Swedish Regulations for Steel Structures, BSK 99
# CONTENTS

## 0 INTRODUCTION .......... 7

0:1 The formulation and application of the regulations .......... 7

0:2 Symbols and abbreviations ...... 8

0:21 Symbols ................. 8

0:22 Abbreviations .............. 10

0:3 Type approval and production control ..................... 11

0:4 Terminology .............. 11

## 1 SCOPE AND GENERAL REQUIREMENTS .......... 15

1:1 Scope ....................... 15

1:2 General requirements .......... 15

1:21 Requirements in the ultimate limit states ............... 15

1:211 Material failure and instability .. 15

1:212 Tilting, uplift and sliding ....... 16

1:213 Accidental actions and progressive collapse ............ 16

1:214 Safety Classes ............... 16

1:215 Ductility ..................... 17

1:22 Requirements in the serviceability limit states ........ 18

1:221 Deformations and displacements ................. 18

1:222 Oscillations ................. 18

1:23 Durability ..................... 18

1:3 Design by calculation and testing ...................... 21

1:31 Calculation ................. 21

1:4 Documentation ................ 22

1:41 Drawings ..................... 22

1:42 Welding procedure sheet ....... 23

1:43 Erection schedule ............. 24

1:44 Inspection scheme ............ 25

## 2 DESIGN ASSUMPTIONS ...... 27

2:1 Loads ......................... 27

2:11 Fatigue load ................. 27

2:2 Characteristic values .......... 28

2:21 Values for strength .......... 28

2:22 Values for strength in conjunction with fatigue load ... 32

2:23 Modulus of elasticity, shear modulus and Poisson's ratio ... 32

2:24 Bolted connections ........... 33

2:25 Welded connections ........... 33

2:3 Deviations in size and shape .... 34

2:31 Columns ..................... 35

2:32 Beams ....................... 35

2:33 Deviations in cross sectional dimensions ................ 35

## 3 DESIGN IN THE ULTIMATE LIMIT STATES .......... 37

3:1 Scope ......................... 37

3:2 Analytical models for design .......... 37

3:3 Calculation of forces and moments ..................... 38

3:31 Analytical model .............. 38

3:32 Limit state theory ............. 38

3:33 Movement at supports, at points of restraint and in connections .... 39

3:34 Induced forces ................ 39

3:35 Local buckling ................ 39

3:36 Flange curling and shear deformations ................ 39

3:4 Calculation of resistance .......... 40

3:41 Analytical model .............. 40

3:411 Strain distribution .......... 40

3:412 Design conditions for stresses .... 41

3:413 Local reduction in cross section .. 42

3:414 Plastic flow and local buckling .. 42

3:42 Design values of material properties ................ 45

3:43 Stress-strain curve .......... 47

3:44 Residual stresses .......... 48

3:45 Flange curling and shear deformations ........ 48

3:46 Fatigue ............. 50

3:47 Shell structures ............ 50

3:48 Bolted connections ........... 50

3:49 Welded connections ........... 51

## 4 DESIGN IN THE SERVICEABILITY LIMIT STATES ...................... 53

4:1 Scope ......................... 53

4:2 Calculation of deformations and vibrations ............... 53

## 5 DESIGN BY TESTING .......... 55
6 DESIGN METHODS.............57
6:1 Scope ................................... 57
6:2 Calculation of the resistance of structural members .............. 57
6:21 Limiting values of slenderness for parts of the cross section ... 57
6:211 Cross section classes ........................................ 57
6:212 Design methods for different cross section classes ............. 59
6:22 Tensile force ........................................ 60
6:23 Compressive force ........................................ 60
6:231 Initial curvature, initial inclination and load eccentricity....... 61
6:232 Loss of restraint ........................................ 61
6:233 Reduction factor for flexural buckling .......................... 62
6:24 Bending moment ........................................ 65
6:241 Cross sectional classes ........................................ 65
6:242 Shape factors in flexure ........................................ 65
6:243 Moment ........................................ 66
6:244 Lateral torsional buckling .................................... 66
6:25 Axial force and bending moment .................................. 69
6:251 Check on the capacity of the cross section ...................... 70
6:252 Flexural buckling ........................................ 72
6:253 Flexural torsional buckling .................................... 73
6:26 Shear force and concentrated force ................................ 74
6:261 Shear force ........................................ 74
6:262 Web crippling below a concentrated force ........................ 76
6:263 Local compression ........................................ 77
6:27 Torsional moment ........................................ 77
6:271 Pure torsion ........................................ 77
6:272 Combined torsion ........................................ 78
6:273 Torsional moment, shear force and bending moment ............ 78
6:3 Design of welded connections ................................... 79
6:31 Design sections ........................................ 79
6:311 Butt welded connections ........................................ 79
6:312 Fillet welded connections ........................................ 79
6:32 Capacity in the ultimate limit states ............................ 80
6:33 Interaction in connections .................................... 82
6:34 Detailing of welded connections ................................ 82
6:4 Design of bolted connections ................................... 83
6:41 Conditions ........................................ 83
6:42 Calculation of forces ........................................ 83
6:43 The capacity of bolts in the ultimate limit states .................. 85
6:431 Tension ........................................ 85
6:432 Shear ........................................ 85
6:433 Combined tension and shear .................................. 86
6:44 Slip ........................................ 86
6:45 Detailing of connections .................................... 87
6:5 Design with respect to fatigue .................................. 89
6:51 Design principles ........................................ 89
6:511 Calculation of stress range .................................. 89
6:512 Design criteria ........................................ 89
6:52 Characteristic fatigue strength .................................. 90
6:521 General ........................................ 90
6:522 Detail Categories ........................................ 90
6:523 Strength in conjunction with a constant stress range ............ 91
6:524 Design in conjunction with a variable stress range ................ 93
6:525 Fatigue in conjunction with breathing .......................... 96
7 MATERIALS.....................97
7:1 General requirements for materials ................................ 97
7:11 Constructional steels ........................................ 97
7:12 Plates, bars and hollow sections ................................ 97
7:13 Filler metal ........................................ 98
7:14 Materials for bolted connections ................................ 99
7:141 General requirements ........................................ 99
7:142 Bolts and nuts ........................................ 99
7:143 Washers ........................................ 100
7:144 Threaded structural elements ................................ 100
7:2 Ductility ........................................ 101
7:21 Ductility Classes ........................................ 101
7:22 Properties in the thickness direction ............................ 103
7:3 Identification and marking of materials .......................... 104
8 EXECUTION AND WORKMANSHIP .........107
8:1 General ........................................ 107
8:11 Qualifications of the supervisor ................................ 107
8:12 Workmanship Classes .................................... 107
8:13 Cutting Classes .................................... 108
8:14 Welding Classes .................................... 109
8:15 Bolted Connection Classes .................................. 110
8:2 Handling of materials .................................... 111
9:2 Acceptance inspection........140
9:21 Type approved or production
controlled materials and
products..........................140
9:22 Workshop products which are not
production controlled in
accordance with BKR 99,
Clause 1:4......................141
9:221 The competence of the
independent expert............141
9:3 Supervision of construction....141
9:4 Documentation..................141
9:5 The building owner's
responsibilities according to the
Planning and Building Act....142
9:6 Basic inspection ..............143
9:61 Material – not subject to
production control ..........143
9:62 Dimensions and shape.....144
9:63 Welded connections .........145
9:631 Filler metal.....................145
9:64 Bolted connections .........145
9:641 Bolts and nuts ...............145
9:642 Washers in highly preloaded
bolted connections ..........146
9:65 Corrosion protection.......146
9:66 Fire protection coating......146
9:7 Additional inspection .........147
9:71 Structure related inspection
measures.........................147
9:72 Structural elements subject to
tensile forces in the thickness
direction........................148
9:73 Welded connections .........148
9:731 Visual inspection of welds...148
9:732 Non-destructive testing.....149
9:733 Other checks .................150
9:74 Cathodic protection .........150

10 MAINTENANCE ...............151
10:1 Introduction ..................151
10:2 Routine inspection ..........151
10:21 General .....................151
10:22 Structural members .........152
10:23 Welded connections .........152
10:24 Connections comprising
fasteners.........................152
10:25 Corrosion protection .......152
10:26 Frequency of routine
inspections......................153
<table>
<thead>
<tr>
<th>Contents</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:3 Periodic detailed inspection</td>
<td>153</td>
</tr>
<tr>
<td>10:31 General</td>
<td>153</td>
</tr>
<tr>
<td>10:32 Structural members</td>
<td>154</td>
</tr>
<tr>
<td>10:33 Welded connections</td>
<td>154</td>
</tr>
<tr>
<td>10:34 Connections comprising fasteners</td>
<td>154</td>
</tr>
<tr>
<td>10:35 Corrosion protection</td>
<td>154</td>
</tr>
<tr>
<td>10:36 Frequency of periodic detailed inspection</td>
<td>154</td>
</tr>
<tr>
<td>10:4 Actions in the event of defect or damage</td>
<td>155</td>
</tr>
<tr>
<td>10:41 General</td>
<td>155</td>
</tr>
<tr>
<td>10:42 Corrosion protection</td>
<td>155</td>
</tr>
<tr>
<td>10:5 Documentation of maintenance</td>
<td>156</td>
</tr>
</tbody>
</table>

APPENDIX 1
Example of a welding procedure sheet | 157 |

APPENDIX 2
Example of an additional inspection schedule | 161 |

APPENDIX 3
Detail Categories | 165 |

APPENDIX 4
Leak testing | 179 |

APPENDIX 5
Standards | 181 |

LIST OF REFERENCES | 187 |

INDEX | 189 |
INTRODUCTION

0:1 The formulation and application of the regulations

Swedish Regulations for Steel Structures, BSK 99, is part of a series of handbooks published by the Swedish National Board of Housing, Building and Planning (Boverket) as a complement to Boverket's Design Regulations, BKR 99. Other handbooks in this series are

- Swedish Regulations for Concrete Structures (BBK 94) with Supplement 1
- Design by Testing
- Snow Load and Wind Action (BSV 97) and
- Vibrations, Induced Deformation and Accidental Actions

These regulations are intended to be used together with BKR 99 and contain

- extracts from BKR 99. The numbering of equations has, however, been made in accordance with BSK 99.

Extracts from BKR 99 are given within frames.

- comments on the rules in BKR 99, examples of solutions, methods and calculation methods.

The mandatory provisions in BKR 99 are compulsory and apply in full to new buildings. The requirements also apply to additions although sometimes with certain modifications as due regard shall be given to the extent of the additions and the condition of the building. Information on other alterations than additions is given in BÄR 96.

The general recommendations regarding the application of the mandatory provisions in BKR 99 indicate how someone *can or should* act in order to comply with the requirements of the mandatory provisions. The individual is however at liberty to select other technical solutions and methods if these comply with the requirements of the mandatory provisions. The general recommendations may also contain certain explanatory information. The general recommendations are preceded by the phrase General recommendation and are indented and printed in a smaller type immediately after the mandatory provision to which they refer.

Corrections, if any, to this edition will be published on Boverket's website:

http://www.boverket.se
BSK 99 has been prepared by a working group comprising

- Göran Alpsten, StBK Stalbyggnadskontroll
- Johan Anderson, Swedish Institute of Steel Construction
- Ruben Aronsson, Swedish Institute of Steel Construction
- Staffan Boström, Swedish National Rail Administration
- Björn Christensson, Swedish National Rail Administration
- Lars Göransson, Swedish National Board of Housing, Building and Planning (Boverket)
- Bertil Hagstad, Certification Authority for Steel in Building Structures, SBS
- Torsten Höglund, KTH
- Bernt Johansson, LTU
- Robert Ronnebrant, Swedish National Road Administration
- Anders Samuelsson, SSAB
- Agneta Wargsjö, Swedish National Road Administration
- Sture Åkerlund, Swedish National Board of Housing, Building and Planning (Boverket)

In addition, a group under the guidance of the Swedish Corrosion Institute has also participated in the work.

### 0:2 Symbols and abbreviations

#### 0:21 Symbols

Only relatively common symbols are set out below. Other symbols are explained where they occur in the text. The symbols conform to SS-ISO 3898. However, the subscript a, which denotes structural steel, has been omitted.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>Area</td>
</tr>
<tr>
<td>$E$</td>
<td>Modulus of elasticity</td>
</tr>
<tr>
<td>$F$</td>
<td>Force, action</td>
</tr>
<tr>
<td>$G$</td>
<td>Shear modulus</td>
</tr>
<tr>
<td>$I$</td>
<td>Moment of inertia</td>
</tr>
<tr>
<td>$M$</td>
<td>Bending moment</td>
</tr>
<tr>
<td>$N$</td>
<td>Normal force</td>
</tr>
<tr>
<td>$T$</td>
<td>Torsional moment</td>
</tr>
<tr>
<td>$V$</td>
<td>Shear force</td>
</tr>
<tr>
<td>$W$</td>
<td>Section modulus in accordance with the elastic theory</td>
</tr>
</tbody>
</table>
Z  Section modulus or torsional modulus in accordance with the plastic theory
a  Distance, dimension of fillet weld
b  Width
d  Diameter
e  Eccentricity
f  Strength value
fu  Ultimate strength value
fy  Yield strength value
i  Radius of gyration
l, L  Length
n  Number
t  Thickness
α  Angle, ratio
β  Angle, ratio
γ  Partial factor, ratio
γf  Partial factor for load
γm  Partial factor for a material property
γn  Partial factor for Safety Class
ev  Strain (compressive strain)
η  Shape factor
μ  Slenderness ratio
σ  Normal stress
σ1, σ2  Principal stresses
τ  Shear stress
ω  Reduction factor
ωb  Reduction factor in conjunction with lateral torsional buckling
ωc  Reduction factor in conjunction with instability
ωv  Reduction factor in conjunction with shear buckling
**Subscripts:**
- b: Bending, bolt
- c: Compression
- cr: Critical
- d: Design value
- e: Effective
- f1: Flange
- FLS: Fatigue limit state
- gr: Gross
- k: Characteristic value
- net: Net
- r: Stress range
- t: Tension
- u: Ultimate
- ULS: Ultimate limit state
- w: Weld, web of girder
- x, y, z: Coordinate directions
- y: Yield

**0:22 Abbreviations**

- ANSI: American National Standards Institute
- ASNT: American Society for Non-destructive Testing
- ASTM: American Society for Testing and Materials
Type approval and production control

The concepts type approval and production control are used with the definitions given in BKR 99, Clause 1:4.

Terminology

Terms which are not specifically defined in BKR 99 or in these regulations have the meaning set out in Publication No TNC 95, Glossary of Planning and Building Terms 1994.

Breathing is the phenomenon that occurs when initial dents in a slender plate (e.g. the web of a beam) increase and decrease when subjected to a fluctuating load in the plane of the plate.
Capacity is synonymous with loadbearing capacity and is often used in compound terms (e.g. shear capacity, moment capacity). Unless otherwise specified, the term refers to the design value of capacity.

Distortion in a connection in tension is an effect, which occurs when the plates forming part of the connection sustain large deformations. Owing to prying action, distortion gives rise to incremental forces in the bolts.

Ductility Class (Quality Class) Steel is assigned to Ductility Classes A–E, with respect to its ability to resist brittle fracture. Classification is based on the impact strength of the steel determined by a Charpy test.

The effective cross section is a cross section in which one or more cross sectional components are of effective thickness or effective width.

The effective thickness of a slender plane cross sectional component is the reduced thickness which, on the assumption of linear stress distribution, gives rise to the same stiffness or capacity as the actual cross sectional component under non-linear stress distribution conditions. In these regulations, the concept of effective thickness is used to take account of deviations from linear stress distribution due to buckling.

The effective width of a wide plane cross sectional component is the reduced width which, on the assumption of linear stress distribution, gives rise to the same stiffness or capacity as the actual cross sectional component under non-linear stress distribution conditions.

In flange curling, a flange in a beam in flexure is deformed towards the neutral layer.

Independent expert is an inspector who has not been involved in the design or execution of the project in consideration. Such an inspector may be appointed by e.g. the building owner, designer, contractor or fabricator and is then part of the building owner’s control system. An independent expert may in some cases be nominated by the building owner as an independent expert according to PBL, see also Subclause 9:221.

Independent expert according to PBL is an inspector who has not been involved in the design or execution of the project in consideration. The local building committee may require a certificate or undertake an examination of such an inspector if the committee finds that the building owner's production control is not sufficient to meet public requirements for specific parts of the project. The building owner submits a proposal for the position as independent expert and the committee decides whether the proposal is acceptable or not.

A plastic hinge or yield region is a region of limited extent in a structure where a considerable increase in curvature occurs under the action of a substantially constant moment.
Service temperature is, depending on the property to be considered, the lowest or highest temperature that occurs in a structural member during normal service.

A square butt weld is a full penetration weld in a square, single V or double V butt joint.

A T-butt weld is a square butt weld in a T joint with close square, single bevel or double bevel preparation.
1 SCOPE AND GENERAL REQUIREMENTS

1:1 Scope

BKR 99, Section 8

The provisions of this section relate to loadbearing structures of steel (carbon steels, carbon manganese steels, microalloyed steels, quenched and tempered steels, thermomechanically rolled steels, cold forming steels and stainless structural steels).

General recommendation:

Structures of thin gauge cold formed steel sheet, designed, constructed and inspected in accordance with StBK-N5, Swedish Code for Thin Gauge Steel Structures 79, comply with the requirements for loadbearing structures set out in Section 2.

BSK 99 does not cover stainless structural steel. Design methods for loadbearing structures of stainless structural steel are given in SS-ENV 1993-1-4 and the associated NAD(S).

1:2 General requirements

1:21 Requirements in the ultimate limit states

1:211 Material failure and instability

BKR 99, Subclause 2:111

Loadbearing structures shall be designed and detailed so that an adequate degree of safety is provided with respect to material failure and instability in the form of lateral and local buckling, lateral instability and similar during the construction of the structure, its service life and in the event of fire.

General recommendation:

Failure or instability may also occur due to deformations in the supporting ground.
1:212 Tilting, uplift and sliding

*BSR 99, Subclause 2:112*

Buildings and their parts shall be designed and detailed so that an adequate degree of safety is provided with respect to tilting, uplift and sliding.

1:213 Accidental actions and progressive collapse

*BSR 99, Subclause 2:113*

Buildings shall be designed so that the risk of progressive collapse is slight. This may be accomplished by designing and detailing buildings either in such a way that they can withstand accidental actions or in such a way that primary damage is limited. Such damage shall not give rise to progressive collapse and severe destruction in any part of the structure other than the region of primary damage and the region adjoining this.

Special measures need not be taken in buildings in which the risk of serious accidents due to progressive collapse is slight, or in buildings which are so small that primary damage causes total destruction.

General recommendation:

The requirement relating to accidental actions and progressive collapse normally applies only to elements of structure assigned to Safety Class 3. See Boverket’s handbook *Vibration, induced deformation and accidental actions.*

A stairway which constitutes the only escape route in a building shall at all times be designed for accidental actions.

1:214 Safety Classes

*BSR 99, Subclause 2:115*

With regard to the extent of injury to persons which the failure of an element of structure may cause, this shall be assigned to one of the following Safety Classes:

- Safety Class 1 (low), little risk of serious injury to persons,
- Safety Class 2 (normal), some risk of serious injury to persons,
- Safety Class 3 (high), great risk of serious injury to persons.

General recommendation:

In addition to the Safety Class requirement which relates only to injury to persons, the building owner may stipulate more stringent requirements, for instance with respect to property damage.
In selecting the Safety Class, the following principles shall be applied. Elements of structure may be assigned to Safety Class 1 if at least one of the following requirements is complied with:

- persons are present only in exceptional cases in or in the vicinity of the building,
- the element of structure is of such nature that a failure cannot reasonably be expected to cause injury to persons, or
- the element of structure has properties such that a failure does not cause collapse but only loss of serviceability.

Elements of structure shall be assigned to Safety Class 3 if the following conditions simultaneously apply:

- the design and use of the building are such that many persons are often present in or in the vicinity of the building,
- the element of structure is of such nature that collapse involves a high risk of injury to persons, and
- the element of structure has properties such that failure causes immediate collapse.

The classification of other elements of structure shall be not lower than Safety Class 2

In design in the ultimate limit states on the basis of the method of partial factors, the Safety Class for an element of structure shall be taken into consideration by means of the partial factor $n_{\gamma}$ in the way set out below:

- Safety Class 1, partial factor $n_{\gamma} = 1.0$,
- Safety Class 2, partial factor $n_{\gamma} = 1.1$,
- Safety Class 3, partial factor $n_{\gamma} = 1.2$.

