090-3.

During the execution of the structures, the responsible work supervisor or a separately appointed specialist work supervisor will supervise that the plans and instructions concerning the manufacture of aluminium structures and the installation of the aluminium elements are followed and that the appropriate documents are prepared for the work.

If it is observed during the execution that a structural component, its detail or structure does not meet the requirements laid down in the execution documents, the occurrence locations and causes of the deviations are analysed. This is done to determine whether the deviation can be approved without a repair. If necessary, calculations are used to demonstrate that the confidence interval re-

quired by standards SFS-EN 1999 and their National Annexes is achieved. If it cannot be demonstrated that the deviation is acceptable without a repair, the repair will be carried out to the necessary extent. The deviation and corrective action will be recorded in the quality control archive.

The quality control material is documented and compiled into a single entity. The quality control documentation consists of the quality control documentation compiled at the aluminium structure manufacturing plant and during the execution at the worksite.

4.1.1 Fire protection supervision

The fireproofed structure is marked by attaching a necessary amount of signs that indicate the fire protection information to the completed structure for each fire compartment. These signs present the following:

- the structure's R fire class used in the design
- the product name and possible product approval identifier of the fireproofing agent
- the fireproofing contractor
- the installation time for the fireproofing
- the inspector of the fireproofing.

Unless more detailed instructions are presented, the fireproofing is inspected visually at least once every three years. Damage to the fireproofing will be repaired according to instructions from the fireproofing product manufacturer.

The documentation concerning the fireproofed structures will be compiled for inclusion in the operating and maintenance instructions of the building.

4.2 Conformity of structures

The suitability appraisal for structures is based on the aluminium structures being designed appropriately pursuant to standards SFS-EN 1999 and their national annexes, and on the aluminium structures being executed and inspected pursuant to the execution documents.

5. References

SFS-EN 1090-3	Execution of steel structures and aluminium structures. Part 3: Technical requirements for aluminium structures
SFS-EN 1990	Eurocode. Basis of structural design

SFS-EN 1999-1-1	Eurocode 9. Design of aluminium structures. Part 1-1: General structural rules
SFS-EN 1999-1-2	Eurocode 9. Design of aluminium structures. Part 1-2: Structural fire design
SFS-EN 1999-1-3	Eurocode 9: Design of aluminium structures. Part 1-3: Structures susceptible to fatigue
SFS-EN 1999-1-4	Eurocode 9. Design of aluminium structures. Part 1-4: Cold-formed structural sheeting
SFS-EN 1999-1-5	Eurocode 9. Design of aluminium structures. Part 1-5: Shell structures

6. National annexes to Eurocodes SFS-EN 1999

National Annex to standard SFS-EN 1999-1-1 Part 1-1: General structural rules

As regards standard SFS-EN 1999-1-1, the recommended values set forth in standard SFS-EN 1999-1-1 and all the annexes to standard SFS-EN 1999-1-1 are followed unless otherwise stated in this National Annex.

The Non-Contradictory Complementary Information (NCCI) is presented in italics.

National choice is permitted in the following clauses of standard SFS-EN 1999-1-1:

- 1.1.2(1)
- 2.1.2(3)
- 2.3.1(1)
- 3.2.1(1), Note 1
- 3.2.2(1)
- 3.2.2(2), Note 1
- 3.2.3.1(1), Note 2
- 3.3.2.1(3), Note 1
- 3.3.2.2(1)
- 5.2.1(3)
- 5.3.2(3)
- 5.3.4(3)
- 6.1.3(1), Note 1
- 6.1.3(1), Note 2
- 6.2.1(5), Note 2
- 7.1(4)
- 7.2.1(1)
- 7.2.2(1)
- 7.2.3(1)
- 8.1.1(2)
- 8.9 (3)
- A.2(1)
- C.3.4.1(2)
- C.3.4.1(3)
- C.3.4.1(4)
- K.1(1)
- K.3(1), Note 1
- K.3(1), Note 3.

A national choice has been made in the clauses marked ●.

Reliability management

2.1.2(3)

A quality plan is drawn up for each project (SFS-EN 1090-3, Table A.1).

As far as essential tolerances are concerned standard SFS-EN 1090-3 is followed and part 3.4 of this instruction.

Regulations and instructions related to the quality plan are given in the building legislation.

Actions and environmental influences

2.3.1(1)

The characteristic values of ice loads are determined according to standard ISO 12494.