In design with respect to

- fire, and
- accidental actions and the risk of progressive collapse, the value of $n_{\gamma}$ may be put equal to 1.0 irrespective of Safety Class.

One condition which must be complied with in order that the above values of the partial factor $n_{\gamma}$ in Safety Classes 2 and 3, as set out in Subsection 2:115, shall be applicable is that a design check is carried out.

**Ductility**

Steel structures shall be designed, detailed and constructed so that they have ductility properties such that a rapid increase in stress or a local stress concentration does not cause failure of the structure.

General recommendation:

The requirement concerning ductility may be considered to have been complied with if the structure is made of materials of properties in accordance with Subclauses 7:21 and 7:22 of *Swedish Regulations for Steel Structures BSK 99*. 
1:222  Requirements in the serviceability limit states

*BKR 99, Subclause 2:12*

General recommendation:

In addition to requirements specified in the serviceability limit states, which primarily relate only to safety and health, the building owner may stipulate more stringent requirements, for instance with respect to appearance and comfort.

If there are no other requirements, then, in design using a probabilistic method substantially in accordance with ISO 2394-1998, *General Principles on the Reliability for Structures*, the risk that the serviceability limit states will be exceeded may be put at $\beta = 1.3 – 2.3$ depending on the type of serviceability limit state.

Calculation of deformations and oscillations may be performed in accordance with the elastic theory using an analytical model which gives a reasonable description of the stiffness, mass, damping and boundary conditions of the construction.

1:221  Deformations and displacements

*BKR 99, Subclause 2:121*

Elements of structure and their supports shall have such stiffness that deformations or displacements of the element of structure, when used as intended, do not adversely affect its function or damage other elements of structure. Apart from the immediate deformation when an action is applied, consideration shall also be given to the effect of

– the duration of, and variations in, the action,
– the environment of the element of structure, including temperature and humidity, and
– the long-term properties of the material.

1:222  Oscillations

*BKR 99, Subclause 2:122*

Elements of structure shall be designed so that oscillations which occur do not cause inconvenience.

1:23  Durability

*BKR 99, Subclause 2:13*

Elements of structure and materials in loadbearing structures shall either be durable, or it shall be possible for them to be protected and maintained, so that the requirements in the ultimate and serviceability limit states are complied with during the service life of the building.
**BKR 99, Subclause 2:13 (continuation)**

If permanent protection is not possible, consideration shall be given during design to the expected changes in properties, or the structure shall be designed so that the affected parts are accessible for recurrent protective treatment.

General recommendation:

The term service life refers to the time assumed in design during which a structure which receives normal maintenance exhibits the required degree of serviceability. Unless some other values can be shown to be more correct, the design service life of structures in Safety Classes 2 and 3 should be not less than

- 50 years for structural elements which are accessible for inspection and maintenance, and
- 100 years for structural elements which are not accessible for inspection and maintenance.

The design service life of structures is the assumed average service life.

---

**BKR 99, Subclause 8:12**

Steel structures shall be designed, detailed and constructed with due regard to the risk of corrosion, wear and similar phenomena.

General recommendation:

Provisions regarding corrosion protection are set out in Subsection 8:56.

---

With regard to the corrosive aggressivity of the surroundings a structural element of steel may normally be assigned to one of the Corrosivity Categories C1–C5-M or Im1–Im3 according to Table 1:23a–b. Reference values for the average loss of mass for steel and zinc are given in Table 1:23c. The Corrosivity Categories are in accordance with the classes given in SS-EN ISO 12944-2.

Information on the protection of steel structures against corrosion is given in Clause 8:7. The main principles of the Building Act regarding maintenance and appropriate maintenance schemes are given in Section10.
**Table 1:23a**  
Corrosivity Categories in accordance with  
SS-EN ISO 12944-2, with regard to atmospheric corrosivity and examples of typical environments

<table>
<thead>
<tr>
<th>Corrosivity Category</th>
<th>Corrosivity of Environment</th>
<th>Examples of typical environments in a temperate climate (informative only)</th>
<th>Exterior</th>
<th>Interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Very low</td>
<td>Heated premises in dry air and with an insignificant level of pollution, e.g. office buildings, shops, schools, hotels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>Low</td>
<td>Unheated premises with changeable temperature and humidity. Infrequent condensation and a low level of air pollution, e.g. sports halls, depots.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>Medium</td>
<td>Premises with moderate humidity and a low level of air pollution from processing plants, e.g. breweries, dairies, laundries.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>High</td>
<td>Premises with high humidity and a high level of air pollution from processing plants, e.g. chemical plants, swimming pools, ship- and boatyards.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C5-I</td>
<td>Very high (Industrial)</td>
<td>Premises with almost permanent condensation and with a high level of air pollution.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C5-M</td>
<td>Very high (Marine)</td>
<td>Premises with almost permanent condensation and with a high level of air pollution.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 1:23b**  
Corrosivity Categories for water and soil and examples of typical environments

<table>
<thead>
<tr>
<th>Corrosivity Category</th>
<th>Environment</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Im1</td>
<td>Fresh water</td>
<td>Hydro-electric power plants</td>
</tr>
<tr>
<td>Im2</td>
<td>Sea or brackish water</td>
<td>Harbour constructions, such as jetties, locks</td>
</tr>
<tr>
<td>Im3</td>
<td>Soil</td>
<td>buried tanks, steel pipes</td>
</tr>
</tbody>
</table>
### Table 1.23c  Mass loss for steel and zinc in different corrosivity categories

<table>
<thead>
<tr>
<th>Corrosivity Category</th>
<th>Mass loss per unit of area and reduction of thickness (one year exposure)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mass loss (g/m²)</td>
</tr>
<tr>
<td>Steel</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>≤ 10</td>
</tr>
<tr>
<td>C2</td>
<td>&gt; 10 to 200</td>
</tr>
<tr>
<td>C3</td>
<td>&gt; 200 to 400</td>
</tr>
<tr>
<td>C4</td>
<td>&gt; 400 to 650</td>
</tr>
<tr>
<td>C5-I</td>
<td>&gt; 650 to 1500</td>
</tr>
<tr>
<td>C5-M</td>
<td>&gt; 650 to 1500</td>
</tr>
</tbody>
</table>

1 Generally, the rate of corrosion is higher in the beginning of the exposure.

---

### 1:3  Design by calculation and testing

**BK 99, Clause 2:3**

Design shall be carried out by calculation, testing or some combination of these. However, calculation and testing are not required if this is obviously unnecessary.

A finished structure has sufficient stiffness and robustness when swaying (oscillations), excessive cracking, deformations and similar occur only to an insignificant extent.

Sections 2–6 assume that verification is carried out by calculation in accordance with the partial factor method. However, where relevant, a probabilistic method may be used as an alternative.

---

### 1:31  Calculation

**BK 99, Subclause 2:31**

Calculations shall be based on an analytical model which gives a reasonable description of the behaviour of the structure in the limit states concerned. The selected analytical model and the input parameters shall be documented.

If a certain calculation method has a high degree of uncertainty, this shall be taken into consideration. Imposed forces shall be calculated in view of the behaviour of the structure in the limit state concerned.
General recommendation:
- the resilience of supports, end restraints, stiffeners and bracings,
- incremental forces and moments due to deformations,
- action eccentricities,
- interaction between structures/elements of structures, and
- temporal effects.

**1:4 Documentation**

**BKR 99, Subclause 2:34**

Loadbearing structures shall be documented on drawings and in other documents in such a way that a check can be made that the requirements concerning resistance, stability and durability have been complied with.

**1:41 Drawings**

Drawings for a steel structure should contain the following:

- **a)** Information regarding the regulations which apply for design and execution, and information regarding the Safety Class.

- **b)** Information regarding load assumptions and the intended service life (see Subclause 1:23). This information can often be given by reference to the appropriate clause in *BKR 99*.

- **c)** Information regarding Corrosivity Category in accordance with Table 1:23a–c.

- **d)** Information regarding parent material concerning
  - strength,
  - ductility properties.
  
  This information can often be given by reference to the appropriate standard.

- **e)** Information regarding Workmanship Class and Cutting Class.
f) Information regarding welded connections, comprising
   – weld quality,
   – weld type,
   – heat treatment and preparation, if any,
   – data governing the choice of electrode type.

   Information regarding weld quality and weld type should be given on the basis of SS–ISO 5817 supplemented with Table 8:14 for weld quality and SS–ISO 2553 for welding symbols.

g) Information regarding faying surfaces which are assumed to transmit compressive force in bearing (see Subclause 8:63).

h) Information regarding bolted connections, comprising
   – class of bolted connection,
   – the strength and dimensions (diameter and length) of bolts and nuts,
   – the placing of bolts,
   – preparation, if any, of contact surfaces in the connection.

i) Information regarding dimensions for fabrication and for erection at the reference temperature. The reference temperature is +20°C for structures in heated spaces and, unless otherwise is specified, +5°C in all other cases.

j) Information regarding tolerances for dimensions where deviations are of essential significance for the loadbearing capacity and performance of the structure.

k) Information regarding corrosion protection or other measures taken with regard to the risk of corrosion.

l) Information regarding Fire Resistance Class, where relevant.

m) Reference to an erection schedule.

n) Information regarding measures required for basic inspection and additional inspection. This information can be given by reference to Section 9 and to the inspection scheme in accordance with Subclause 1:44 respectively.

1:42 **Welding procedure sheet**

*BSK 99, Subclause 8:532*

A welding procedure sheet shall be drawn up for welding. An exception may be made for simple work of routine character.
General recommendation:

The person who directs and supervises welding should draw up the welding procedure sheet in consultation with the designer.

In conjunction with welding of a complicated nature for which practical experience is not available, welding tests should be carried out before the welding procedure sheet is drawn up.

Examples of what a welding procedure sheet should contain are given in Subclause 1:42 of BSK 99.

Welding of routine character may be work of which the fabricator has extensive practical experience regarding e.g. the welding process, the design of the structure and the joint, filler metal and welding parameters.

The welding procedure sheet should contain appropriate data concerning

a) welding process

b) joint type and joint preparation

c) welding position and welding sequence

d) type and dimension of filler metal

e) welding parameters in conjunction with mechanised welding

f) measures required before, during and after welding, e.g. raised working temperature

g) temporary welds which are not specified on drawings but are necessary with regard to fabrication, handling, transport or erection (e.g. clips, supporting plates, hoisting devices) and whether or not and how these should be removed.

Some of the information in the welding procedure sheet may e.g. be given by reference to Welding Procedure Specifications (WPS) attached to the welding procedure sheet.

An example of a welding procedure sheet is given in Annex 1.

**Erection schedule**

Erection shall be carried out in accordance with an erection schedule. Work shall not begin until an erection schedule is available.

General recommendation:

The person who directs and supervises erection should draw up the erection schedule in consultation with the designer.

Examples of what an erection schedule should contain are given in Subclause 1:43 of BSK 99.
The erection schedule should contain appropriate data concerning

a) erection sequence

b) provision of temporary connections

c) provision of temporary braces and anchorages

d) required erection scaffolds

e) the position and provision as necessary of lifting points

1:44 Inspection scheme

BKR 99, Subclause 2.621, fourth paragraph

A scheme shall be drawn up for additional inspection.

The scheme should specify the method and scope of inspection for the relevant structural element, see Section 9.

An example of an inspection scheme is given in Annex 2.
2 DESIGN ASSUMPTIONS

BKR 99, clause 2:5, first paragraph

A structure shall

…
– be designed so that a good standard of workmanship is made possible and so that the stipulated maintenance can be carried out

…

A structure should, for instance, be given such dimensions that the space is sufficient for welding, surface finish and normal maintenance painting to be carried out with satisfactory results. Detailing of structures which are intended to be protected against corrosion with a protective coating should comply with the highest performance in SS–EN 12944-3 and follow the advice and directions given in Handbook for protective painting, Chap. 2.

2:1 Loads

2:11 Fatigue load

BKR 99, Subclause 2:21, fourth–sixth paragraphs

Actions which have so many variations that fatigue failure may occur shall be regarded as fatigue actions.

General recommendation:

– Dynamic actions imposed by moving parts of machinery,
– Wind action if the effect of gusts or vortex shedding is significant.

The actions imposed by cranes, overhead cranes and other materials handling equipment may be fatigue actions.

BKR 99, Subclause 8:21

A decision is to be made in each individual case whether actions other than those referred to in Subclause 2:21 are to be regarded as fatigue actions.

An action which gives rise to fewer than $10^3$ stress cycles during the service life of the structure need not be regarded as a fatigue action.

Regarding fatigue loads from vehicles on public roads and streets which may have impact on structural elements, see BRO 94, 21.2226.
2:2 Characteristic values

**BKR 99, Subclause 2:22, second paragraph**

The characteristic values for the strength properties of a material and for those deformation properties which affect the resistance shall be put at the lower 5% fractile unless some other value is specified in the section relating to the material concerned. For deformation properties which have no effect on resistance, the 50% fractile shall be taken.

**BKR 99, Subclause 8:22**

The basic values of strength and other properties which are set out in this subsection presuppose materials which comply with the requirements for materials in Clause 8:4.

The basic values apply for structures with a service temperature within the range –40°C to 100°C.

2:21 Values for strength

**BKR 99, Subclause 8:221**

For general structural steel, the characteristic values, \( f_{yk} \) for the upper yield strength or 0.2\% proof strength, and \( f_{uk} \) for the ultimate tensile strength, shall be taken from tables (a) – (e) below.

General recommendation:

Corresponding designations according to SS-EN 10 002-1 are \( R_{eH} \), \( R_{p0.2} \) and \( R_m \) respectively. SS-ISO 3898 uses the designation \( f_{y,\text{sup}} \) for the upper yield stress.

The required minimum value \( f_{yk} \) is approximately equal to the 0.01 fractile.

Information regarding conditions and restrictions, if any, for the use of standardised steel are given in Swedish National Application Documents, NAD(S), with reference to the relevant edition of the standard in question.

The fact that the characteristic value for \( f_{yk} \) is approximately equal to the 0.01 fractile rather than the normal 0.05 fractile has been taken into consideration when determining the partial factors.
### Table 2:21a  Characteristic strength values of steels in accordance with SS-EN 10 025+A1, hot rolled products of non-alloy structural steels

<table>
<thead>
<tr>
<th>SS-EN 10 025+A1</th>
<th>Material thickness (mm)</th>
<th>Characteristic strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductility Class (Quality Class)</td>
<td></td>
<td>$f_{uk}$ (MPa)</td>
</tr>
<tr>
<td>B</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– 16</td>
<td>340</td>
</tr>
<tr>
<td></td>
<td>(16) – 40</td>
<td>340</td>
</tr>
<tr>
<td></td>
<td>(40) – 100</td>
<td>340</td>
</tr>
<tr>
<td>S235JRG2</td>
<td>S275J2G3</td>
<td>– 16</td>
</tr>
<tr>
<td></td>
<td>(16) – 40</td>
<td>410</td>
</tr>
<tr>
<td></td>
<td>(40) – 63</td>
<td>410</td>
</tr>
<tr>
<td></td>
<td>(63) – 80</td>
<td>410</td>
</tr>
<tr>
<td></td>
<td>(80) – 100</td>
<td>410</td>
</tr>
<tr>
<td>S275JR</td>
<td>S355J2G3</td>
<td>– 16</td>
</tr>
<tr>
<td></td>
<td>(16) – 40</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td>(40) – 63</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td>(63) – 80</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td>(80) – 100</td>
<td>490</td>
</tr>
<tr>
<td>S355J0</td>
<td>S355J2G3</td>
<td>– 16</td>
</tr>
<tr>
<td></td>
<td>(16) – 40</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td>(40) – 63</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td>(63) – 80</td>
<td>490</td>
</tr>
<tr>
<td></td>
<td>(80) – 100</td>
<td>490</td>
</tr>
</tbody>
</table>

### Table 2:21b  Characteristic strength values of steels in accordance with SS-EN 10 113, hot-rolled products in weldable fine grain structural steels

<table>
<thead>
<tr>
<th>SS-EN 10 113</th>
<th>Material thickness (mm)</th>
<th>Characteristic strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductility Class (Quality Class)</td>
<td></td>
<td>$f_{uk}$ (MPa)</td>
</tr>
<tr>
<td>D</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>S355N</td>
<td>S355NL</td>
<td>– 16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(16) – 40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(40) – 63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(63) – 80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(80) – 100</td>
</tr>
<tr>
<td>S355M</td>
<td>S355ML</td>
<td>– 16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(16) – 40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(40) – 63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(63) – 80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(80) – 100</td>
</tr>
<tr>
<td>S420M</td>
<td>S420ML</td>
<td>– 16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(16) – 40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(40) – 63</td>
</tr>
<tr>
<td>S460M</td>
<td>S460ML</td>
<td>– 16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(16) – 40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(40) – 63</td>
</tr>
</tbody>
</table>
Table 2:21c  Characteristic strength values of steels in accordance with SS-EN 10 137, plates and wide flats made of high yield strength structural steels in the quenched and tempered or precipitation hardened conditions

<table>
<thead>
<tr>
<th>SS-EN 10 137</th>
<th>Material thickness (mm)</th>
<th>Characteristic strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductility Class (Quality Class)</td>
<td></td>
<td>$f_{uk}$ (MPa)</td>
</tr>
<tr>
<td>D</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>S460QL</td>
<td>S460QL1</td>
<td>– 50 (50) – 100</td>
</tr>
<tr>
<td>S500QL</td>
<td>S500QL1</td>
<td>– 50 (50) – 100</td>
</tr>
<tr>
<td>S550QL</td>
<td>S550QL1</td>
<td>– 50 (50) – 100</td>
</tr>
<tr>
<td>S620QL</td>
<td>S620QL1</td>
<td>– 50 (50) – 100</td>
</tr>
<tr>
<td>S690QL</td>
<td>S690QL1</td>
<td>– 50 (50) – 100</td>
</tr>
</tbody>
</table>

Table 2:21d  Characteristic strength values of steels in accordance with SS–EN 10 149, hot-rolled flat products made of high yield strength steels for cold forming

<table>
<thead>
<tr>
<th>SS-EN 10 149</th>
<th>Material thickness (mm)</th>
<th>Characteristic strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductility Class (Quality Class)</td>
<td></td>
<td>$f_{uk}$ (MPa)</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S355MC</td>
<td>1.5 – 20</td>
<td>430</td>
</tr>
<tr>
<td>S420MC</td>
<td>1.5 – 20</td>
<td>480</td>
</tr>
<tr>
<td>S500MC</td>
<td>1.5 – 20</td>
<td>550</td>
</tr>
</tbody>
</table>
### Table 2:21e  Characteristic strength values of steels in accordance with SS–EN 10 210, hot finished structural hollow sections of non-alloy and fine grain structural steels

<table>
<thead>
<tr>
<th>SS-EN 10 210 Ductility Class (Quality Class)</th>
<th>Material thickness (mm)</th>
<th>Characteristic strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>D</td>
</tr>
<tr>
<td>S235JRH</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
<tr>
<td>S355J2H</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
<tr>
<td>S355NH</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
<tr>
<td>S355NLH</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
</tbody>
</table>

### Table 2:21f  Characteristic strength values of steels in accordance with SS–EN 10 219, cold formed structural hollow sections of non-alloy and fine grain steels

<table>
<thead>
<tr>
<th>SS–EN 10 219 Ductility Class (Quality Class)</th>
<th>Material thickness (mm)</th>
<th>Characteristic strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>D</td>
</tr>
<tr>
<td>S235JRH</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
<tr>
<td>S275J2H</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
<tr>
<td>S355NH</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
<tr>
<td>S355MH</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
<tr>
<td>S420MH</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
<tr>
<td>S460MH</td>
<td>–16</td>
<td>(16) – 40</td>
</tr>
</tbody>
</table>
Table 2:21g Characteristic strength values of steels in accordance with SS-EN 10 155, structural steels with improved atmospheric corrosion resistance

<table>
<thead>
<tr>
<th>SS–EN 10 155 Ductility Class (Quality Class)</th>
<th>Material thickness (mm)</th>
<th>Characteristic strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>S355J0WP1</td>
<td>S235J0W</td>
<td>S235J2W</td>
</tr>
<tr>
<td>S355J0W</td>
<td></td>
<td>– 16 (16) – 40 (40) – 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>340 340 235</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– 16 (16) – 40 (40) – 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>490 490 355</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– 16 (16) – 40 (40) – 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>490 490 355</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– 16 (16) – 40 (40) – 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>490 490 355</td>
</tr>
</tbody>
</table>

1 Requirements regarding impact strength should be verified by testing.

2 This value only applies to sectional members.

2:22 Values for strength in conjunction with fatigue load

*BKR 99, Subclause 8:222*

The mechanical properties in conjunction with fatigue action shall be determined with regard to the magnitude and number of stress variations, the effect of notches, and workmanship.