Range of materials

3.2.1(1), Note 1

Aluminium alloys and tempers according to other SFS-EN standards should be determined separately in each project in such a way that the aluminium alloy and temper to be used fulfils the requirements given in standard SFS-EN 1999-1-1. In these cases, the parameters needed in the design, see Tables 3.1a, 3.1b, 3.2a, 3.2b and 3.2c of the standard, should be chosen based on the most unfavourable situation if the use of other values cannot be demonstrated. Other aluminium alloys and tempers may be used if their properties and suitability have been reliably analysed.

General

3.2.3.1(1), Note 2

The quality requirements for castings should be determined for each project such that they correspond to the general principles given in Annex C.

General

3.3.2.1(3), Note 1

Non-standardised products may be used if the product characteristics have been reliably analysed.

Preloaded bolts

3.3.2.2(1)

Non-standardised bolts may be used if the product characteristics have been reliably analysed.

General

6.1.1(1)P

If a deviation is made from the tolerances underlying the design rules into a direction that is unfavourable in terms of structural resistance, calculations shall be used to indicate that the confidence interval required by standard SFS-EN 1999 and its National Annexes is achieved.

Partial factors

6.1.3(1), Note 1

In accidental limit states (with the exception of fire), the same design expressions and conditions and partial material factors are used as in the normal temperature design, except for $\gamma_{M2} = 1.1$.

General

7.1(4)

Permanent deformations at serviceability limit states are not allowed if they cause harm.

Vertical deflections

7.2.1(1)

The final vertical and horizontal deflections due to characteristic load combinations calculated with a static load should not exceed the values in Table 1, if the deflections are harmful, unless other values are determined to be more suitable due to type of structure, use or the nature of the activity. Precamber (w_c , see standard SFS-EN 1990) may be used for compensation of the deflection of the permanent load unless harm is caused by it.

Table 1. Serviceability limit states for deflections

Structure	Serviceability limit state for deflection
Main girders: - roofs - floors	$L/300$ $L/400$
Cantilevers	$L/150$
Roof purlins	$L/200$
Wall purlins	$L/150$
Sheetings: - in roofs, with no risk for accumulation of water or other risk for failure of the - in roofs, with risk for accumulation of water or other risk for failure of the roof - when $L \leq 4.5$ m - when $4.5 \text{ m} < L \leq 6.0$ m - when $L > 6.0$ m - in floors - in walls - in cantilevers	$L/100$ $L/150$ 30 mm $L/200$ $L/300$ $L/100$ $L/100$
Horizontal deflection of the structure - 1- and 2-storey buildings - other buildings	$H/150$ $H/400$
L is the span H is the height of the building at the point of local application	

Horizontal deflections

7.2.2(1)

Horizontal deflection limits are presented in Table 1 of clause 7.2.1(1) of this National Annex.

Dynamic effects

7.2.3(1)

In order to account for dynamic effects, the NCCI 1 document that is appended to the instructions concerning national choices for standard SFS-EN 1993-1-1 may be applied.

Introduction

8.1.1(2)

The partial factor for adhesive bonded connections should be determined based on tests taking guidance given in Annex D of standard SFS-EN 1990 into account.

When calculating the resistance of welds, the prerequisite for the use of partial factor $\gamma_{M2} = 1.25$ is that the weld class is at least C according to standards SFS-EN ISO 10042.

Design rules for reliability differentiation – Design supervision levels

A.2(1)

The selection of the consequences class is presented in the Ministry of Environment Decree 3/16 on the application of standard SFS-EN 1990.

Rules related to the control of design are set forth in the building legislation.

A.5(1), Note 1

The execution class is determined according to Tables A.1, A.2 and A.3 in the standard.

Shear lag phenomenon at ultimate limit states

K.3(1), Note 3

Limit for plastic strain should be determined for each project.

National Annex to standard SFS-EN 1999-1-2 Part 1-2: Structural fire design

As regards standard SFS-EN 1999-1-2, the recommended values set forth in standard SFS-EN 1999-1-2 and all the annexes to standard SFS-EN 1999-1-2 are followed unless otherwise stated in this National Annex.

The Non-Contradictory Complementary Information (NCCI) is presented in italics.

National choice is permitted in the following clauses of standard SFS-EN 1999-1-2:

- 2.3(1)
- 2.3(2)
- 2.4.2(3), Note 1
- 2.4.2(3), Note 3
- 4.2.2.1(1)
- 4.2.2.3(5)
- 4.2.2.4(5)

A national choice has been made in the clauses marked ●.

Parametric fire exposure

2.1.3

As regards the separating function, standard SFS-EN 1994-1-2 and its National Annex may be used.