The characteristic fatigue strength selected shall be such that it is not greater than the mean value less twice the standard deviation obtained in fatigue tests on test specimens of the same detailing and notch action.

See also Clause 6:5.

2:23 Modulus of elasticity, shear modulus and Poisson's ratio

*BKR 99, Subclause 8:223*

Unless other values are shown to be more correct, the characteristic values $E_k$ for the modulus of elasticity and $G_k$ for the shear modulus shall be put equal to 210 GPa and 81 GPa respectively.
In structures which presuppose interaction between steel and concrete, the modulus of elasticity of the reinforcement may be given the same characteristic value as that applicable for the structural steel.

General recommendation:
The value of Poisson's ratio may be put equal to 0.3 in the elastic state and to 0.5 in the plastic state.

### 2:24 Bolted connections

BKR 99, Subclause 8:224
The design of bolted connections shall be based on the characteristic values $f_{\text{buk}}$ of the ultimate strength of the bolts in accordance with table (a) below.

<table>
<thead>
<tr>
<th>Designation</th>
<th>$f_{\text{buk}}$ (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt 4.6</td>
<td>400</td>
</tr>
<tr>
<td>Bolt 8.8</td>
<td>800</td>
</tr>
<tr>
<td>Bolt 10.9</td>
<td>1000</td>
</tr>
</tbody>
</table>

Bolt 4.6 is not normally used in steel structures.

### 2:25 Welded connections

BKR 99, Subclause 8:225
General recommendation:
In welded structures, special attention should be paid to the carbon equivalent.

Design of welded connections shall be based on the following:
- For weld metal derived from standardised consumable electrodes, the characteristic strength $f_{\text{euk}}$ shall be put equal to the ultimate strength ($R_m$).
- For weld metal derived from consumable electrodes which are not standardised, $f_{\text{euk}}$ shall be put equal to the nominal minimum value of the ultimate strength according to the manufacturer's documentation.

General recommendation:
The strength properties of non-standardised electrodes should be checked in accordance with Swedish Standard SS 06 01 01 or SS 06 01 11.
Standardised consumable electrodes can be found in SS-EN 499 and SS-EN 757 for covered electrodes, SS-EN 758 for tubular cored electrodes, SS-EN 440 for wire electrodes for MIG/MAG and SS–EN 756 for wire electrodes for submerged arc welding. See also Subclause 7:13.

Table 2:25 Examples of electrodes in conformity with Standards

<table>
<thead>
<tr>
<th>Characteristic strength, ( f_{\text{eq}} ) (MPa)</th>
<th>Yield strength (MPa)</th>
<th>Ductility Class</th>
<th>Electrodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>440</td>
<td>355</td>
<td>C</td>
<td>EN 499–E 35 0</td>
</tr>
<tr>
<td>440</td>
<td>355</td>
<td>E</td>
<td>EN 499–E 35 4 B</td>
</tr>
<tr>
<td>500</td>
<td>420</td>
<td>D</td>
<td>EN 499–E 42 2 B</td>
</tr>
<tr>
<td>500</td>
<td>420</td>
<td>E</td>
<td>EN 499–E 42 4 B</td>
</tr>
<tr>
<td>690</td>
<td>620</td>
<td>E</td>
<td>EN 757–E 62 4 B</td>
</tr>
</tbody>
</table>

2:3 Deviations in size and shape

BKR 99, Subclause 2:23

Deviations in size and shape shall be taken into consideration in design if they are of significance in verifying that the requirements in the ultimate and serviceability limit states have been complied with. The dimensional deviations of individual elements of structure and the structure as a whole may be considered separately.

The deviations may be taken into consideration by calculating the forces and moments on the assumption that the deviations are equal to at least the tolerances specified on drawings or in specifications. Alternatively, the deviations may be taken into consideration by calculating the capacity using methods which take account of the effects of deviations in size and shape, see Clause 6:2.

Examples of deviations in size and shape which are of essential significance for the loadbearing capacity are

- curvature of columns and braces,
- warping and buckling in flange and web plates, and
- other similar deviations which are of significance in design in accordance with second order theory.

Deviations in the span of girders, columns and braces are normally of negligible effect, provided that they do not give rise to substantial induced forces.
2:31 Columns

*BKR 99, Subclause 8:226*

In designing columns and other similar elements of structure in compression which have normal fabrication and erection tolerances, the deviations from size and shape shall be taken into consideration.

General recommendation:

These deviations should be taken into consideration as set out below unless a special investigation shows that some other method is more correct:

– The structure is assumed to have an unintended initial curvature and initial inclination in the direction of deflection under consideration.
– The initial curvature is expressed as the greatest distance $e_0$, between the real and theoretical system lines. The curvature is assumed to be sinusoidal or parabolic, with the deviation $e_0 = 0.0015l$ where $l$ denotes the length of the column. For parts of a longer structure the same rules may be applied.
– The initial inclination for an element of structure which does not interact with others is assumed to be 0.005. If a number of elements interact, the initial inclination may be assumed to be smaller.
– The effect due to unintended load eccentricity may be assumed to have been allowed for by the assumption regarding initial curvature.

Values of tolerances greater than those normally specified for fabrication and erection may be applied. In such cases, correspondingly larger values shall also be used in the design assumptions.

2:32 Beams

Deviations in size and shape in the case of beams in flexure should be taken into account by basing calculation on an assumed least initial curvature and least initial buckling in accordance with the tolerance values given in Figure 8:62. When tolerance values are larger, these should be adopted as calculation assumptions.

2:33 Deviations in cross sectional dimensions

Examples of deviations in size which may be of essential significance for the loadbearing capacity are:

– deviations in cross sectional dimensions,
– deviations in the placing of bolts,
– deviations in the throat thickness of welds.

Deviations in cross sectional dimensions may be considered to have been allowed for in the design values for strength and for the modulus of elasticity in accordance with Subclause 3:42, provided that the specified tolerances do not exceed the values given in Subclause 7:12. If larger tolerances are specified, the effect of deviations should be taken into account by calculating forces and moments, and capacity, on the basis of a reduced cross section.
The dimensions of this reduced cross section are obtained by deducting from the nominal dimensions the difference between the specified tolerances and those given in Subclause 7:12.

Deviations in the throat thickness of welds or the placing of bolts, which meet the requirements in SS–ISO 5817 and *Tolerances for steel structures*, publication 112, Swedish Institute of Steel Construction (1992) respectively, are taken into account in the design methods given in Clauses 6:3 and 6:4.
3 DESIGN IN THE ULTIMATE LIMIT STATES

3:1 Scope

The rules in this chapter apply for structural elements such as beams, columns, braces, frames, arches, trusses, shells, panels etc of normal type and of normal cross sectional shapes and details. It is assumed that the structural members are made of steel with strength values within the limits given in Subclause 2:21, Tables (a)–(g).

For other cases, reference is to be made to the literature, or design is to be carried out by testing in accordance with Design by testing.

3:2 Analytical models for design

BKR 99, Subclause 2:31

Calculations shall be based on an analytical model which gives a reasonable description of the behaviour of the structure in the limit states concerned. The selected analytical model and the input parameters shall be documented.

If a certain calculation method has a high degree of uncertainty, this shall be taken into consideration. Imposed forces shall be calculated in view of the behaviour of the structure in the limit state concerned.

General recommendation:

- Examples of factors which should be taken into consideration are
  - the resilience of supports, end restraints, stiffeners and bracings,
  - incremental forces and moments due to deformations,
  - action eccentricities,
  - interaction between structures/elements of structures, and
  - temporal effects.
3:3 **Calculation of forces and moments**

3:31 **Analytical model**

*BKR 99, Subclause 8:311, first paragraph*

The analytical model shall pay special attention to the effect of the following factors unless their effect has negligible significance for the results:
- local buckling,
- flange curling and shear deformations.

*BKR 99, Subclause 8:3122, first paragraph*

In conjunction with fatigue action, the effects of actions shall be calculated by the elastic theory.

3:32 **Limit state theory**

*BKR 99, Subclause 8:311, second paragraph*

If the limit state theory is applied in calculating forces and moments, the structure shall be designed so that its deformation capacity is sufficiently large for the intended distribution of forces and moments to be attained.

General recommendation:

Examples of the way in which this deformation requirement can be satisfied are given in Subclause 3:32 of *BSK 99*.

The deformation capacity may be considered to be sufficiently large if the following conditions are met:

- The structure is made of steel in Ductility Class B or better and has also in other respects appropriate mechanical properties. This condition may be considered to be satisfied for the steels given in Subclause 2:21, Tables (a)–(g), with the exception of SS-EN 10137-2 – S690QL, S690QL1 and SS-EN 10149-2 – S500MC.

- Within the assumed yield regions, local buckling, a reduced cross section (see Subclause 3:413) or the capacity of a connection is not critical for the resistance of the structure.

- The structure is designed so that flexural or lateral torsional buckling, for a deformation smaller than that corresponding to the intended distribution of forces and moments, does not cause a reduction in the resistance of the structure. Actions due to deformation are also taken into account during design.

For steels SS–EN 10137-2 – S690QL, S690QL1, and SS–EN 10149-2 – S500MC and for steels other than those in Subclause 2:21, Tables (a)–(g), a
special investigation may verify that the mechanical properties are suitable for application of the limit state theory. For steels of the same type as those in Subclause 2:21, Tables (a)–(g), this assessment may be made by comparing the properties of the steel concerned with the properties of one or more of the steels in the tables.

When the limit state theory is applied, a check should be made to ensure that loads lower than the design load cannot cause the structure to fail owing to the distribution of forces and moments being different from that which applies in conjunction with the design load.

3:33 Movement at supports, at points of restraint and in connections

If a structural system is not subjected to fatigue loading and if restraint between different structural members in the system is not necessary in order that the calculated resistance should be attained, the effect of restraint may be ignored in calculating forces and moments. This applies, for example, in the case of trusses.

3:34 Induced forces

The effect of induced forces may be calculated for the same cross section as that used in calculating forces and moments due to external loads. If the conditions according to Subclause 3:32 for the application of the limit state theory are met, the effect of induced forces may be ignored in the ultimate limit states, even if calculation of moments is otherwise carried out in accordance with elastic theory.

3:35 Local buckling

In calculating forces and moments, the effect of a reduction in stiffness due to local buckling may be taken into account in accordance with K18, Subclauses 18:23 and 18:34. If the effect of local buckling on the capacity of the member is negligible in accordance with Subclause 3:414, the effect of buckling may also be ignored in calculating forces and moments.

3:36 Flange curling and shear deformations

Regarding the effects of flange curling and shear deformations in flanges see K18, Clause 18:7.
3:4  Calculation of resistance

3:41  Analytical model

BKR 99, Subclause 8:312, first paragraph

A model for calculation of the resistance shall pay special attention to the following:
– the effect of local buckling,
– the effect of flange curling and shear deformations.

The favourable effect of plastic flow may, under certain conditions, be utilised in the calculation, see Subclause 3:414.

In calculating the loadbearing capacity by analysis of the stability of structural systems and individual structural members, the analysis should be based on the following:
– design conditions regarding material properties in accordance with Sections 2 and 3,
– design conditions regarding deviations in size and shape in accordance with Clause 2:3,
– calculation of internal forces and moments in accordance with Clause 3:3 by means of second order theory, and
– calculation of resistance with regard to internal forces in accordance with Clause 3:4.

In analysing, for example, a frame system, the same design conditions should apply for the determination of forces and moments as for the determination of resistance. If, in calculating the resistance, it is assumed that plastic flow will occur in the cross section, the effect of plastic flow on the stiffness and deformation properties of the frame system must be taken into account.

Simplified methods for the analysis of frame systems are given in K18, Subclauses 18:55 and 18:56.

3:411  Strain distribution

In calculating the resistance with respect to internal forces in the ultimate limit states, the strains in every cross section should be assumed to have a distribution that is continuous and corresponds to a stress distribution which satisfies the equilibrium conditions.

In calculations, special attention should be paid to the fact that originally plane cross sections in many cases do not remain plane after deformation, or that the shape of the cross section is changed owing to the deformation. Normally, however, strain may be assumed to be linear within each originally plane part of a structural member, e.g. a plane web or a plane flange in a beam, with the exception of the following cases:
– in the vicinity of concentrated forces and reductions in the cross section,
– in conjunction with flange curling,
– in conjunction with shear deformations in a flange,
– if local buckling occurs.

In Figures 3:411a–d examples are given of the relationship between deformation and strain distribution for some common cases.

a) shows a case with plane strain distribution.

b) shows a case where the load acts outside the shear centre and causes the beam to twist, which may give rise to warping of the cross section.

c) and d) show two cases where the cross section does not retain its shape on being deformed and the strain distribution is not plane. The effect of this is normally negligible, unless the wall thickness is small in relation to the width of the different parts of the cross section.

Figure 3:411a–d Examples of the relationship between deformation and strain distribution for a simply supported beam subjected to a uniformly distributed load.

3:412 Design conditions for stresses

In calculating resistance with regard to internal forces, the following conditions for the stresses should be satisfied unless it is shown by a separate investigation that some other condition is applicable. The conditions need not be checked if the calculation is carried out in accordance with the methods given in Section 6.

Uniaxial state of stress

The following condition should apply in conjunction with a uniaxial state of stress:

$$|\sigma| \leq f_{yd}$$  \hspace{1cm} (3:412a)
Where there is a local reduction in cross section in accordance with Subclause 3:413, expression 3:412a may be replaced by the following condition:
\[ |\sigma| \leq f_{ud} \quad (3:412b) \]

**Biaxial state of stress**

The following condition applies in conjunction with a biaxial state of stress:
\[ \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2} \leq \alpha f_{yd} \quad (3:412c) \]

Where there is a local reduction in cross section in accordance with Subclause 3:413, expression 3:412c may be replaced by the following condition:
\[ \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2} \leq f_{ud} \quad (3:412d) \]

If \( \sigma \) and \( \tau \) are calculated in accordance with the elastic theory, \( \alpha \) in formula 3:412c may be put equal to 1.1. If the calculation is carried out in accordance with the plastic theory, the value of \( \alpha \) is 1.0.

In expressions 3:412c and d, \( \sigma_x \) and \( \sigma_y \) are normal stresses and \( \tau \) shear stresses in relation to an arbitrarily selected system of coordinates \( x, y \).

**Triaxial state of stress**

In conjunction with a triaxial state of stress, the design condition should be determined by a special investigation.

**3:413 Local reduction in cross section**

In regions where the cross section is locally reduced, for example by bolt holes or recesses, it is permissible for the yield stress of the material to be exceeded and for yield to occur locally, on condition that the consequent deformations do not cause major interference with the performance of the structure.

The effect on capacity due to local reductions in cross section may thus be taken into account by determining the capacity on the basis of the net cross section selected in the most unfavourable manner and on the basis of \( f_{ud} \).

When the limit state theory is applied, within a yield region the capacity of a locally reduced cross section, calculated on the basis of \( f_{ud} \), should be greater than the capacity of the gross cross section calculated on the basis of \( f_{yd} \).

**3:414 Plastic flow and local buckling**

The favourable effect of plastic flow may be allowed for in calculating the capacity if the slenderness of the part of the cross section concerned is less than the limiting values given in Figure 3:414b. An increase in capacity greater than that corresponding to 25% of the capacity of the part of the cross section concerned, calculated in accordance with the elastic theory,
should not normally be allowed for. However, this limit does not apply to a solid cross section nor to a flat plate which is deflected perpendicular to its plane, as shown in Figure 3:414a.

![Deflection of a flat plate perpendicular to its plane.](image)

**Figure 3:414a**  Deflection of a flat plate perpendicular to its plane.

In calculating the capacity, the effect of local buckling may be taken into account by performing the calculation for effective cross sections of reduced dimensions, see K18, Clause 18:2. If parts of the cross section of a member have a slenderness smaller than the limiting values given in Figure 3:414c, the effect of local buckling is negligible.

If the calculated stresses in the ultimate limit state investigated are smaller than $f_{yd}$, the following rules may be applied on condition that the stresses are calculated in accordance with Clause 3:3, with due regard to second order forces and moments etc.

<table>
<thead>
<tr>
<th>Limiting values for slenderness</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b/t \leq 1.0 \sqrt{E_d/f_{yd}}$</td>
</tr>
</tbody>
</table>

---

**Figure 3:414b**  Limiting values for slenderness with regard to plastic flow.
The effect of local buckling may be considered negligible if the slenderness of different parts of the cross section is smaller than the limiting values given in Figure 3:414c, the tabulated limiting values being calculated by applying the appropriate values of the compressive stresses instead of $f_{yd}$ or by applying the appropriate values of the shear stresses instead of $f_{yd}/\sqrt{3}$. If a part of the cross section is simultaneously subjected to bending stresses and shear stresses, both conditions shall be met.

The limiting values given in Figure 3:414c are intended for use in assessing whether the slenderness is sufficiently small in order that the effect of buckling may be ignored. A more differentiated assessment may be made by carrying out calculations in accordance with Section 6. In applying the calculation methods in Section 6, some plastic flow may normally be taken into account even if the limiting values in Figure 3:414b are exceeded.

<table>
<thead>
<tr>
<th>Limiting values for slenderness</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b/t \leq 1.14 \frac{E_d}{f_{yd}}$ for $\psi = 1.0$</td>
</tr>
<tr>
<td>$b/t \leq 3.2 \frac{E_d}{f_{yd}}$ for $\psi = -1.0$</td>
</tr>
</tbody>
</table>

Flat plate restrained along two parallel edges, subjected to compressive stresses parallel to the edges.

$\sigma_1$ $\psi \sigma_1$ $\sigma_1$

Flat plate with one restrained and one free edge, subjected to compressive stresses parallel to the edges.

$\sigma$ $\sigma$

Flat plate restrained along two parallel edges, subjected to shear stresses.

$\tau$ $\tau$ $\tau$

Figure 3:414c Limiting values for slenderness with regard to local buckling.

Figure 3:414d illustrates the behaviour of an I-shaped girder in the ultimate limit state for cross sections of different slendernesses. The stress distribution is dependent on the degree of plastic flow and on whether local buckling occurs. In order to simplify the figure, it has been assumed that the cross section is not affected by any residual stresses. The principle of behaviour is valid for all types of cross sections.
### 3:42 Design values of material properties

**BKR 99, Subclause 2:22, first paragraph**

In determining the design value of a material property, the uncertainty in the relationship between the value of the material property as determined by tests on the material and the corresponding value in the finished structure shall be taken into consideration.

**BKR 99, Subclause 8:312, third–fifth paragraphs**

The design values of strength, modulus of elasticity and shear modulus at the ultimate limit states shall be determined from formulae (a)–(e) below.

\[
f_{yd} = \frac{f_{yk}}{\gamma_m \gamma_h}
\]  
(a)

\[
f_{ud} = \frac{f_{uk}}{1.2 \gamma_m \gamma_h}
\]  
(b)

If \( f_{ud} < f_{yd} \) the value of \( f_{ud} \) may be put equal to \( f_{yd} \)

\[
f_{rd} = \frac{f_{rk}}{1.1 \gamma_h}
\]  
(c)
\[ E_d = \frac{E_k}{\gamma_m \gamma_n} \]  
\[ G_d = \frac{G_k}{\gamma_m \gamma_n} \]  

**NOTATION**

- \( f_{yk} \): characteristic value of yield strength according to Subclause 8.221
- \( f_{uk} \): characteristic value of ultimate tensile strength according to Subclause 8.221
- \( f_{rk} \): characteristic value of fatigue strength according to Subclause 8.222
- \( E_k \): characteristic value of modulus of elasticity according to Subclause 8.223
- \( G_k \): characteristic value of shear modulus according to Subclause 8.223
- \( \gamma_m \): partial factor with regard to the uncertainty in determining the resistance
- \( \gamma_n \): partial factor with regard to the Safety Class according to Subclause 2.115
- \( f_{yd} \) and \( f_{ud} \) refer to both compressive strength and tensile strength.

In the ultimate limit state the value of the partial factor \( \gamma_m \) shall be as follows:

a) \( \gamma_m = 1.0 \) if the tolerances specified on the drawings or in other documents are so tight that dimensional deviations inside these tolerances have little significance for design.

b) \( \gamma_m = 1.1 \) if the conditions in a) above are not satisfied.

Dimensional deviations inside tolerance limits may be considered to have little significance if a calculation of resistance, based on a cross section with dimensional deviations equal to the lower limit of deviation, gives rise to not more than 6% reduction in the utilised capacity based on the nominal cross sectional dimensions (basic size).

Without a special investigation of the significance of dimensional deviations, the value \( \gamma_m = 1.0 \) may be selected in the following cases, on condition that design is carried out in accordance with the principles given in Section 3 and that additional inspection of dimensional deviations is carried out in accordance with Clause 9:7.

- Plates which have a thickness not less than 5.0 mm and comply with the tolerance rules in SS-EN 10 029, Tolerance Class A, B or C or as an alternative SS-EN 10 051, category A with improved tolerances for flatness.
– Hot or cold rolled plates which have a thickness less than 5.0 mm and whose tolerances conform to SS-EN 10 029, tolerance class A, B or C, SS-EN 10 051+A1, category A with improved tolerances for flatness, SS-EN 10 131 with improved tolerances for flatness (FS) and SS-EN 10 143 FS, on condition that the calculation is based on an assumed plate thickness that is not more than 5% greater than the thickness corresponding to the lower limit of deviation, but not greater than the basic size of the plate.

– Hot rolled IPE-, HEA-, HEB- and HEM members with tolerances according to SS-EN 10 034.

– Square and rectangular hollow sections according to SS-EN 10 219 with a plate thickness $t > 8 \text{ mm}$ and circular hollow sections according to the same standard with $d \leq 406.4 \text{ mm}$ and $t > 8 \text{ mm}$.

– Hot rolled U members with tolerances according to SIS 21 27 25.

\begin{quote}
\textit{BKR 99, Subclause 2:322, second paragraph}

Unless some other value is specified in the section dealing with the specific material, the value of $\gamma_m$ may be put equal to 1.0 in design

– for accidental action,

– with respect to progressive collapse,

– with respect to fire, and

– in the serviceability limit states.
\end{quote}

### 3:43 Stress-strain curve

For the steel types listed in Subclause 2:21, Tables (a), (b) and (e)–(g), design may be based on a schematic stress-strain curve in accordance with Figure 3:43.

Design may also be based on a stress-strain curve which is representative for the relevant steel type and has been documented by tests. The curve should be modified in such a way that the ratios of $f_{ud}$ to $f_{yd}$ and of $\varepsilon_{\text{max}}$ to $A_z$ are the same as in Figure 3:43.

When load is removed, the stress-strain curve is a straight line parallel to that part of the stress-strain curve which passes through the origin.

The effect of residual stresses on stiffness and resistance shall be taken into consideration.

General recommendation:

Examples of models for residual stresses are given in Clause 3:44 of BSK 99. The effect of residual stresses may be considered to have been allowed for in design in accordance with BSK 99.

Design may be based on the examples of schematic residual stress distributions given in Figure 3:44. These examples refer to rolled and welded I-shaped girders of 40 mm maximum thickness and to welded rectangular hollow sections of the same maximum wall thickness.

The magnitudes and distributions of residual stresses depend, inter alia, on the method of fabrication, shape of cross section and wall thickness. Primarily, residual stresses affect resistance in the event of instability and fatigue, and the risk of brittle failure. See also, for example, "Variations in mechanical and cross-sectional properties of steel" by Göran Alpsten, Proceedings of the International Conference on the Planning and Design of Tall Buildings, ASCE-IABSE.

3:45 Flange curling and shear deformations

Regarding the effects of flange curling and shear deformations see K18, Clause 18:7.
Figure 3:44 Examples of schematic residual stress distributions for various cross sections.

Notation:

- $f_{yk}$: characteristic value of strength for parent material
- $t, t_1, t_w$: thicknesses
- $\sigma_c$: compressive stress based on the condition that residual stresses of the section do not lead to a resulting normal force or moment

The figure shows only residual stresses in one of the flanges and in one of the walls of the hollow section. The specified values are residual stresses in MPa (+ tensile stress, – compressive stress).
3:46  **Fatigue**

*BKR 99, Subclause 8:3122, second and third paragraphs*

General recommendation:

The effect of fatigue may be taken into consideration by making a special additional calculation of the resistance with respect to fatigue, account being taken of the effect of, for instance, the stress spectrum and notch action.

Design may alternatively be carried out on the basis of tests. In such a case the factor of safety with respect to fatigue failure shall be commensurate with the requirement concerning strength in Subclause 8:222.

Calculation methods for design with respect to fatigue are given in Clause 6:5.

3:47  **Shell structures**

*BKR 99, Subclause 8:3123*

General recommendation:

Examples of suitable methods for the design of shell structures are given in Shell Handbook, Mekanförbundets förlag, Stockholm 1990.

3:48  **Bolted connections**

*BKR 99, Subclause 8:3124*

The resistance of a bolted connection in the ultimate limit states shall be calculated for both the bolts and the parent material. In calculating the resistance, the effect of any deformations in the connection shall be taken into consideration. In a high strength friction grip connection the resistance shall also be calculated with respect to slip.

The design value of the strength of bolts in the ultimate limit states shall be determined from formula (a) below.

\[
\frac{f_{bud}}{\gamma_m \gamma_n} = \frac{f_{buk}}{\gamma_m \gamma_n} \quad \text{(a)}
\]

**NOTATION**

- \(f_{bud}\): characteristic value of the ultimate strength of the bolts in accordance with Subclause 8:224
- \(\gamma_m\): partial factor with regard to the uncertainty in determining the resistance
- \(\gamma_n\): partial factor with respect to the Safety Class in accordance with Subsection 2:115

In the ultimate limit states, the value of the partial factor \(\gamma_m\) shall be put equal to 1.2.
3:49 Welded connections

*BKR 99, Subclause 8:3125*

The resistance of a welded connection in the ultimate limit states shall be calculated for both the weakest section through the weld and the section immediately adjoining the weld. For a welded connection of limited length, stresses may for design purposes be assumed to be uniformly distributed over the length of the weld.

General recommendation:

Examples of suitable methods for calculating the resistance of welded connections are given in Clause 6:3 of *BSK 99*. 
4 DESIGN IN THE SERVICEABILITY LIMIT STATES

4:1 Scope

This section applies to structural members such as beams, columns, braces, frames, trusses, shells, panels of normal type and of normal cross sectional shapes and details. It is also assumed that members are made of materials in accordance with Clause 2:2.

For other cases, reference is to be made to the literature, or design is to be carried out in accordance with Boverket's handbook Design by testing.

4:2 Calculation of deformations and vibrations

BKR 99, Subclause 2:12, third paragraph

General recommendation:
Calculation of deformations and oscillations may be performed in accordance with the elastic theory using an analytical model which gives a reasonable description of the stiffness, mass, damping and boundary conditions of the construction.

BKR 99, Subclause 8:32

General recommendation:
General requirements concerning design in the serviceability limit states are set out in Section 2:12.

If plastic deformations occur their effect shall be taken into consideration, but residual stresses may be ignored.

In the serviceability limit states, the design values may be put equal to the appropriate characteristic values.

General recommendation:
Design in the serviceability limit states should be in accordance with the elastic theory, with the analytical model in accordance with Subclause 8:31 as appropriate.

The favourable effect on the stiffness due to interaction with other members, assumed to be non-structural, may be taken into account.
BKR 99, Subclause 2:322, second paragraph

Unless some other value is specified in the section dealing with the specific material, the value of $\gamma_m$ may be put equal to 1.0 in design

– for accidental action,
– with respect to progressive collapse,
– with respect to fire, and
– in the serviceability limit states.
5 DESIGN BY TESTING

Information on design by testing is given in Boverket's handbook *Design by testing*. 
6 DESIGN METHODS

6:1 Scope

This section provides examples of design methods which primarily are intended to be used in conjunction with structures and loading conditions of common occurrence in the ultimate limit states and in conjunction with fatigue.

One condition for the use of these methods is that they are applied in their entirety and that the rules in Sections 7–9 regarding materials, execution and control are taken into consideration.

6:2 Calculation of the resistance of structural members

6:21 Limiting values of slenderness for parts of the cross section

Limiting values of slenderness for parts of the cross section, with respect to the effect of local buckling, are given in Table 6:211a for various cross sectional parts and for stress distributions in the ultimate limit states.

Members in which parts of the cross section have a slenderness greater than the limiting value in Column 2, i.e. thin walled cross sections, should be designed with respect to the effective thicknesses of the individual parts of the cross section, see K18, Clause 18:2.

6:211 Cross section classes

Depending on the slenderness of the parts of the cross section, cross sections are assigned to Cross Section Class 1, 2 or 3. Classification is governed by the limiting values in Table 6:211a.

Cross sections which can attain full plastic flow without buckling of any part of the cross section due to the compressive strain required for the development of a plastic hinge are assigned to Cross Section Class 1.

Cross sections which can attain the yield stress in that part of the cross section where the compressive stress is highest, without any part of the cross section buckling, are assigned to Cross Section Class 2. Normally, some plastic flow may take place before local buckling occurs, but not to such an extent that a plastic hinge forms.

Cross sections in which local buckling occurs at a stress lower than the yield stress are assigned to Cross Section Class 3.
Table 6:211a  Limiting values of slenderness for parts of the cross section

<table>
<thead>
<tr>
<th>Part of cross section</th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flange of I, T, U and L section Stiffener</td>
<td>$f_{yk}$</td>
<td>$f_{yk}$</td>
<td>$\beta_t &lt; 2\sqrt{E_k/f_{yk}}$</td>
</tr>
<tr>
<td>$\beta_t = b_t/t_t$</td>
<td>$\beta_t \leq \beta_{tp}$ where $\beta_{tp} = 0.3\sqrt{E_k/f_{yk}}$</td>
<td>$\beta_t \leq \beta_{tel}$ where $\beta_{tel} = 0.44\sqrt{E_k/f_{yk}}$</td>
<td></td>
</tr>
<tr>
<td>Flange of box girder</td>
<td>$f_{yk}$</td>
<td>$f_{yk}$</td>
<td>$\beta_t &lt; 0.4E_k/f_{yk}$</td>
</tr>
<tr>
<td>$\beta_t = b_t/t_t$</td>
<td>$\beta_t \leq \beta_{tp}$ where $\beta_{tp} = 1.0\sqrt{E_k/f_{yk}}$</td>
<td>$\beta_t \leq \beta_{tel}$ where $\beta_{tel} = 1.14\sqrt{E_k/f_{yk}}$</td>
<td></td>
</tr>
</tbody>
</table>

The slenderness of cross sections in Class 1 is smaller than the limiting values in Column 1 of Table 6:211a. Cross sections in Class 2 have a slenderness which is intermediate between the limiting values in Columns 1 and 2, and those in Class 3 are intermediate between Columns 2 and 3. If different parts of a cross section fall into different classes, the cross section is assigned to the higher class. A cross section may be assigned to different classes in conjunction with normal force and in flexure in different directions.

Members in accordance with Swedish Standards, see Subclause 7:12 – Types HEA, HEB, HEM, IPE and U – which are only subjected to a bending moment, are assigned to Cross Section Class 1 if $f_{yk} \leq 275$ MPa.
Table 6:211a  Limiting values of slenderness for parts of the cross section (continuation)

<table>
<thead>
<tr>
<th>Part of cross section</th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web of beam ( b_w )</td>
<td>( \beta_w \leq \beta_{wpl} )</td>
<td>( \beta_w \leq \beta_{wel} )</td>
<td>( \beta_{w2} &lt; 0.4 \frac{E_k}{f_{yk}} )</td>
</tr>
<tr>
<td>( b_w )</td>
<td>( \beta_{wpl} = \beta_1 \sqrt{\frac{E_k}{f_{yk}}} )</td>
<td>( \beta_{wel} = \beta_2 \kappa_f \sqrt{\frac{E_k}{f_{yk}}} )</td>
<td>( \beta_{w2} = \frac{b_{wht}}{t_w} )</td>
</tr>
<tr>
<td>( t_w )</td>
<td>( \beta_1 = 1.46 )</td>
<td>( \beta_2 = 1.14 )</td>
<td>where</td>
</tr>
<tr>
<td>( \beta_w = \frac{b_w}{t_w} )</td>
<td>( \beta_1 = 2.4 )</td>
<td>( \beta_2 = 3.2 )</td>
<td>( b_{wht} = ) total height of the beam</td>
</tr>
<tr>
<td>( t_w )</td>
<td>( \beta_1 = 0.52 + 0.94/\alpha_1 )</td>
<td>( \beta_2 = 1.6/\alpha ) if ( \alpha \leq 1.00 )</td>
<td>( f_{ytk} = ) yield stress of flange</td>
</tr>
<tr>
<td>( \beta_1 \leq \beta_{fpl} ) which results in ( \beta_{fpl} ) for a flange being smaller than ( \beta_{wpl} ) for a web subjected to concentric axial compression.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \beta_1 \leq \beta_{fpl} ) for web of I-beam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \kappa_f = 5 - 4 \beta_1 / \beta_{fpl} ) for web of box girder.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \kappa_f ) is however put to max 1.5 and min 1.0.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circular hollow section ( r/t \leq 0.05 \frac{E_k}{f_{yk}} )</td>
<td>( r/t \leq 2000 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 6:212 Design methods for different cross section classes

In Cross Section Class 1, the limit state theory may be used in calculating forces and moments, see Subclause 3:32, and the cross section may be designed according to the plastic theory.
Cross Section Class 2 presupposes that internal forces are calculated in accordance with the elastic theory. However, in designing the cross section some plastic flow can be utilised, see Subclause 6:242 and K18, Clause 18:2.

In Cross Section Class 3, internal forces are calculated and the cross section is designed in accordance with the elastic theory. Local buckling is considered by using an effective cross section, see K18, Clause 18:2.

6:22 Tensile force

The resistance of a member subjected to a tensile force is the lower of the following values:

\[ N_{Rtd} = A_{gr} f_{yd} \]  
(6:22a)

\[ N_{Rtd} = A_{net} f_{ud} \]  
(6:22b)

- \( A_{gr} \) gross area
- \( A_{net} \) net area of section which is locally reduced. If the reduction in section is not local, \( A_{gr} \) in formula 6:22a shall be replaced by \( A_{net} \).

Where holes are staggered, as in Figure 6:22, different sections must be tested to find the least net area \( A_{net} \). The width \( b \) shall be reduced by the diameter of each hole along the section line and shall be increased by \( s^2/4g \) but not more than 0.6 \( s \), where \( s \) is the distance between the centres of holes in the direction of force and \( g \) is the distance perpendicular to the direction of force.

![Figure 6:22 Different section lines for the determination of \( A_{net} \).](image)

6:23 Compressive force

For a member in Cross Section Class 1 or 2 which is subjected to a compressive force, the resistance is:

\[ N_{Rcd} = \omega_c A_{gr} f_{yd} \]  
(6:23)

where \( \omega_c \) is a reduction factor with respect to flexural buckling.
The value of the reduction factor $\omega_c$ for flexural buckling is determined in accordance with Subclause 6:233. For a member which has a unisymmetrical or non-symmetrical cross section and for a member which is braced in the direction of the minor axis, torsional or flexural-torsional buckling may be critical with regard to capacity. In such cases, $\omega_c$ is determined in accordance with $K18$, Subclause 18:37.

For a member in Cross Section Class 3, the capacity with respect to compressive force is determined in accordance with $K18$, Subclause 18:34.

In determining the capacity with respect to compressive force for a built up member, special consideration should be given to the fact that interaction between the different components is not complete. The lacing bars and ties which connect the main members should normally be designed in such a way that the capacity of the main members is critical with regard to the capacity of the built up member. $K18$, Clause 18:35 gives a method for the design of built up members.

### 6:231 Initial curvature, initial inclination and load eccentricity

When the resistance of a member is calculated in accordance with formula 6:23, the effect of an initial curvature with a deviation from straightness equal to 0.0015$l$ according to Subclause 2:31 is allowed for. If the deviation is larger, design should be carried out in accordance with the provisions of Subclause 6:25 for a member in simultaneous flexure and compression, the bending moment being equal to the compressive force due to the design load multiplied by the difference between this larger deviation and 0.0015$l$.

The effect of initial inclination in accordance with Subclause 2:31 gives rise to horizontal forces which can be taken into account in accordance with $K18$, Subclause 18:55.

Load eccentricity at one end of a member should be determined on the basis of structural detailing and the assumed tolerances. The effect of load eccentricity should be taken into account in accordance with the provisions of Subclause 6:25 for a member in simultaneous flexure and compression. The influence of unforeseen eccentricity may be considered to have been allowed for by means of the assumed initial curvature.

### 6:232 Loss of restraint

The effect of loss of restraint due to various deformations in the connections between the different structural members, e.g. in the case of a column rigidly fixed in a foundation, is allowed for by increasing the effective length. Unless a special calculation is carried out with regard to the effect of such movement, the effective length should be taken as $\beta_{cd}L$, the value of $\beta_{cd}$ being given in Figure 6:232 for the calculation of the slenderness parameter in formula 6:233a.

If the load or cross section varies along the member, the effective length, for similar support conditions, is determined by multiplying the theoretical effective length by the factor $\beta_{cd}/\beta_{db}$. The value of $\beta$ should be selected from Figure 6:232 for the case which most closely resembles the support condition in question.
With regard to calculation of the effective length, reference should also be made to K18, Subclause 18:38.

<table>
<thead>
<tr>
<th>Support condition</th>
<th>Axial compression</th>
<th>Support condition</th>
<th>Axial compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member pin-jointed at both ends</td>
<td>$N$</td>
<td>Member rigidly fixed at both ends. Supports capable of lateral displacement</td>
<td>$N$</td>
</tr>
<tr>
<td></td>
<td>$\beta_{cd} = 1$</td>
<td>$\beta_{cd} = 1.2$</td>
<td>$\beta_{cd} = 1$</td>
</tr>
<tr>
<td></td>
<td>$\beta_{th} = 1$</td>
<td>$\beta_{th} = 1$</td>
<td>$\beta_{th} = 1$</td>
</tr>
<tr>
<td>Member rigidly fixed at one end, free at the other end.</td>
<td>$N$</td>
<td>Member rigidly fixed at one end, pin-jointed at the other end. Fixed nodes.</td>
<td>$N$</td>
</tr>
<tr>
<td></td>
<td>$\beta_{cd} = 2.1$</td>
<td>$\beta_{cd} = 0.8$</td>
<td>$\beta_{cd} = 0.6$</td>
</tr>
<tr>
<td></td>
<td>$\beta_{th} = 2$</td>
<td>$\beta_{th} = 0.7$</td>
<td>$\beta_{th} = 0.5$</td>
</tr>
<tr>
<td>Member rigidly fixed at both ends. Fixed nodes.</td>
<td>$N$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\beta_{cd} = 0.6$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\beta_{th} = 0.6$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 6:232 Values of $\beta_{th}$ and $\beta_{cd}$ for theoretical support conditions. The marks across the deflected shape indicates the design section.

6:233 Reduction factor for flexural buckling

The reduction factor for flexural buckling, $\alpha_c$, is a function of the cross sectional shape and the method of fabrication of a member according to Table 6:233 and of the slenderness parameter of the member according to formula 6:233a.

The effect of residual stresses is allowed for in the table by classifying members into four groups, a–d, with reference to cross sectional shape, thickness and the method of fabrication.