Member analysis

2.4.2(3), Note 1

Values pursuant to the Ministry of Environment Decrees 3/16 and 5/16 concerning the application of standards SFS-EN 1990 and SFS-EN 1991-1-2 are used.

2.4.2(3), Note 2

When using the partial factors from standard SFS-EN 1990 and the Ministry of Environment Decree 3/16 concerning its application, Figure 1 in standard SFS-EN 1999-1-2 will change as presented in Figure 1.

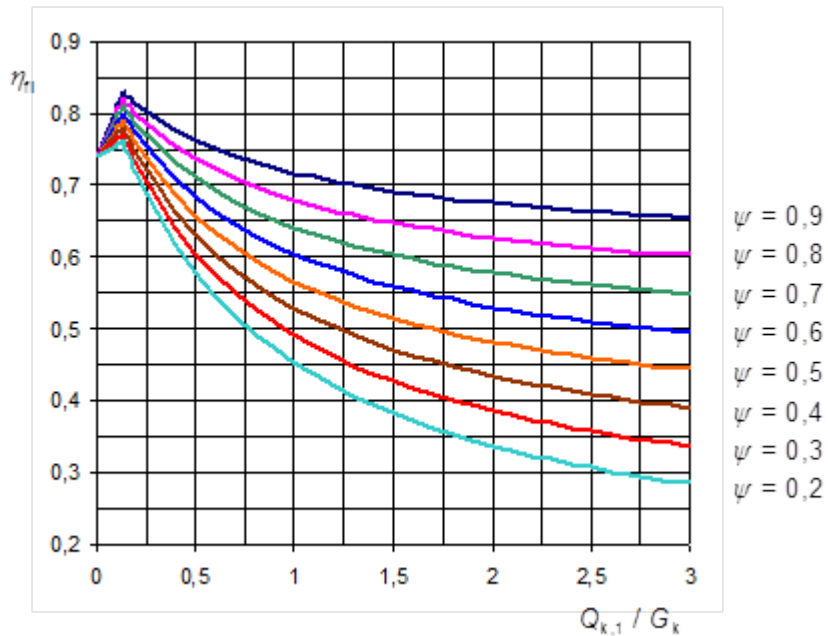


Figure 1. The variation of the reduction factor η_{fi} as a function of the load ratio of the characteristic values of dominant variable action and permanent action $Q_{k,1}/G_k$ according to the load combination rules presented in the Ministry of Environment Decree concerning standard SFS-EN 1990.

2.4.2(3), Note 3

Approximate values are not used.

Cross-section classification

4.2.2.1(1)

The actual drop in modulus of elasticity may be taken into account.

Beams

4.2.2.3(5)

The actual drop in modulus of elasticity can be taken into account.

Columns

4.2.2.4(5)

The actual drop in modulus of elasticity can be taken into account.

National Annex to standard SFS-EN 1999-1-3 Part 1-3: Structures susceptible to fatigue

As regards standard SFS-EN 1999-1-3, the recommended values set forth in standard SFS-EN 1999-1-3 and all the annexes to standard SFS-EN 1999-1-3 are followed unless otherwise stated in this National Annex.

The Non-Contradictory Complementary Information (NCCI) is presented in italics.

National choice is permitted in the following clauses of standard SFS-EN 1999-1-3:

- 2.1.1(1)P
- 2.2.1(4)
- 2.3.1(2)
- 2.3.2(6)
- 2.4(1), Note 1
- 2.4(1), Note 2
- 3(1)
- 4(2)
- 5.8.1(1)
- 5.8.2(1)
- 6.1.3(1), Note 1
- 6.1.3(1), Note 2
- 6.2.1(2), Note 2
- 6.2.1(7)
- 6.2.1(11)
- E(5)
- E(7)
- I.2.2(1)
- I.2.3.2(1), Note 2
- I.2.4(1)
- L.2.2(5)
- L.3(2)
- L.4(3)P, Note 1
- L.4(3)P, Note 2
- L.4(4)
- L.4(5)
- L.5.1(1).

A national choice has been made in the clauses marked ●.