In conjunction with flexural buckling, the slenderness parameter $\lambda_c$ of a member is determined in accordance with the formula:

$$\lambda_c = \sqrt{\frac{A}{N_{cr}}} = \frac{l_c}{\pi \sqrt{\frac{f_{yk}}{E_k}}}$$  \hspace{1cm} (6:233a)

- $A$ cross sectional area of member
- $E_k$ characteristic value of modulus of elasticity
- $N_{cr}$ critical load of member with respect to flexural buckling ($E = E_k$)
$f_{yk}$ characteristic value of yield strength

$i$ radius of gyration of member

$l_c$ effective length (see Subclause 6:232)

The value of the reduction factor is determined from Figure 6:233 or calculated from the following formula:

$$\omega_c = \frac{\alpha - \sqrt{\alpha^2 - 4.4 \lambda_c^2}}{2.2 \lambda_c^2} \quad \text{but not greater than 1.0} \quad (6:233b)$$

$$\alpha = 1 + \beta_1 (\lambda_c - 0.2) + 1.1 \lambda_c^2$$

with $\beta_1 = 0.21$ for Group a

$\beta_1 = 0.34$ for Group b

$\beta_1 = 0.49$ for Group c

$\beta_1 = 0.76$ for Group d

Figure 6:233 The value of the reduction factor for flexural buckling, $\omega_c$, as a function of the slenderness parameter $\lambda_c$, for the different cross sectional groups in accordance with Table 6:233.
Table 6.233  Classification of members on the basis of type of cross section for the determination of $\omega_C$

1. Cross sections with maximum thickness $\leq 40$ mm

<table>
<thead>
<tr>
<th>Type of cross section</th>
<th>Conditions</th>
<th>Group</th>
</tr>
</thead>
</table>
| Circular or rectangular hollow section | Hot formed or stress relieved hollow section  
Hollow section welded at four corners with weld size $a \leq 0.5$ or made up by welding together two U sections  
Other hollow sections | a     |
|                      |                                                                           | b     |
|                      |                                                                           | c     |
| Rolled member of I section | Flexural buckling in the direction of the major axis (rotation of cross section about $x$-$x$)  
$h/b > 1.2$  
$h/b \leq 1.2$ | a     |
|                      | Flexural buckling in the direction of the minor axis (rotation of cross section about $y$-$y$)  
$h/b > 1.2$  
$h/b \leq 1.2$ | b     |
|                      |                                                                           | c     |
| Welded member of I section | Flexural buckling in the direction of the major axis (rotation of cross section about $x$-$x$)  
Flexural buckling in the direction of the minor axis (rotation of cross section about $y$-$y$) | b     |
|                      |                                                                           | c     |
| U section | Flexural buckling with rotation of cross section about $x$-$x$  
$y$-$y$ | b     |
|                      |                                                                           | c     |
| T or angle section, or rolled member of solid section | Wall thickness $\leq 20$ mm  
Wall thickness $> 20$ mm | b     |
|                      |                                                                           | c     |
2. Cross sections with maximum thickness (40) – 100 mm

<table>
<thead>
<tr>
<th>Type of cross section</th>
<th>Conditions</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolled member:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexural buckling with rotation of cross section about ( x \times x )</td>
<td>d</td>
<td></td>
</tr>
<tr>
<td>Flexural buckling with rotation of cross section about ( y \times y )</td>
<td>d</td>
<td></td>
</tr>
<tr>
<td>Welded member comprising rolled plates:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexural buckling with rotation of cross section about ( x \times x )</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td>Flexural buckling with rotation of cross section about ( y \times y )</td>
<td>d</td>
<td></td>
</tr>
<tr>
<td>Welded member comprising rolled plates with thermally cut edges</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td>Solid section</td>
<td></td>
<td>c</td>
</tr>
</tbody>
</table>

6:24 Bending moment

6:241 Cross sectional classes

Cross sections are assigned to different classes in accordance with Subclause 6:211.

It is presupposed that the limit state theory only is applied to Cross Section Class 1. It is further presupposed that the bending moment capacity within the yield region is not reduced owing to a local reduction in cross section.

6:242 Shape factors in flexure

For cross sections of Class 1, the shape factor in flexure is \( \eta = Z/W \). However, for all cross sections with the exception of solid sections, the value of \( \eta \) shall not be put greater than 1.25 unless a special analysis is carried out regarding the validity of the design rules and the influence of dimensional deviations.

For cross sections of Class 2, the value of \( \eta \) may be put equal to 1.0. A higher value of may be determined by interpolation.

For cross sections of Class 3, the value of \( \eta \) is less than 1.0.

With regard to the determination of \( \eta \), reference should be made to K18, Subclause 18:42.
6:243  Moment

The capacity with respect to bending moment of beams of cross section with at least one plane of symmetry is the least of the following values:

\[ M_{Rtd} = \eta_t W_t f_{yd} \]  \hspace{1cm} \text{for extreme tension fibre} \hspace{1cm} (6:243a)

\[ M_{Rcd} = \omega_b \eta_k W_c f_{yd} \]  \hspace{1cm} \text{for extreme compression fibre} \hspace{1cm} (6:243b)

\[ M_{Rud} = \eta_t W_{net} f_{ud} \]  \hspace{1cm} \text{for extreme tension fibre} \hspace{1cm} (6:243c)

\( W_t, W_c \)  \hspace{0.5cm} \text{section modulus of gross cross section with respect to the extreme tension and compression fibre}

\( W_{net} \)  \hspace{0.5cm} \text{section modulus of net cross section}

\( \eta \)  \hspace{0.5cm} \text{shape factor in flexure, see Subclause 6:242; } \eta_t \text{ for extreme tension fibre and } \eta_c \text{ for extreme compression fibre}

\( \omega_b \)  \hspace{0.5cm} \text{reduction factor for lateral torsional buckling in accordance with Subclause 6:2442.}

Formula 6:243c applies where there is a local reduction in cross section, see Figure 6:22. If such reduction is not local, \( W_{net} \) should be substituted into formulae 6:243 a and b instead of \( W_t \) and \( W_c \).

6:244  Lateral torsional buckling

If a beam is braced in accordance with Subclause 6:2441, lateral torsional buckling will not occur \((\omega_b = 1)\). In any other case \( \omega_b \) is calculated in accordance with Subclause 6:2442.

6:2441  Lateral bracing of a beam

The following condition applies for a beam subjected to one or more point loads which give rise to a linearly varying moment in the beam. It is presupposed that the compression flange of the beam is braced at the points where the loads are applied.

If forces and moments are calculated in accordance with the limit state theory, lateral torsional buckling will have no effect on the capacity with respect to bending moment provided that the distance \( l_1 \) between the brace at the plastic hinge and the nearest brace (to the compression flange) complies with the following condition:

\[ \frac{l_1}{b_{lot}} \leq \left[ 0.6 - 0.2 \frac{M_2}{M_1} - 0.1 \left( \frac{M_2}{M_1} \right)^2 \right] \sqrt{\frac{E_k}{f_{yk}}} \]  \hspace{1cm} (6:2441)
the total width of the compression flange. If the flange is not rectangular, \( b_{\text{tot}} \) is replaced by \( 3.5 i_{f1} \), where \( i_{f1} \) is the radius of gyration of the flange.

\[ M_1 \] the numerically largest moment within the portion of the beam under consideration.

\[ M_2 \] the moment at the opposite end of the beam portion. The ratio \( M_2 / M_1 \) is positive if \( M_1 \) and \( M_2 \) bend the beam the same way, and negative otherwise.

If forces and moments are calculated in accordance with the elastic theory, lateral torsional buckling has no effect on the resistance provided that the distance between bracing points is not more than 20% greater than the limiting value according to formula 6:2441.

A bar which is bracing several beams may be designed for an axial force in accordance with K18, Subclause 18:45.

### 6:2442 Reduction factor for lateral torsional buckling

The following method may be applied for beams of channel section and for I-shaped girders of unisymmetric or bisymmetric cross section which are subjected to bending in the plane of the beam.

The reduction factor \( \omega_b \) is a function of the slenderness \( \lambda_b \) of the beam and its method of fabrication as follows:

The slenderness parameter \( \lambda_b \) with respect to lateral torsional buckling of a beam is determined by the following formula:

\[
\lambda_b = \sqrt{\frac{\eta_c W_c f_{yk}}{M_{cr}}} \quad (6:2442a)
\]

\( M_{cr} \) critical moment for lateral torsional buckling in accordance with the elastic theory \( (E = E_k) \)

\( W_c \) section modulus with respect to extreme compression fibre

\( \eta_c \) shape factor for extreme compression fibre.

The reduction factor \( \omega_b \) is determined from Figure 6:2442 or calculated from the following formulas:

1) Hot rolled beam

\[
\omega_b = \frac{1.02}{\sqrt{1 + \lambda_b^4}} \quad \text{but not greater than 1.0} \quad (6:2442b)
\]

2) Welded beam in Cross Section Class 1 in accordance with Subclause 6:211

\[
\omega_b = \frac{1.04}{\left(1 + \lambda_b^3\right)^{2/3}} \quad \text{but not greater than 1.0} \quad (6:2442c)
\]
3) Welded beam in Cross Section Classes 2 and 3 in accordance with Subclause 6:211

\[ \omega_b = \frac{1.16}{1 + \lambda_b^2} \quad \text{but not greater than 1.0} \]  \hspace{1cm} (6:2442d)

Calculation is normally carried out for the section where the bending moment is greatest. If the section with the greatest bending moment is different from the section where lateral deflection in lateral torsional buckling is a maximum, calculation may be carried out for a special design section.

![Figure 6:2442](image)

**Figure 6:2442**  The value of the reduction factor \( \omega_b \) for lateral torsional buckling as a function of the slenderness parameter \( \lambda_b \) for different types of beams.

The following formulas apply for a beam of bisymmetric cross section which is subjected to one or more point loads that give rise to flexure in the direction of the major axis in accordance with Subclause 6:2441, but in which the distance between the bracing points is greater than that stipulated in Subclause 6:2441.

The critical moment for lateral torsional buckling, \( M_{1cr} \), is given by

\[
M_{1cr} = \frac{\pi}{\kappa_{cr} l_1} \sqrt{B_y \left( C + \frac{\pi^2 C_w}{l_1^2} \right)} \]  \hspace{1cm} (6:2442e)

- \( B_y \): lateral flexural stiffness of beam \( (=EI_y) \)
- \( C \): torsional stiffness of beam
- \( C_w \): warping stiffness of beam
- \( l_1 \): distance between points where the compression flange is braced
- \( \kappa_{cr} = 0.6 + 0.3 \frac{M_2}{M_1} + 0.1 \left( \frac{M_2}{M_1} \right)^2 \)
- \( M_1 \): the numerically greatest bending moment
the moment at the opposite end of the beam portion under consideration. The ratio $M_2/M_1$ is positive if $M_1$ and $M_2$ bend the beam the same way, and negative otherwise.

The moment at the design section is $\kappa_m M_1$, the value of $\kappa_m$ being determined as follows:

$$\kappa_m = 0.8 + 0.2(M_2/M_1)$$

but at least 0.8.

The bending moment capacity with respect to lateral torsional buckling is determined using $\omega_b$ according to Figure 6:2442, the value of $\lambda_b$ being calculated from the formula:

$$\lambda_b = \frac{\eta_k W_c f_{yk}}{\kappa_m M_{fct}}$$  \hspace{1cm} (6:2442f)

The design conditions are that $\kappa_m M_1$ is less than $M_{Red}$ in accordance with formula 6:243b and that $M_1$ is less than $M_{Red}$ with $\omega_b = 1$ according to the same formula.

### 6:25 Axial force and bending moment

This subclause gives examples of methods for the verification of whether a member has sufficient resistance in the ultimate limit state when it is simultaneously subjected to an axial force and a bending moment. The methods are applicable to members of bisymmetric cross section unless otherwise specified. In the case of members of unisymmetric cross section, the resistance with respect to flexural torsional buckling may be calculated in accordance with K18, Subclause 18:37.

All the quantities must be substituted into the interaction formulas in this subclause with positive signs. The coordinate directions selected are given in Figure 6:25.

The conditions given in formulas 6:251a, b and c (check on the capacity of the cross section) must at all times be met by all cross sections, and are sufficient for the case where neither flexural buckling nor lateral torsional buckling can occur ($\lambda_c < 0.2$ and $\lambda_b < 0.4$).

If the member is subjected to a compressive force and the slenderness parameter with respect to flexural buckling, $\lambda_c$, is greater than 0.2, the appropriate condition according to formula 6:252a or b (flexural buckling) must be met. The design condition is such that second order effects have been allowed for. An alternative method for the verification of a member simultaneously subjected to an axial force and a bending moment is given in K18, Subclause 18:56.

If one or both flanges can deflect laterally, the conditions according to formulas 6:253 a and b (flexural torsional buckling) must also be met.

In sections with bolt holes, the condition according to formula 6:251d must be met in conjunction with tensile force and bending moment.
6:251 Check on the capacity of the cross section

- I-shaped sections symmetrical about two axes

\[
\left( \frac{N_{Sd}}{N_{Rd}} \right)^{\gamma_0} + \frac{M_{Sxd}}{M_{Rxd}} \leq 1.00
\]

(6:251a)

and

\[
\left( \frac{N_{Sd}}{N_{Rd}} \right)^{\alpha_0} + \left( \frac{M_{Sxd}}{M_{Rxd}} \right)^{\beta_0} + \left( \frac{M_{Syd}}{M_{Ryd}} \right)^{\gamma_0} \leq 1.00
\]

(6:251b)

\[\alpha_0 = \eta_x^2 \eta_y^2 \quad \text{but} \geq 1 \text{ and} \leq 2\]

\[\beta_0 = \eta_y^2 \quad \text{but} \geq 1 \text{ and} \leq 1.56\]

\[\gamma_0 = \eta_x^2 \quad \text{but} \geq 1\]

When moments act in two directions, both conditions shall be met.

- Solid sections and hollow sections

\[
\left( \frac{N_{Sd}}{N_{Rd}} \right)^{\psi} + \left[ \left( \frac{M_{Sxd}}{M_{Rxd}} \right)^{1.7} + \left( \frac{M_{Syd}}{M_{Ryd}} \right)^{1.7} \right]^{0.6} \leq 1.00
\]

(6:251c)

\[\psi = \eta_x \eta_y \quad \text{but} \geq 1 \text{ and} \leq 2\]

- Unisymmetric and other bisymmetric sections in conjunction with flexure in one plane

Formula 6:251a is to be applied, with

\[\gamma_0 = \eta_{\text{max}}^2 \quad \text{but} \geq 1 \text{ and} \leq 1.56\]
where $\eta_{\text{max}}$ is the greatest value of the shape factors $\eta_1$ and $\eta_2$ for the two extreme fibres, see Figure 6:251.

Notations in formulas 6:251a, b and c,

- $N_{\text{sd}}$: axial force due to design loads
- $M_{\text{sd},x}, M_{\text{sd},y}$: bending moment due to design loads about the $x$- and $y$-axis
- $N_{\text{rd}}$: $A_{\text{gr}} f_{yd}$
- $M_{\text{rd},x} = \eta_x W_x f_{yd}$
- $M_{\text{rd},y} = \eta_y W_y f_{yd}$

where $\eta_x$ and $\eta_y$ are shape factors in accordance with Sub-clause 6:242 in flexure about the $x$- and $y$-axis respectively.

![Figure 6:251 Shape factors for a unisymmetric section in Cross Section Class 1.](image)

**Interaction formula for check on cross sections with a local reduction, e.g. bolt holes**

$$\frac{N_{\text{sd}}}{N_{\text{rd}}} + \frac{M_{\text{sd}}}{M_{\text{rd}}} \leq 1.00 \quad (6:251\text{d})$$

- $N_{\text{sd}}$: tensile force
- $M_{\text{sd}}$: bending moment in accordance with second order theory, see e.g. K18, Subclause 18:36. (Plastic hinge theory should not be applied.)
- $N_{\text{rd}}$: capacity with respect to tensile force according to formula 6:22b
- $M_{\text{rd}}$: moment capacity of extreme tension fibre according to formula 6:243c.

When the moment acts about two axes, the term $M_{\text{sd}}/M_{\text{rd}}$ with respect to the moment about the other axis of flexure is to be added to the left hand side of formula 6:251d.
6:252  **Flexural buckling**

*Interaction formulas for flexural buckling*

- for flexure about the $x$-axis of a beam of bisymmetric I section

\[
\left( \frac{N_{sd}}{N_{Rxcd}} \right)^{\gamma_{xc}} + \frac{M_{Sxd}}{M_{Rxd}} \leq 1.00 \quad (6:252a)
\]

- for flexure about the $y$-axis of a beam of bisymmetric I section

\[
\left( \frac{N_{sd}}{N_{Rycd}} \right)^{\alpha_{c}} + \left( \frac{M_{Syd}}{M_{Ryd}} \right)^{\gamma_{yc}} \leq 1.00 \quad (6:252b)
\]

Notations in formulas 6:252 a and b,

- $N_{sd}$ axial force due to design loads
- $N_{Rxcd}$ $\omega_{xc} A f_{yd}$ where $\omega_{xc}$ is the reduction factor for buckling with rotation of the section about the $x$-axis
- $N_{Rycd}$ $\omega_{yc} A f_{yd}$ where $\omega_{yc}$ is the reduction factor for buckling with rotation of the section about the $y$-axis
- $M_{Sxd}$, $M_{Syd}$ bending moments about the $x$- and $y$-axis respectively due to design loads in accordance with first order theory, $M_{Sxd}$ and $M_{Syd}$ being determined as follows:
  a) Member subjected to end moments but no transverse loads

  \[
  M = 0.6 M_1 + 0.4 M_2 \text{ but } \geq 0.4 M_1
  \]

  where $M_1$ is the numerically larger end moment and $M_2$ the numerically smaller one. The sign of $M_2$ is the same as that of $M_1$ if the two moments bend the beam the same way, otherwise it has the opposite sign.

  b) In other cases, $M$ is put equal to the numerically greatest moment, unless some other value is shown to be more appropriate.

- $M_{Rxcd}$ $\eta_x W_x f_{yd}$ = moment capacity in flexure about the $x$ axis
- $M_{Ryld}$ $\eta_y W_y f_{yd}$ = moment capacity in flexure about the $y$ axis

  $\eta_x$ and $\eta_y$ are shape factors ($\eta_y \leq 1.25$, see Subclause 6:242)

- $\alpha_c = \alpha_0 \omega_{yc}$ but $\geq 0.8$
- $\gamma_{xc} = \gamma_0 \omega_{xc}$ but $\geq 0.8$
- $\gamma_{yc} = \gamma_0 \omega_{yc}$ but $\geq 0.8$

where $\alpha_0$ and $\gamma_0$ are in accordance with Subclause 6:251 and $\omega_{xc}$ and $\omega_{yc}$ are reduction factors, see $N_{Rxcd}$ and $N_{Rycd}$ above.
In the case of solid sections and hollow sections, formula 6:251c may be applied with $\psi$ replaced by $\psi_c \omega_x$ or $\psi_c \omega_y$, depending on the direction of flexure. $\omega_x \psi_c$ and $\omega_y \psi_c$ shall not be assigned a smaller value than 0.8. $N_{Rd}$ is replaced by $N_{Rxd}$ or $N_{Ryd}$ depending on the direction of flexure.

- all other sections

For sections other than solid and hollow, formula 6:252a may be applied for flexure about one of the two axes, at which for flexure about the y axis, $\gamma_{xc}$, $M_{Sxd}$, $M_{Rxd}$ and $N_{Rxd}$ is replaced by $\gamma_{yc}$, $M_{Syd}$, $M_{Ryd}$ and $N_{Rycd}$ respectively.

### 6:253 Flexural torsional buckling

The following conditions apply for members of bisymmetric I section. In the case of other members, reference should be made to appropriate literature.

\[
\left( \frac{N_{Sd}}{N_{Rxd}} \right)^{\gamma_{xc}} + \frac{M_{Sxd}}{M_{Rxd}} \leq 1.00 \quad (6:253a)
\]

\[
\left( \frac{N_{Sd}}{N_{Rycd}} \right)^{\gamma_{yc}} + \left( \frac{M_{Sxd}}{M_{Rxd}} \right)^{\beta_{e}} + \left( \frac{M_{Syd}}{M_{Ryd}} \right)^{\gamma_{yc}} \leq 1.00 \quad (6:253b)
\]

- $N_{Sd}$ axial force due to design loads
- $M_{Sxd}$, $M_{Syd}$ bending moments about the $x$ and $y$ axis due to design loads. $M_{Sxd}$ in formula a and $M_{Syd}$ in formula b are moments in accordance with first order theory. For members with hinges at both ends and for members in frames with fixed (non-displaceable) nodes, $M_{Sxd}$ in formula b is also a moment in accordance with first order theory. For members in frames with free (displaceable) nodes, $M_{Sxd}$ in formula b is a moment in accordance with second order theory.
- $N_{Rxd}$ bending moment in flexure about the $x$ axis without reduction with respect to lateral torsional buckling in accordance with Subclause 6:2442
- $M_{Rxd}$ moment capacity in flexure about the $x$ axis without reduction with respect to lateral torsional buckling in accordance with Subclause 6:2442
\( M_{R,yd} \) moment capacity in flexure about the \( y \)-axis.

\[ \alpha_c = \alpha_0 \omega_{yc} \quad \text{but} \geq 0.8 \]

\[ \beta_c = \beta_0 \]

\[ \gamma_{xc} = \gamma_0 \omega_{xc} \quad \text{but} \geq 0.8 \]

\[ \gamma_{yc} = \gamma_0 \omega_{yc} \quad \text{but} \geq 0.8 \]

where \( \alpha_0 \), \( \beta_0 \) and \( \gamma_0 \) are in accordance with Subclause 6:251 and \( \omega_{xc} \) and \( \omega_{yc} \) are reduction factors, see \( N_{Rxc} \) and \( N_{Ryc} \).

### 6:26 Shear force and concentrated force

#### 6:261 Shear force

The capacity with respect to shear force is

- for members of I, channel and box section the lesser of

\[
V_{Rd} = \omega_v A_w f_{yd} \quad (6:261a)
\]

\[
V_{Rd} = 0.58 A_{w,\text{net}} f_{ud} \quad (6:261b)
\]

- for flat and round bars

\[
V_{Rd} = 0.50 A f_{yd} \quad (6:261c)
\]

- for circular hollow sections in accordance with Skalhandboken, Subclause 32:17.

Notations in formulas 6:261a, b and c

- \( A_w \) area of web \( h_w t_w \) according to Figure 6:261
- \( A_{w,\text{net}} \) net area of web in sections with bolt holes, see Subclause 3:413
- \( A \) area of cross section
- \( \omega_v \) reduction factor with respect to shear buckling which for a web without stiffeners other than those at the supports is obtained from Table 6:261 as a function of the slenderness parameter:

\[
\lambda_w = 0.35 \frac{b_w}{t_w} \sqrt{\frac{f_{yk}}{E_k}} \quad (6:261d)
\]

\( b_w \) width of web between fillets or welds, see Table 6:211a and Figure 6:261

\( t_w \) thickness of web
Table 6:261 gives values in Columns 1 and 2.

Column 1 applies for
– webs with double stiffeners or similar at end supports (stiff end support)
– webs at internal supports in continuous beams

Column 2 applies for
– webs with single stiffeners at end supports (weak end support)

<table>
<thead>
<tr>
<th>$\lambda_w$</th>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 0.75</td>
<td>0.67</td>
<td>0.67</td>
</tr>
<tr>
<td>0.75 – 1.20</td>
<td>$0.5/\lambda_w$</td>
<td>$0.5/\lambda_w$</td>
</tr>
<tr>
<td>1.20 –</td>
<td>$0.79/(\lambda_w + 0.70)$</td>
<td>$0.5/\lambda_w$</td>
</tr>
</tbody>
</table>

The following condition applies for a stiff end support, see Figure 6:261

$$A_c > 4b_w t_w^2 / e$$ and $e > 0.1b_w$ (6:261e)

When a member of I, channel or box section is subjected to a shear force $V$ and a bending moment $M$, the following condition applies.

For beams in Cross Section Class 1, $V$ and $M$ need only be checked separately, $V_{sd} \leq V_{Rd}$ and $M_{sd} \leq M_{Rd}$, if the conditions for the application of the limit state theory in accordance with Subclause 3:32 are complied with.

For beams in Cross Section Class 2, the same condition as for beams in Cross Section Class 1 applies. In addition, the following condition applies

$$\frac{M_{sd}}{M_{Rd}} + 0.63 \frac{V_{sd}}{V_{Rd}} \leq 1.38$$ (6:261f)

$M_{sd}$ bending moment due to design loads
6 DESIGN METHODS

$V_d$ shear force due to design loads

$M_{Rd}$ moment capacity in accordance with Subclause 6:243 with $\omega_b = 1$

$V_{Rd}$ shear capacity in accordance with formula 6:261a or b as appropriate.

For beams in Cross Section Class 3 see K18, Subclause 18:28.

6:262 Web crippling below a concentrated force

If forces and moments are calculated in accordance with the limit state theory, stiffeners should be provided below all concentrated forces within the assumed yield regions.

The capacity $F_{Rcd}$ with respect to web crippling below a concentrated force for structural members with

$$\frac{b_w}{t_w} \leq 2.4 \sqrt{\frac{E_k}{f_{yk}}}$$

is

$$F_{Rcd} = l_{sc} \cdot t_w \cdot f_{yd}$$  \hspace{1cm} (6:262a)

For structural members of greater slenderness, $F_{Rcd}$ is determined from the formula

$$F_{Rcd} = 0.7 t_w^2 \sqrt{E_d \cdot f_{yd}}$$  \hspace{1cm} (6:262b)

For a load whose distance from the end of the beam is greater than the depth of web $b_w$

$$l_{sc} = l_s + 2t_p + k(t_t + r)$$  \hspace{1cm} (6:262c)

where $k = 2$ applies in conjunction with fatigue loads and $k = 5$ in other cases. The notations $l_s$, $t_p$, $t_t$ and $r$ are shown in Figure 6:262.

For a load at the end of the beam

$$l_{sc} = l_s + t_p + t_t + r \hspace{1cm} \text{but not greater than } 500 \frac{t_w^2}{b_w}$$  \hspace{1cm} (6:262d)

For a load between the end of the beam and at a distance of $b_w$ from the end of the beam, the value of $l_{sc}$ is to be obtained by interpolation between formulae 6:262c and d.
6:263 Local compression

In design with respect to local compression in accordance with Hertz, where fatigue loads do not occur, the design value of strength is put equal to the smallest of the values $4.5 f_{yd}$ and $2.0 f_{uk}$.

6:27 Torsional moment

6:271 Pure torsion

In pure torsion, the capacity of an open cross section with respect to torsional moment is

$$T_{Rd} = 0.58 Z_v f_{yd} \quad (6:271a)$$

$$Z_v \quad \text{section modulus in torsion in accordance with the plastic theory}$$

The capacity with respect to torsional moment of a rectangular hollow section in pure torsion is

$$T_{Rd} = 2(\omega_t t)_{\min} A_t f_{yd} \quad (6:271b)$$

$$A_t \quad \text{area bounded by the centre lines of parts of the cross section}$$

$$t \quad \text{material thickness}$$

$$\omega_t \quad \text{reduction factor obtained from Table 6:271 as a function of the slenderness } \lambda_w$$

$$\lambda_w = 0.35 \frac{b_w}{t_w} \sqrt{\frac{f_{yk}}{E_k}} \quad (6:271c)$$

If the material thickness is constant, capacity is determined by the part of the cross section for which the slenderness $b_w/t_w$ is greatest. Otherwise, capacity is determined by the part of the cross section for which the value of $\omega_t t$ is least.
With regard to circular hollow sections, reference should be made to Shell Handbook.

**Table 6:271 The reduction factor $\omega_t$ with respect to shear buckling in torsion of a closed cross section comprising plane portions**

<table>
<thead>
<tr>
<th>$\lambda_w$</th>
<th>$\omega_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.75$</td>
<td>$0.58$</td>
</tr>
<tr>
<td>$0.75 - 2.37$</td>
<td>$0.435/\lambda_w$</td>
</tr>
<tr>
<td>$2.37 -$</td>
<td>$0.58/\lambda_w^{4/3}$</td>
</tr>
</tbody>
</table>

**6:272 Combined torsion**

Where warping of a cross section subjected to a torsional moment is prevented, and where torsion is combined with a normal force or bending moment or with both of these, the stresses caused by warping should also be taken into account in calculating capacity.

**6:273 Torsional moment, shear force and bending moment**

The following condition may be applied for solid and hollow sections:

$$\left(\frac{V_{sd}}{V_{rd}} + \frac{T_{sd}}{T_{rd}}\right)^2 + \left(\frac{M_{sd}}{M_{rd}}\right)^2 \leq 1.00$$  (6:273)

- $V_{sd}$ shear force due to design loads
- $T_{sd}$ torsional moment due to design loads
- $M_{sd}$ bending moment due to design loads
- $V_{rd}$ capacity with respect to shear force in accordance with Subclause 6:261
- $T_{rd}$ capacity with respect to torsional moment in accordance with Subclause 6:271
- $M_{rd}$ capacity with respect to bending moment in accordance with Subclause 6:243

For a rectangular hollow section, formula 6:261f should be applied if $T_{sd} = 0$. 
6:3 Design of welded connections

6:31 Design sections

6:311 Butt welded connections

For a welded connection with complete penetration the capacity is calculated at the section adjacent to the weld, see Figure 6:311a. If the ultimate strength of the filler metal is lower than that of the parent material, the capacity is calculated at the section through the weld.

A welded connection with incomplete penetration is calculated as for a fillet weld in accordance with Subclause 6:312 and with the depth of the design section in accordance with Figure 6:311b.

![Figure 6:311a Examples of design sections for butt welded connections (the arrow indicates the direction of force).](image)

![Figure 6:311b Examples of the depth of design section for different types of welds with incomplete penetration.](image)

6:312 Fillet welded connections

In a fillet welded connection, the design section is taken both at the section through the weld which has the least nominal sectional area, and at the section immediately adjacent to the weld, as shown in Figure 6:312b.

For the design section through the weld, the height of the section is equal to the nominal throat thickness of the weld, which is the height of the largest triangle that can be inscribed between the fusion faces and the top surface of the weld in accordance with Figure 6:312a. The length of the section, the effective weld length, is the length without crater pipes etc.
Figure 6:312a  Nominal throat thickness \( a \) for a fillet weld.

A weld length greater than 60 times the throat thickness should not be taken into account for a fillet weld if the weld in its longitudinal direction transmits a force which, for the sake of simplicity, is assumed to be uniformly distributed over the length of the weld. For a structure not subject to fatigue loading (see Subclause 2:11) and where the risk of brittle fracture is small (in accordance with Table 7:21b not greater than 5), the weld length which may be taken into account may however be increased to 100 times the throat thickness.

Normally, the throat thickness of a weld should not be less than 3 mm. When the throat thickness exceeds 15 mm, the reduction in strength in large fillet welds should be taken into account.

Figure 6:312b  Design sections for a fillet weld with equal leg lengths.

6:32  Capacity in the ultimate limit states

For a parent material with \( f_{uk} \) not greater than 500 MPa, a butt welded connection which is subjected to a load that is not a fatigue load may be considered to have a strength equal to that of the parent material if the ultimate strength of the filler metal is at least the same as that of the parent material. For other welded connections, the capacity should be checked for design sections through the weld and adjacent to the weld.

The capacity of a design section through the weld is determined by the design value of the strength of the weld metal, \( f_{wd} \) calculated from
\[
f_{\text{wd}} = \begin{cases} 
\frac{\varphi \sqrt{f_{\text{uk}} f_{\text{euk}}}}{1.2 \gamma_n} & \text{om } f_{\text{uk}} < f_{\text{euk}} \\
\frac{\varphi f_{\text{euk}}}{1.2 \gamma_n} & \text{om } f_{\text{uk}} \geq f_{\text{euk}}
\end{cases}
\]  
(6:32a)

\(f_{\text{uk}}\) characteristic strength of the parent material. In the case of more than one material the lowest value applies.

\(f_{\text{euk}}\) characteristic strength of the electrode material

The reduction factor \(\varphi\) should be put equal to 0.9. For a butt weld in Weld Classes WA and WB, however, \(\varphi\) may be put equal to 1.0.

The capacity in the ultimate limit state for a design section through the weld is calculated in accordance with the following expressions (symbols in accordance with Figure 6:32).

\[F_{R||} = 0.6 d l f_{\text{wd}}\]  
(6:32b)

and

\[F_{R\alpha} = \frac{d l f_{\text{wd}}}{\sqrt{2 + \cos 2\alpha}}\]  
(6:32c)

\(d\) height of design section, i.e. \(d\) is equal to the throat thickness of the weld \(a\) for a section through a fillet weld, and \(d\) is equal to \(s\) for a butt welded connection with incomplete penetration

\(l\) effective weld length

\(F_{\|}\) the component of the resultant force in the longitudinal direction of the design section

\(F_{\alpha}\) the component in a plane perpendicular to the longitudinal direction

\(\alpha\) the angle between \(F_{\alpha}\) and the design section

**Figure 6:32** Symbols for the calculation of the capacity of design sections through butt and fillet welds.
Where a weld is subjected to forces in both the transverse and longitudinal directions, the following condition should be met.

\[
\left( \frac{F_{\text{SII}}}{F_{R||}} \right)^2 + \left( \frac{F_{\text{SII}}}{F_{Ra}} \right)^2 \leq 1.00
\]  

(6:32d)

For a design section adjacent to the weld, the capacity is calculated in accordance with formulas 6:32b–d, \( f_{\text{wd}} \) in formulas 6:32b and c being replaced by \( f_{\text{ud}} \) for the parent material if this value is less than \( f_{\text{wd}} \) and \( d = z \).

### 6:33 Interaction in connections

Longitudinal and transverse fillet welds in e.g. a connection comprising splice plates, or at the attachment of a section bar, may be designed for a distribution of forces calculated in accordance with the elastic theory or for some other distribution of forces which can be demonstrated to be applicable.

Where a welded connection is combined with a bolted connection, the welded connection is normally designed for the entire force unless it is demonstrated that acceptable interaction occurs. In the case of a welded connection combined with a high strength friction grip bolt connection, Class S3 in accordance with Subclause 8:51, interaction may be assumed.

### 6:34 Detailing of welded connections

Where a butt weld is made between elements of different thicknesses, the thicker element should be tapered at a slope of 1:2 or flatter, see Figure 6:34.

Transmission of pressure between two parts of a welded structure may be assumed to take place in direct bearing between the faying surfaces provided that the faying surfaces are well fitted to each other, see Subclause 8:63. Such faying surfaces should be marked on drawings.

A welded connection in Corrosivity Category C1 or C2 may be detailed with the backing strip left in position, provided that the effect of stress concentration is allowed for. Such a backing strip should be marked on drawings.

\[\text{Slope not to exceed 1:2}\]

Figure 6:34 Tapering of thicker element in a butt welded connection.
6:4 Design of bolted connections

6:41 Conditions

This subclause provides design methods for certain specified bolted connections which are listed in Table 6:41. With regard to material requirements and classification, reference is to be made to Subclauses 7:14 and 8:51. With regard to the basic values of strength, reference is to be made to Subclause 2:24.

Table 6:41 Specified bolted connections

<table>
<thead>
<tr>
<th>Bolted Connection Class</th>
<th>Strength Classes</th>
<th>Permissible action in conjunction with fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1, S1 (fine)</td>
<td>8.8</td>
<td>−</td>
</tr>
<tr>
<td>S1F</td>
<td>10.9</td>
<td>$F_t$</td>
</tr>
<tr>
<td>S2</td>
<td>8.8</td>
<td>$F_v$</td>
</tr>
<tr>
<td>S2F</td>
<td>10.9</td>
<td>$F_t + F_v$</td>
</tr>
<tr>
<td>S3, S3 (coarse)</td>
<td>10.9</td>
<td>$F_t + F_v$</td>
</tr>
</tbody>
</table>

1 $F_t =$ tensile force, $F_v =$ shear force
2 S1(fine) is to be used if movements in the connection would cause substantial deterioration in the performance of the structure.

6:42 Calculation of forces

In designing a connection subjected to a tensile force, prying forces may occur due to deformations (distortion) in the connection. These prying forces are to be added to the tensile force due to the external load, see Figure 6:42a. Tensile forces in the bolts due to preloading are to be disregarded.

Prying forces due to distortion may be disregarded if the moment capacity of the plates which transmit tensile forces to the bolts is greater than the bending moment due to design loads with $F_p = 0$. In this case the shape factor $\eta$ for the plates may be taken as 1.5.
In connections containing bolts of the same dimension which are subjected to an axial shear force, the force is assumed to be uniformly distributed over all the bolts if the length \( L \) of the connection in the direction of force is less than \( 15d \), where \( d \) is the bolt diameter.

If the length of the connection is greater, the greatest force \( F_{\text{Svd}} \) on a bolt is to be calculated from the formula

\[
F_{\text{Svd}} = \frac{F_S}{n} \left(0.925 + \frac{L}{200d}\right) \quad (6:42)
\]

- \( n \) number of bolts
- \( L \) length of connection according to Figure 6:42b
- \( d \) bolt diameter

If the shear force acts eccentrically in the shear plane, the force on the bolts due to the moment is calculated in accordance with the elastic theory on the assumption of rigid plates and flexible bolts.

An eccentricity perpendicular to the shear plane which is less than the plate thickness may be disregarded. If a packing plate is used, the effect of this is to be allowed for by increasing the force on the bolts by 1.25% for each mm by which the thickness of the packing plate exceeds 6 mm. This increase in force is not required in high strength friction grip bolted connections if the packing plate is finished in the same way as the other contact surfaces in the connection.
6:43 The capacity of bolts in the ultimate limit states

6:431 Tension

The design value of capacity in tension, $F_{Rtd}$, is calculated from the formula

$$F_{Rtd} = \phi_t A_s f_{bud}$$

(6:431)

$A_s$ stress area of bolt

$\phi_t$ reduction factor which is

1.0 for highly preloaded bolts in Strength Class 10.9

0.6 for normally tightened bolts

$f_{bud}$ design value of the ultimate strength of bolt, i.e. $\frac{f_{bud}}{\gamma_m \gamma_n}$

For a threaded structural member, e.g. a foundation bolt, the resistance of the member is to be calculated in the same way as for an ordinary structural member, i.e. $F_{Rtd} = A_s f_{yd}$.

6:432 Shear

The design value for the capacity in shear (force perpendicular to the longitudinal axis of the bolt) is the lesser of the values $F_{Rvd}$ corresponding to shear failure of the bolt and $F_{Rbd}$ corresponding to bearing failure of the plate.

$$F_{Rvd} = 0.6 A_1 f_{bud}$$

(6:432a)

$A_1$ nominal area of the bolt if the shear plane cuts the shank of the bolt, and the stress area of the bolt, $A_s$, if the plane cuts the threaded portion of the bolt

$$F_{Rbd} = 1.2 \left( \frac{e_1}{d} - 0.5 \right) d_s t f_{bud}$$

(6:432b)

$d$ bolt diameter

$$d_s \begin{cases} d & \text{in contact with shank of bolt} \\ \sqrt{4 A_s / \pi} & \text{in contact with thread} \end{cases}$$

$e_1$ distance from the centre of a hole to a free edge or to the centre of an adjacent hole measured in the direction of force. If $e_1 > 3d$, the value to be used is $e_1 = 3d$

$t$ thickness of the structural member which transmits the force to the bolt.
6:433 Combined tension and shear

When tensile and shear forces act simultaneously, the following condition applies

\[
\left( \frac{F_{St}}{F_{Rtd}} \right)^2 + \left( \frac{F_{Sv}}{F_{Rvd}} \right)^2 \leq 1.00
\]  

(6:433)

\(F_{St}, F_{Sv}\) calculated tensile force and shear force respectively due to the design load in the ultimate limit state

\(F_{Rtd}\) capacity in tension in accordance with formula 6:431, but calculated on the nominal bolt area if the shear plane intersects the unthreaded shank of the bolt

\(F_{Rvd}\) capacity in shear in accordance with formula 6:432a.

6:44 Slip

For a high strength friction grip bolted connection, the resistance with respect to slip, \(F_{Rsd}\), is calculated from the formula

\[
F_{Rsd} = \mu_d \left( \beta A_s f_{buk} - 0.8 F_{St} \right)
\]  

(6:44)

\(\mu_d\) coefficient of friction \(\mu_k/\gamma_n\), where \(\mu_k\) is obtained from Table 6:44 or is determined by tests in accordance with SS 27 11 17. In the serviceability limit state, \(\gamma_n = 1.0\) is applies

\(A_s\) stress area of bolt

\(F_{St}\) calculated tensile force due to design loads

\(\beta\)

0.7 for Bolted Connection Class S3

0.6 for Class S3 (coarse) or for Class S3 with holes elongated by not more than \(d/4\)

0.5 for Class S3 with holes elongated by not more than \(1.5d\)

Where a welded connection and a bolted connection in the same plane interact the bolted connection should be designed with respect to slip in the ultimate limit state.

Bolted connections with elongated holes should be constructed to Bolted Connection Class S3 or S3 (coarse). It is stipulated that elongated holes are covered by at least 8 mm plates, with the hole diameter in accordance with SS–ISO 273, medium series. When elongated holes are used, the consequences of a slip in the connection in the longitudinal direction of the hole must be assessed in order that a decision may be made whether the slip is to be regarded to act in the ultimate limit state.
Table 6:44  Characteristic value of coefficient of friction $\mu_k$ for different surface finishes

<table>
<thead>
<tr>
<th>Surface finish</th>
<th>$\mu_k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean mill scale</td>
<td>0.3</td>
</tr>
<tr>
<td>Grit or shot blasted or flame cleaned surface</td>
<td>0.5</td>
</tr>
<tr>
<td>Hot dip zinc coated surface</td>
<td>0.15</td>
</tr>
<tr>
<td>Hot dip zinc coated and grit or shot blasted surface</td>
<td>0.35</td>
</tr>
<tr>
<td>Sprayed zinc coated surface</td>
<td>0.3</td>
</tr>
<tr>
<td>Sprayed aluminium coated surface</td>
<td>0.5</td>
</tr>
<tr>
<td>Zinc silicate paint, coat thickness $\leq 100 \mu m$</td>
<td>0.4</td>
</tr>
</tbody>
</table>

6:45  Detailing of connections

In detailing a connection, the endeavour should be to limit its size. Care should also be taken to ensure that there is sufficient space for satisfactory tightening of the connection and for future maintenance.