Basic requirements

2.1.1(1)P

In addition to the rules set forth in standard SFS-EN 1999-1-3, an inspection programme should be drawn up in adherence to the following rules:

- a) Damage tolerant design should ensure that when damage occurs due to accidental action, deterioration of material, corrosion or fatigue, the remaining structure can sustain at least the used combination of actions without failure beyond an agreed extent, until the damage can be detected and the damaged structure can be repaired or replaced.
- b) The combination of actions to be considered and the extent of failure to be accepted should be agreed between the client, the designer and the competent authority and recorded in the execution specification. When the damage tolerant concept is used, the execution specification should include information concerning the methods of inspection and inspection intervals to be used as well as the procedure to be followed when the structure has reached the end of its service life.
- c) To ensure sufficient robustness, provisions should be made for inspection and maintenance at appropriate intervals that comply with the safety requirements. Guidance for the use, maintenance and inspection of the fatigue loaded structure should be given in the use and maintenance instructions of the fatigue loaded structure or of the building. Guidance for the use, maintenance and inspection of the fatigue loaded structure should be given to the owner of the structure during the final review.
- d) All structural parts of a fatigue loaded structure, including all connections, should be sufficiently accessible for appropriate inspection and maintenance. The real possibilities for carrying out the required inspections should be taken into account when the partial factors are chosen.

Classified structural details

6.2.1(2), Note 2

The recommended values given in Annex L are followed.

In fatigue loaded structures, defects that reduce fatigue resistance are eliminated in a manner that ensures the design prerequisites pursuant to standard SFS-EN 1999-1-3 are met, or it is ensured that no defects larger than allowed in the design pursuant to standard SFS-EN 1999-1-3 occur.

Prerequisites for design compliant with the damage tolerance principle

A.3.1(1)

See also clause 2.1.1(1)P of this National Annex.

Partial factors γ_{Mf} and values for variable D_{Lim}

L.4(3)P, Note 2

Consequences classes are used pursuant to Table L.2. The selection of the consequences class is presented in the Ministry of Environment Decree 3/16 on the application of standard SFS-EN 1990.

L.4(5)

The value of variable D_{Lim} is limited pursuant to condition (L.5).

Service class

L.5.1(1)

The instructions provided in standards SFS-EN 1999-1-1, SFS-EN 1999-1-3 and SFS-EN 1090-3 are used in the determination of the service class.

Annex H

Improving fatigue strength of welds

Annex H may be used, provided that adequate guidance is provided to guarantee that the execution corresponds adequately well to the methods and ways of execution used in testing.

National Annex to standard SFS-EN 1999-1-4 Part 1-4: Cold-formed structural sheeting

As regards standard SFS-EN 1999-1-4, the recommended values set forth in standard SFS-EN 1999-1-4 and all the annexes to standard SFS-EN 1999-1-4 are followed unless otherwise stated in this National Annex.

National choice is permitted in the following clauses of standard SFS-EN 1999-1-4:

- 2(3)
- 2(4)
- 2(5), Note 1
- 3.1(3)
- 7.3(3)
- A.1(1), Note 2
- A.1(1), Note 3
- A.3.4(3).

A national choice has been made in the clauses marked ●.

Basis of Design

2(5), Note 1

Sheeting structures in structural classes II and III of standard SFS-EN 1999-1-3 are in consequences class CC1. Sheeting structures in structural class I of SFS-EN 1999-1-3 for loads vertical to surface causing bending are in consequences class CC1. However, in structural class sheeting, this does not apply to loads which are induced when sheeting is used to transfer shear forces parallel to the surface of the sheeting (diaphragm action) or normal forces.

General

3.1(3)

Furthermore, the following aluminium alloys pursuant to EN 485-2 may be used: EN AW 3105 temper H19 and EN AW 5754: tempers H12, H14, H16, H26, H36, H18, H28 and H38. Other aluminium alloys and products may be used if their properties and suitability have been reliably analysed.

Deflections

7.3(3)

Deflection limits are given in the National Annex to standard SFS-EN 1999-1-1.

Design values

A.3.4(3)

The partial factor should be determined based on testing according to Annex D of standard SFS-EN 1990. In addition, the rules given in Annex A of SFS-EN 1999-1-4 should be used, if applicable. If only the characteristic value, but not the design model, is determined based on testing, then the recommended values for partial factors γ_M should be used.

National Annex to standard SFS-EN 1999-1-5 Part 1-5: Shell structures

As regards standard SFS-EN 1999-1-5, the recommended values set forth in standard SFS-EN 1999-1-5 and all the annexes to standard SFS-EN 1999-1-5 are followed unless otherwise stated in this National Annex.

The Non-Contradictory Complementary Information (NCCI) is presented in italics.

National choice is permitted in the following clauses of standard SFS-EN 1999-1-5:

- 2.1(3)P
- 2.1(4).

Consequences class and reliability differentiation

2.2(1)

Contains a reference to national rules; however, national choice is not permitted for the clause in question. The National Annex to standard SFS-EN 1990 provides instructions on the selection of the consequences class.