It is stipulated that a connection should normally have at least two bolts.

The specified minimum distances for bolts with respect to resistance and assembly are given in Table 6:45. The table also includes the specified maximum distances with respect to the risk of corrosion in structures in Corrosivity Category C3 or higher. The relevant symbols are given in Figure 6:45.

Table 6:45  Specified edge distances and distances between centres of bolts

<table>
<thead>
<tr>
<th>Minimum edge distance</th>
<th>$e_t \geq 1.2 d^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>in conjunction with tensile force</td>
<td>$e_2 \geq 1.2 d$</td>
</tr>
<tr>
<td>in conjunction with shear force</td>
<td>$e_2 \geq 1.5 d^1$</td>
</tr>
<tr>
<td>Minimum distance between centres</td>
<td>$e_c \geq 2.5 d^1$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum edge distance</th>
<th>$e_t, e_2 \leq 6 t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>unstiffened edge</td>
<td></td>
</tr>
<tr>
<td>stiffened edge</td>
<td>$e_t, e_2 \leq 8 t$</td>
</tr>
<tr>
<td>Maximum distance between centres</td>
<td>$e_c \leq 14 t$</td>
</tr>
</tbody>
</table>

$^1$ When the bearing pressure is fully utilised, the distance should be $3d$ in the direction of force, see formula 6:432b.
In close tolerance connections and in shear connections in which bolts with fine series holes are used in order to limit movements in the connection, it is normally stipulated that the unthreaded portion of the shank terminates outside the parent material. In such cases one or more washers should be used underneath the nut. In high strength friction grip bolted connections and in bolted connections where medium series holes are used, the threaded portion may terminate inside the parent material.

Washers should be used in the following cases:
- if the unthreaded portion of the shank terminates outside the parent material
- if the structure has been given a surface finish, at which the washer is placed below the element which is being rotated
- if the bearing pressure due to a preloading force exceeds the ultimate strength of the parent material without a washer. The bearing pressure is calculated on the contact surface between the parent material and the head of the bolt or between the parent material and the nut
- if the contact surface is not perpendicular to the direction of the bolt (a tapered washer should be used).
6:5 Design with respect to fatigue

6:51 Design principles

6:511 Calculation of stress range

The term stress range $\sigma_{rd}$ refers to the difference between the maximum and minimum stress at a specific point in a cross section, stresses being calculated as nominal stresses without consideration of local stress variations due, for instance, to the detailed geometry of a weld. Stresses should be calculated in accordance with the elastic theory. For a section through a fillet weld, the stress components should be calculated as shown in Figure 6:511.

![Figure 6:511 Stress components in a design section through a fillet weld.](image)

For bolted connections in Classes S3 and S3 (coarse) in accordance with Table 8:51, the stress range should be calculated on the basis of the gross area, and for other Classes (S1F, S2 and S2F) on the basis of the net area.

In the case of highly preloaded connections S1F, S2F, S3 and S3 (coarse), with bolts subjected to an external tensile force, the variation in tension in the bolts may be assumed to correspond to 20% of the variation in the external tensile force unless some other figure is shown to be more correct.

6:512 Design criteria

For members only subjected to normal stress, the design criterion with respect to fatigue is

$$\sigma_{rd} \leq f_{rd}$$

(6:512a)

where $f_{rd} = f_k/(1.1 \gamma_k)$ is the design value of the fatigue strength in accordance with Subclause 3:42. If $\sigma_{rd}$ is smaller than 25 MPa, this design criterion is satisfied for structures in Workmanship Classes GA and GB.
If the stress range comprises only shear stresses, the design criterion is

\[ \tau_{rd} \leq f_{rvd} \]  

(6:512b)

where \( f_{rvd} = 0.6 \, f_{rd} \) with \( f_{rd} \) in accordance with formula 6:512a. For bolts in Strength Classes 8.8 and 10.9, \( f_{rvd} = 0.9 \, f_{rd} \).

In conjunction with a state of multiaxial stress, with the stress ranges \( \sigma_{r\parallel} \), \( \tau_{r\parallel} \), \( \sigma_{r\perp} \) and \( \tau_{r\perp} \), the following criterion also applies for each individual stress component in addition to the criteria in accordance with formulas 6:512a and b:

\[
\sqrt{\frac{\sigma_{r\parallel}^2}{f_{rd\parallel}^2} + \frac{\sigma_{r\perp}^2}{f_{rd\perp}^2} + \frac{\tau_{r\parallel}^2}{f_{rvd}^2} + \frac{\tau_{r\perp}^2}{f_{rvd}^2}} \leq 1.10
\]  

(6:512c)

For certain types of connections given in Appendix No. 3, Type 26 section a–a, and for Types 43–50, the multiaxiality of the state of stress is to be allowed for in determining the value of \( C \). In such cases the criterion in accordance with formula 6:512c need not be satisfied.

6:52 Characteristic fatigue strength

6:521 General

The characteristic fatigue strength, \( f_{k} \), is to be calculated with due regard to the stress concentration effects characterised by the Detail Category \( C \) in accordance with Subclause 6:522, the number of stress cycles \( n_t \) during the service life of the structure, and the shape of the stress spectrum in accordance with Subclauses 6:523 and 6:524.

6:522 Detail Categories

The Detail Category \( C \) is a measure of the characteristic fatigue strength for \( 2 \cdot 10^6 \) stress cycles at a constant stress range.

Connection categories for parent material and welded connections are given in Table B3:1 in Appendix No. 3. The values given assume Workmanship Class GA or GB in accordance with Subclause 8:12.

If the Detail Category is not evident from Table B3:1, for instance in the case of intersecting welds, the Detail Category for two or more interacting stress concentration factors is to be determined as follows.

In the case of two interacting stress concentration factors, the Detail Category is to be regarded equal to the least value of \( C \) for the two stress concentration factors, reduced by one step in the series of \( C \) values in accordance with Figure 6:523. In the case of more than two interacting stress concentration factors, the Detail Category is to be regarded equal to the least value of \( C \) reduced by two steps.
A hole in the vicinity of a weld is assumed to affect the fatigue strength of the weld if the distance between the edge of the hole and the edge of the weld is less than the diameter of the hole. The effect of the hole is to be allowed for in the calculation by increasing the calculated nominal stress range by multiplication by the factor $\frac{\sqrt{200}}{C}$, where $C$ is the Detail Category for the hole, determined in accordance with No. 08 in Table B3:1.

In the case of a circular hole which is filled by a bolt that has been tightened at least by the normal tightening effort in accordance with Clause 8:5, the Detail Category for the hole in Table B3:1 may be increased by two steps in the series of $C$ values in Figure 6:523.

Connection categories for connections comprising fasteners are given in Table B3:2. The tabulated values of $C$ allow for the influence of secondary effects such as moments due to local eccentricity in the connection and any deviations from the assumed equal distribution of the force on the connection over the bolts. If the moment due to eccentricity is allowed for in calculating the stress range, the value of $C$ for the parent material, Nos. 01–12 in Table B3:2, may be put equal to 100 provided that the hole is filled with a tightened bolt.

### 6:523 Strength in conjunction with a constant stress range

In conjunction with a stress spectrum with a constant stress range and fewer than $5 \cdot 10^6$ stress cycles, the characteristic value of the fatigue strength is

$$f_{rk} = C \left( \frac{2 \cdot 10^6}{n_t} \right)^{\frac{1}{3}} \quad (6:523a)$$

- $C$  
  Detail Category in accordance with Table B3:1 or B3:2
- $n_t$  
  number of stress cycles during the assumed service life of the structure.

In the case of structures which are not appreciably affected by corrosion, for instance where the corrosion protection is well maintained in accordance with Clause 8:7, it may be assumed that the fatigue limit in conjunction with a constant stress range is reached at $5 \cdot 10^6$ stress cycles. In the case of other structures, the fatigue limit in conjunction with a constant stress range is assumed to be reached at $10^8$ stress cycles.

The relationship between the characteristic value of the fatigue strength and the number of stress cycles is given in Figure 6:523.
Figure 6:523  Characteristic fatigue strength $f_{tk}$. The full lines are to be applied for structures not affected by corrosion and with a stress spectrum with a constant stress range ($\kappa = 1$). For a variable stress range, reference is to be made to Subclause 6:524.

The fatigue strength of parent material which is not affected by welding or thermal cutting may be increased by multiplying the value of $f_{tk}$ according to Figure 6:523 by the material factor $\varphi_m$ in accordance with Table 6:523. The parent material may be considered to be unaffected by welding or thermal cutting if the distance to the edge of the weld or cut edge is at least $3t$ or at least 50 mm, where $t$ is the thickness of the parent material.

Table 6:523  Material factor for parent material unaffected by welding or thermal cutting

<table>
<thead>
<tr>
<th>Ultimate strength (MPa)</th>
<th>$\varphi_m$</th>
<th>Ultimate strength (MPa)</th>
<th>$\varphi_m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$340 \leq f_{uk} &lt; 410$</td>
<td>1.0</td>
<td>$490 \leq f_{uk} &lt; 600$</td>
<td>1.20</td>
</tr>
<tr>
<td>$410 \leq f_{uk} &lt; 450$</td>
<td>1.10</td>
<td>$600 \leq f_{uk}$</td>
<td>1.25</td>
</tr>
<tr>
<td>$450 \leq f_{uk} &lt; 490$</td>
<td>1.15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
On the assumption that the magnitudes of residual stresses are known in the region affected by stress concentration factors and that the residual stresses are added to the stresses of the design stress spectrum in determining the stress ratio $\beta = \sigma_{\text{min}} / \sigma_{\text{max}}$, the value of $f_{rk}$ according to Figure 6:523 may be increased by multiplication by the stress alternation factor $\varphi_c$ in accordance with the following formula:

$$
\varphi_c = \frac{1 - \beta}{1 - 0.7 \beta}
$$

(6:523b)

This formula is to be applied in conjunction with alternating stresses, i.e. when $\beta < 0$. If $\sigma_{\text{max}}$ is also a compressive stress, i.e. $\beta > 0$, $\varphi_c$ may be put equal to 1.43.

The fatigue strength is dependent on dimensions. This may be taken into account by multiplying the value of $f_{rk}$ according to Figure 6:523 by the thickness factor, $\varphi_{\text{dim}}$ in accordance with the following formula:

$$
\varphi_{\text{dim}} = \left( \frac{25 \text{[mm]}}{t} \right)^{0.0763} \geq 1.0
$$

(6:523c)

where $t$ [mm] is the greatest material thickness of the connecting plates at the design point.

### 6:524 Design in conjunction with a variable stress range

In conjunction with a stress spectrum with a variable stress range, the Palmgren-Miner cumulative damage hypothesis is to be applied on the basis of the characteristic fatigue strength in accordance with Subclause 6:523. The design value for each stress range is to be determined by multiplying the calculated nominal stress range for the design load effect by a factor $1.1 \gamma_h$ where $\gamma_h$ depends on the Safety Class in accordance with Subclause 1:214.

In assembling the stress spectra, the 100 stress cycles which have the largest stress range, and stress cycles for which the design values of the stress range are smaller than values corresponding to the fatigue limit $n_t = 10^8$, may be ignored.

The design criterion in conjunction with a variable stress range is as follows:

$$
\sum \left( \frac{n_i}{n_{ti}} \right) \leq 1.0
$$

(6:524)

$n_i$ number of stress cycles at a certain stress range $\sigma_{ri}$

$n_{ti}$ number of stress cycles at a constant stress range in accordance with Figure 6:523 which corresponds to a characteristic strength equal to the stress range $\sigma_{ri}$. 

For standardised stress spectra in accordance with Figure 6:524, Table 6:524 gives values of the characteristic fatigue strength $f_{ek}$ for various spectrum parameters and numbers of stress cycles.

**Figure 6:524  Standardised stress spectra.**

Design is to be carried out in accordance with formula 6:512a, where $\sigma_{rd}$ is the largest nominal stress range in the stress spectrum being considered. Assembly of the stress spectrum may be carried out in accordance with the same principles which, in accordance with the foregoing, apply in using the cumulative damage hypothesis.
Table 6:524  Characteristic fatigue strength in conjunction with standardised stress spectra

<table>
<thead>
<tr>
<th>Characteristic fatigue strength $f_k$ (MPa)</th>
<th>$n_0$</th>
<th>45</th>
<th>50</th>
<th>56</th>
<th>63</th>
<th>71</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>112</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\kappa$</td>
<td>$10^3$</td>
<td>567</td>
<td>630</td>
<td>706</td>
<td>794</td>
<td>895</td>
<td>1010</td>
<td>1130</td>
<td>1260</td>
<td>1410</td>
<td>1570</td>
</tr>
<tr>
<td></td>
<td>$10^4$</td>
<td>263</td>
<td>292</td>
<td>327</td>
<td>368</td>
<td>415</td>
<td>468</td>
<td>526</td>
<td>585</td>
<td>655</td>
<td>731</td>
</tr>
<tr>
<td></td>
<td>$10^5$</td>
<td>122</td>
<td>136</td>
<td>152</td>
<td>171</td>
<td>193</td>
<td>217</td>
<td>244</td>
<td>271</td>
<td>304</td>
<td>339</td>
</tr>
<tr>
<td></td>
<td>$10^6$</td>
<td>56.7</td>
<td>63.0</td>
<td>70.6</td>
<td>79.4</td>
<td>89.5</td>
<td>101</td>
<td>113</td>
<td>126</td>
<td>141</td>
<td>157</td>
</tr>
<tr>
<td>$5 \times 10^6$</td>
<td>33.2</td>
<td>36.8</td>
<td>41.3</td>
<td>46.4</td>
<td>52.3</td>
<td>58.9</td>
<td>66.3</td>
<td>73.7</td>
<td>82.5</td>
<td>92.1</td>
<td></td>
</tr>
<tr>
<td>$10^7$</td>
<td>28.9</td>
<td>32.1</td>
<td>35.9</td>
<td>40.4</td>
<td>45.6</td>
<td>51.3</td>
<td>57.7</td>
<td>64.1</td>
<td>71.8</td>
<td>80.2</td>
<td></td>
</tr>
<tr>
<td>$10^8$</td>
<td>18.2</td>
<td>20.2</td>
<td>22.7</td>
<td>25.5</td>
<td>28.7</td>
<td>32.4</td>
<td>36.4</td>
<td>40.5</td>
<td>45.3</td>
<td>50.6</td>
<td></td>
</tr>
<tr>
<td>$5/6$</td>
<td>$10^3$</td>
<td>661</td>
<td>735</td>
<td>823</td>
<td>925</td>
<td>1040</td>
<td>1180</td>
<td>1320</td>
<td>1470</td>
<td>1650</td>
<td>1840</td>
</tr>
<tr>
<td></td>
<td>$10^4$</td>
<td>309</td>
<td>343</td>
<td>384</td>
<td>433</td>
<td>487</td>
<td>549</td>
<td>618</td>
<td>687</td>
<td>769</td>
<td>858</td>
</tr>
<tr>
<td></td>
<td>$10^5$</td>
<td>144</td>
<td>160</td>
<td>179</td>
<td>202</td>
<td>227</td>
<td>256</td>
<td>288</td>
<td>320</td>
<td>358</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>$10^6$</td>
<td>67.1</td>
<td>74.5</td>
<td>83.4</td>
<td>93.9</td>
<td>106</td>
<td>119</td>
<td>134</td>
<td>149</td>
<td>167</td>
<td>186</td>
</tr>
<tr>
<td></td>
<td>$10^7$</td>
<td>34.2</td>
<td>38.0</td>
<td>42.6</td>
<td>47.9</td>
<td>54.0</td>
<td>60.8</td>
<td>68.4</td>
<td>76.0</td>
<td>85.1</td>
<td>95.0</td>
</tr>
<tr>
<td></td>
<td>$10^8$</td>
<td>21.6</td>
<td>24.0</td>
<td>26.9</td>
<td>30.3</td>
<td>34.1</td>
<td>38.4</td>
<td>43.2</td>
<td>48.0</td>
<td>53.8</td>
<td>60.0</td>
</tr>
<tr>
<td>$2/3$</td>
<td>$10^3$</td>
<td>790</td>
<td>878</td>
<td>983</td>
<td>1110</td>
<td>1250</td>
<td>1400</td>
<td>1580</td>
<td>1760</td>
<td>1970</td>
<td>2190</td>
</tr>
<tr>
<td></td>
<td>$10^4$</td>
<td>373</td>
<td>415</td>
<td>465</td>
<td>523</td>
<td>589</td>
<td>664</td>
<td>747</td>
<td>830</td>
<td>929</td>
<td>1040</td>
</tr>
<tr>
<td></td>
<td>$10^5$</td>
<td>175</td>
<td>195</td>
<td>218</td>
<td>245</td>
<td>277</td>
<td>312</td>
<td>351</td>
<td>390</td>
<td>436</td>
<td>487</td>
</tr>
<tr>
<td></td>
<td>$10^6$</td>
<td>82.0</td>
<td>91.1</td>
<td>102</td>
<td>115</td>
<td>129</td>
<td>146</td>
<td>164</td>
<td>182</td>
<td>204</td>
<td>228</td>
</tr>
<tr>
<td></td>
<td>$10^7$</td>
<td>41.9</td>
<td>46.6</td>
<td>52.2</td>
<td>58.7</td>
<td>66.1</td>
<td>74.5</td>
<td>83.8</td>
<td>93.1</td>
<td>104</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>$10^8$</td>
<td>26.6</td>
<td>29.5</td>
<td>33.0</td>
<td>37.2</td>
<td>41.9</td>
<td>47.2</td>
<td>53.1</td>
<td>59.0</td>
<td>66.1</td>
<td>73.8</td>
</tr>
<tr>
<td>$1/2$</td>
<td>$10^3$</td>
<td>976</td>
<td>1080</td>
<td>1210</td>
<td>1370</td>
<td>1540</td>
<td>1740</td>
<td>1950</td>
<td>2170</td>
<td>2430</td>
<td>2710</td>
</tr>
<tr>
<td></td>
<td>$10^4$</td>
<td>470</td>
<td>522</td>
<td>585</td>
<td>658</td>
<td>742</td>
<td>836</td>
<td>940</td>
<td>1040</td>
<td>1170</td>
<td>1310</td>
</tr>
<tr>
<td></td>
<td>$10^5$</td>
<td>223</td>
<td>248</td>
<td>278</td>
<td>313</td>
<td>352</td>
<td>397</td>
<td>447</td>
<td>496</td>
<td>556</td>
<td>620</td>
</tr>
<tr>
<td></td>
<td>$10^6$</td>
<td>105</td>
<td>117</td>
<td>131</td>
<td>147</td>
<td>166</td>
<td>187</td>
<td>210</td>
<td>234</td>
<td>262</td>
<td>292</td>
</tr>
<tr>
<td></td>
<td>$10^7$</td>
<td>54.0</td>
<td>60.0</td>
<td>67.2</td>
<td>75.6</td>
<td>85.2</td>
<td>96.0</td>
<td>108</td>
<td>120</td>
<td>134</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>$10^8$</td>
<td>35.2</td>
<td>39.1</td>
<td>43.8</td>
<td>49.2</td>
<td>55.5</td>
<td>62.5</td>
<td>70.3</td>
<td>78.1</td>
<td>87.5</td>
<td>97.7</td>
</tr>
<tr>
<td>$1/3$</td>
<td>$10^3$</td>
<td>1260</td>
<td>1400</td>
<td>1560</td>
<td>1760</td>
<td>1980</td>
<td>2230</td>
<td>2510</td>
<td>2790</td>
<td>3130</td>
<td>3490</td>
</tr>
<tr>
<td></td>
<td>$10^4$</td>
<td>627</td>
<td>697</td>
<td>781</td>
<td>878</td>
<td>990</td>
<td>1120</td>
<td>1250</td>
<td>1390</td>
<td>1560</td>
<td>1740</td>
</tr>
<tr>
<td></td>
<td>$10^5$</td>
<td>305</td>
<td>339</td>
<td>380</td>
<td>427</td>
<td>481</td>
<td>542</td>
<td>610</td>
<td>678</td>
<td>759</td>
<td>847</td>
</tr>
<tr>
<td></td>
<td>$10^6$</td>
<td>146</td>
<td>162</td>
<td>182</td>
<td>205</td>
<td>230</td>
<td>260</td>
<td>292</td>
<td>325</td>
<td>364</td>
<td>406</td>
</tr>
<tr>
<td></td>
<td>$10^7$</td>
<td>75.7</td>
<td>84.1</td>
<td>94.2</td>
<td>106</td>
<td>119</td>
<td>135</td>
<td>151</td>
<td>168</td>
<td>188</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td>$10^8$</td>
<td>51.3</td>
<td>57.0</td>
<td>63.9</td>
<td>71.9</td>
<td>81.0</td>
<td>91.3</td>
<td>103</td>
<td>114</td>
<td>128</td>
<td>143</td>
</tr>
<tr>
<td>$1/6$</td>
<td>$10^3$</td>
<td>1680</td>
<td>1870</td>
<td>2090</td>
<td>2350</td>
<td>2650</td>
<td>2990</td>
<td>3380</td>
<td>3740</td>
<td>4190</td>
<td>4670</td>
</tr>
<tr>
<td></td>
<td>$10^4$</td>
<td>904</td>
<td>1000</td>
<td>1130</td>
<td>1270</td>
<td>1430</td>
<td>1610</td>
<td>1810</td>
<td>2010</td>
<td>2250</td>
<td>2510</td>
</tr>
<tr>
<td></td>
<td>$10^5$</td>
<td>465</td>
<td>516</td>
<td>578</td>
<td>651</td>
<td>733</td>
<td>826</td>
<td>929</td>
<td>1030</td>
<td>1160</td>
<td>1290</td>
</tr>
<tr>
<td></td>
<td>$10^6$</td>
<td>232</td>
<td>258</td>
<td>289</td>
<td>325</td>
<td>366</td>
<td>412</td>
<td>464</td>
<td>515</td>
<td>577</td>
<td>644</td>
</tr>
<tr>
<td></td>
<td>$10^7$</td>
<td>123</td>
<td>137</td>
<td>153</td>
<td>173</td>
<td>194</td>
<td>219</td>
<td>246</td>
<td>274</td>
<td>307</td>
<td>342</td>
</tr>
<tr>
<td></td>
<td>$10^8$</td>
<td>81.9</td>
<td>91.0</td>
<td>102</td>
<td>115</td>
<td>129</td>
<td>146</td>
<td>164</td>
<td>182</td>
<td>204</td>
<td>228</td>
</tr>
<tr>
<td>$0$</td>
<td>$10^3$</td>
<td>2220</td>
<td>2470</td>
<td>2760</td>
<td>3110</td>
<td>3500</td>
<td>3950</td>
<td>4440</td>
<td>4940</td>
<td>5530</td>
<td>6170</td>
</tr>
<tr>
<td></td>
<td>$10^4$</td>
<td>1340</td>
<td>1490</td>
<td>1670</td>
<td>1880</td>
<td>2120</td>
<td>2390</td>
<td>2680</td>
<td>2980</td>
<td>3340</td>
<td>3730</td>
</tr>
<tr>
<td></td>
<td>$10^5$</td>
<td>775</td>
<td>861</td>
<td>964</td>
<td>1080</td>
<td>1220</td>
<td>1380</td>
<td>1550</td>
<td>1720</td>
<td>1930</td>
<td>2150</td>
</tr>
<tr>
<td></td>
<td>$10^6$</td>
<td>432</td>
<td>481</td>
<td>538</td>
<td>605</td>
<td>682</td>
<td>769</td>
<td>865</td>
<td>961</td>
<td>1090</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>$10^7$</td>
<td>241</td>
<td>267</td>
<td>299</td>
<td>337</td>
<td>380</td>
<td>428</td>
<td>481</td>
<td>535</td>
<td>599</td>
<td>668</td>
</tr>
<tr>
<td></td>
<td>$10^8$</td>
<td>144</td>
<td>160</td>
<td>179</td>
<td>202</td>
<td>227</td>
<td>256</td>
<td>288</td>
<td>320</td>
<td>359</td>
<td>400</td>
</tr>
</tbody>
</table>
6:525 Fatigue in conjunction with breathing

For slender plates the deflection of initial dents can increase and decrease when subjected to fluctuating loads. This phenomenon is known as breathing. The bending stresses which occur along the edges of the plates in conjunction with breathing, may give rise to fatigue cracks. In order to avoid such cracks the following condition should be satisfied.

\[
\sigma_{rd\parallel} \leq f_{rd\parallel}
\]  
\[
\tau_{rd\parallel} \leq 0.6 \sigma_{rd\parallel}
\]
\[
\sqrt{\frac{\sigma_{rd\parallel}^2 + \sigma_{rd\perp}^2 + \tau_{rd\parallel}^2}{f_{rd\parallel}^2 + f_{rd\perp}^2 + \omega_{v}^2}} \leq 1.1
\]

\(\sigma_{rd\parallel}\) normal stress range along the edge of the plate in connection with the weld, calculated with an effective cross section in the ultimate limit state, see K18.

\(\sigma_{rd\perp}\) normal stress range perpendicular to the edge of the plate

\(\tau_{rd\parallel}\) shearing stress range along the edge of the plate calculated on the basis of the nominal thickness of the plate. The factor \((\omega_{v}/0.6)\) multiplied by \(t_{w}\) gives the effective plate thickness

\(f_{rd\parallel}\) design value of fatigue strength in accordance with Subclause 6:512

\(f_{rd\perp}\) \(f_{rd\parallel}\)

\(\omega_{v}\) reduction factor with respect to shear buckling of cross sections in accordance with Subclause 6:261, column 1 or 2 depending on the detailing of the stiffeners

The normal stress range \(\sigma_{rd\parallel}\) and the shearing stress range \(\tau_{rd\parallel}\) should be calculated at a section taken at a distance \(s\) from the edge of the plate, where \(s\) is 0.25 times the shortest of the edges.
7 MATERIALS

7:1 General requirements for materials

*T BKR 99, Clause 2:4*

Materials for loadbearing structures, inclusive of soil and rock, shall have known and documented properties in those respects which are significant for their use.

Steels made by a process which yields products of uniform quality should be used for steel structures.

The surface properties, dimensions, shapes, homogeneity and mechanical properties of plates, bars and hollow sections should be satisfactory for the intended application.

Requirements for filler metals for welding and for materials for bolted connections and threaded structural elements are given in Subclauses 7:13 and 7:14 respectively.

Requirements regarding ductility are given in Clause 7:2.

7:11 Constructional steels


7:12 Plates, bars and hollow sections

Tolerances for plates, bars and hollow sections should normally be taken from Table 7:12.

Deviations of external and internal properties for steels in accordance with Tables 2:21a–2:21g are considered in SS–EN 10 163 and in the relevant standard and the associated NAD(S).

Plates of different qualities should meet the requirements for surface properties given in SIS 21 91 15.
Table 7:12  Dimensional and shape tolerances for plates, bars and hollow sections

<table>
<thead>
<tr>
<th>Product</th>
<th>Tolerances in accordance with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate</td>
<td>SS-EN 10 029, Tolerance Class A, B or C</td>
</tr>
<tr>
<td></td>
<td>SS-EN 10 051, category A with improved tolerances on flatness</td>
</tr>
<tr>
<td>Flat bar</td>
<td>SS 21 21 50</td>
</tr>
<tr>
<td>Square bar</td>
<td>SS 21 23 25</td>
</tr>
<tr>
<td>Round bar</td>
<td>SS 21 25 02</td>
</tr>
<tr>
<td>Angle</td>
<td>SS-EN 10 056-2</td>
</tr>
<tr>
<td>Tee</td>
<td>SS-EN 10 055</td>
</tr>
<tr>
<td>Channel</td>
<td>SIS 21 27 25</td>
</tr>
<tr>
<td>IPE section</td>
<td>Subclause 8:62 and SS–EN 10 034</td>
</tr>
<tr>
<td>HEA section</td>
<td>-.-</td>
</tr>
<tr>
<td>HEB section</td>
<td>-.-</td>
</tr>
<tr>
<td>HEM section</td>
<td>-.-</td>
</tr>
<tr>
<td>Hot finished structural hollow section</td>
<td>SS-EN 10 210</td>
</tr>
<tr>
<td>Cold formed structural hollow section</td>
<td>SS EN 10 219</td>
</tr>
</tbody>
</table>

7:13  Filler metal

BKR 99, Subclause 8:42

The properties of filler metal for welding shall be such that a welded connection has the intended function and durability. The strength and other essential material properties shall be documented.

The filler metal shall be suited to the welding process, the parent material, the welding procedure and the requirements specified for the welded connection.

Where there is a risk of hydrogen cracking, the filler metal used shall be such as to give rise to a low hydrogen content in the weld metal.

For structures in environments of high or very high aggressivity, the filler metal used shall produce a weld metal which has at least the same corrosion resistance as the parent material.

General recommendation:

Examples of filler metal are given in Clause 7:13 of BSK 99.

Environments of high aggressivity correspond to Corrosivity Category C4 in accordance with Table 1:23a and environments of very high aggressivity correspond to Corrosivity Categories C5-I, C5-M and Im1–Im3 in accordance with Table 1:23a and 1:23b.

For filler metal a higher Ductility Class should be chosen than for the parent material.
For high strength steels and for steels with special properties the choice of filler metal should be based on a report or statement from the manufacturer of the filler metal and the steel in question.

If there is a risk of hydrogen cracking, electrodes with the designation H10 or H5 should be used.

Examples of electrodes for gas-shielded arc welding and submerged arc welding are given in Subclause 2:25.

7:14 Materials for bolted connections

7:141 General requirements

**BKR 99, Subclause 8:41**

Fasteners (bolts, nuts, washers and threaded structural elements) shall have documented strength.

The properties of bolts and associated nuts for preloaded bolted connections shall be such that the nuts and threads are normally stronger than the bolts even in conjunction with unfavourable combinations of properties and sizes. In other connections the strength of the nut shall be not less than the nominal ultimate tensile strength of the bolt.

General recommendation:

Examples of fasteners are given in Clause 7:14 of *BSK 99*.

1 The phrase "preloaded bolted connections" in *BKR 99* is equivalent to the phrase "high preloaded bolted connections" in this publication.

7:142 Bolts and nuts

Bolts and nuts with metric threads for Bolted Connection Classes Sl (fine), S1 and S2 are listed in Table 7:142a. For preloaded connections S1F, S2F, S3 and S3 (coarse), examples of nuts and bolts are given in Table 7:142b. The strength requirements for bolts and nuts are given in SS-ISO 898-1 and -2.

In the case of hot dip zinc coated sections of higher Strength Classes than 8.8 an independent expert should be consulted.

**Table 7:142a  Bolts and nuts for connections S1 (fine), S1 and S2**

<table>
<thead>
<tr>
<th>Strength Class</th>
<th>Type</th>
<th>Dimensions SS-ISO</th>
<th>Product Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt 8.8¹</td>
<td>M6S</td>
<td>4014</td>
<td>A or B</td>
</tr>
<tr>
<td>Nut 8</td>
<td>M6M</td>
<td>4032</td>
<td>A or B</td>
</tr>
</tbody>
</table>

¹ Alternatively, SB 8.8 may be used.
Table 7:142b  Bolts and nuts for connections S1F, S2F, S3 and S3 (coarse)

<table>
<thead>
<tr>
<th>Strength Class</th>
<th>Type, dimensions and product class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt 10.9</td>
<td>ISO 7412 alt DIN 6914⁴ ²</td>
</tr>
<tr>
<td>Nut 10</td>
<td>ISO 7414 alt DIN 6915⁴ ²</td>
</tr>
</tbody>
</table>

1 Products in accordance with ISO standards are recommended but alternatively DIN standards may be used pending a larger supply of products in accordance with ISO standards.

2 The shank of the bolt may be smaller than the exterior diameter of the thread. This should be taken into account for bolts in Bolted Connection Class S2F, where the tolerance of the hole clearance cannot be contained if the exterior diameter of the thread is larger than the shank of the bolt.

Smaller tolerances than those specified in the above tables may be needed in order to meet the requirement of the mandatory provisions regarding high preloaded connections.

7:143 Washers

In S1 and S2 connections, washers of hardness 200 HV or higher should be used, for instance Type BRB in accordance with SS 70. In S1F, S2F, S3 and S3 (coarse) connections, quenched and tempered washers of hardness 290 HV or higher should be used, for instance in accordance with ISO 7415. The hardness should not exceed 400 HV.

7:144 Threaded structural elements

In threaded structural elements, steels in accordance with Subclause 2:21 with $f_{uk} \geq 410$ MPa. Threads and nuts are chosen in accordance with Subclause 7:142. The bar diameter should be chosen so that full thread profile is obtained, and so that the Strength Class of the nut is at least equal to the nominal ultimate tensile strength of the threaded structural element. In Workmanship Class GC reinforcing bars SS-ENV 10 080–B500B or Ks 60S (SS 21 25 15 and SIS 14 21 68) may also be used for foundation bolts. Regarding threading of surface quenched and tempered reinforcing bars, see BBK 94 Subclause 8.3.1.

It is stipulated that threads comply with Tolerance Class 6g in accordance with SS-ISO 965.
7:2 Ductility

7:21 Ductility Classes

General requirements regarding the ductility of steel structures are given in Subclause 1:215.

The risk of brittle fracture may be reduced by appropriate detailing in order to avoid stress concentrations, multiaxial tensile stress and large material thickness ($\geq 40\text{ mm}$).

Material for steel structures should be selected with due regard to Ductility Class in accordance with Table 7:21a or on the basis of a special investigation.

Table 7:21a Choice of Ductility Class

<table>
<thead>
<tr>
<th>Safety Class</th>
<th>Type of structure and service conditions</th>
<th>Ductility Class (Quality Class)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>2 and 3</td>
<td>All structures with values of the parameter $m$ in accordance with Table 7:21b, for</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\sum m \leq 4$</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>$5 \leq \sum m \leq 8$</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>$9 \leq \sum m$</td>
<td>E</td>
</tr>
</tbody>
</table>
Table 7:21b  Parameter m for the choice of Ductility Class in accordance with Table 7:21a

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>( T ) (ºC)</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest service temperature, ( T )</td>
<td>( T \geq 5)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( -40 \leq T &lt; 5)</td>
<td>2</td>
</tr>
<tr>
<td>Tensile stress occurs and ( f_{yk} ) (MPa) is in the interval</td>
<td>( f_{yk} &lt; 300 )</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( 300 \leq f_{yk} &lt; 460 )</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>( 460 &lt; f_{yk} )</td>
<td>2</td>
</tr>
<tr>
<td>Material thickness, ( t ) (mm)</td>
<td>( t \leq 20 )</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( 20 &lt; t \leq 40 )</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>( 40 &lt; t \leq 100 )</td>
<td>2</td>
</tr>
<tr>
<td>Stress concentration effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detail Category</td>
<td>( C )- value</td>
<td>m</td>
</tr>
<tr>
<td>( C )- value &lt; 56</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>56 ( \leq ) ( C )- value &lt; 80</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>( C )- value ( \geq ) 80</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Workmanship Class</td>
<td>GA</td>
<td>GB</td>
</tr>
<tr>
<td>Fatigue load or dynamic load</td>
<td>Does not occur</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Fatigue load(^1) due to, for example, wind or impact by vehicles</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Dynamic load due to, for example, collision forces</td>
<td>4</td>
</tr>
</tbody>
</table>

\(^1\) See Subclause 2:11.
7:22 Properties in the thickness direction

BKR 99, Subclause 8:43

In structures acted upon by tensile forces in the thickness direction, action shall be taken to ensure that transmission of force in the thickness direction is satisfactory in view of the risk of laminar tearing in the steel.

General recommendation:

Action to ensure that transmission of force in the thickness direction is satisfactory should be suited to the Safety Class and degree of utilisation of the structure and its design. It may, for example, consist of the selection of material of guaranteed and verified properties in the thickness direction in accordance with Subclause 7:22 of BSK 99.

For structural members in Safety Classes 2 and 3 with a substantial tensile force in the thickness direction and with details corresponding to any of the cases a–d listed below, material which has been subject to production control and which has improved deformation properties in the thickness direction in accordance with SS-EN 10 164 – Z25 with the associated ultrasonic testing in accordance with Euronorm 160-85, class B should be selected.

a) a detail subject to a high degree of restraint on deformation in conjunction with welding, e.g. for a plate thickness greater than 30 mm or in conjunction with a high degree of fixity (\(\eta_{ULS} > 0.2\), the coefficient of utilisation \(\eta\) is the ratio of load effect and load-bearing capacity (resistance), \(S_d/R_d\), in the limit state being considered)

b) a detail of large weld thickness, \(a\) in Figure 7:22 larger than 10 mm (\(\eta_{ULS} > 0.2\))

c) a detail with a weld near a free edge of the plate, \(e\) in Figure 7:22 less than 10 mm or less than one half the thickness of the plate, \(0.5t\) in accordance with Figure 7:22 (\(\eta_{ULS} > 0.2\))

d) a detail subjected to fatigue loading, with the coefficient of utilisation greater than 0.5 (\(\eta_{FLS} > 0.5\)).

For other details in Safety Classes 2 and 3 where the coefficients of utilisation are \(\eta_{ULS} > 0.5\) and \(\eta_{FLS} \leq 0.5\) respectively, one of the following methods should be selected.

e) Material which has been subject to production control and which has improved deformation properties in the thickness direction in accordance with SS-EN 10 164–Z15 with the associated ultrasonic testing in accordance with Euronorm 160-85, class B is selected.

f) The suitability of the steel for the intended use with respect to the process of steel production, the content of sulphur etc. is verified in a written document by an independent expert.

For connections with \(0.2 \leq \eta_{ULS} \leq 0.5\) and \(\eta_{FLS} \leq 0.5\) or for structures in Safety Class 1 the need for special measures with regard to the risk of laminar tearing should be considered in each individual case.
The load effect is to be calculated both at the section through the material subjected to tensile force in the thickness direction and at the section through the adjacent material. The reason for the investigation at the section through the adjacent material is a wish to limit the size of the welds. Large welds give rise to large residual stresses and increase the risk of laminar tearing, see Figure 7:22.

![Figure 7:22 Symbols and critical sections in conjunction with tensile force in the thickness direction.](image)

### 7:3 Identification and marking of materials

**BKR 99, Subclause 8:51, second paragraph**

Marking shall be such that the relationship between the material and the associated certificate is secured and confusion is prevented.

Regarding certificates see Clause 9:2.

Plates, bars and hollow sections in accordance with Subclause 2:21 should be marked in accordance with the relevant standard. For steels which have been subject to production control in accordance with Table 7:3 colour coding on an end or edge surface may replace marking by wording.

<table>
<thead>
<tr>
<th>Steel</th>
<th>Colour according to SS 03 14 11</th>
<th>NCS notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>S235JRG2</td>
<td>yellow</td>
<td>1070–Y10R</td>
</tr>
<tr>
<td>S275JR</td>
<td>blue</td>
<td>2060–R90B</td>
</tr>
</tbody>
</table>

The marking of filler metal may be carried out by indicating the type of filler metal and the name of the manufacturer on the packaging.

Bolts and nuts should be marked in accordance with SS-ISO 898-1 and -2.
When lots of plates, bars, hollow sections, filler metal etc. are broken down in the workshop or on the site, marking should be transferred to the individual items. As an alternative, the same information should be made available in some other way by means of appropriate routines etc. so that the individual items in both cases can be traced back to the original lot.

Regarding marking of type approved or production controlled material and products, see the reference in *BKR 99*, Clause 1:4.
8 EXECUTION AND WORKMANSHIP

8:1 General

BKR 99, Clause 2.5, first, second and fourth paragraphs

A structure shall
- be designed and executed by competent personal in a workmanlike manner in accordance with the provisions of Sections 4–9
- be designed so that a good standard of workmanship is made possible and so that the stipulated maintenance can be carried out
- be executed in accordance with the relevant project documentation.

During construction care shall be taken to ensure that deviations from nominal dimensions do not exceed the specified tolerances.

Temporary bracing necessary to provide stability during the period of erection shall be provided.

It is stipulated that the fabricator has access to technical facilities and competent staff for the fabrication and erection of steel structures. Fabrication should be carried out in a place with suitable lighting and with the necessary protection against wind, precipitation and low temperatures.

Surfaces which are to be given corrosion protection treatment should be constructed in accordance with SS–EN ISO 12944-3, in the best performance.

8:11 Qualifications of the supervisor

The supervisor who is in charge of the work on steel structures should have appropriate technical education, be familiar with the relevant regulations regarding material, execution and the control of steel structures and should have knowledge of the mode of action of the structure in question.

8:12 Workmanship Classes

With respect to the accuracy of workmanship, steel structures are assigned to Workmanship Classes GA, GB or GC in accordance with Table 8:12.

With regard to the application of the Workmanship Classes, reference should be made to Subclauses 6:522, 7:21, 8:63 and 8:8. The design rules in Subclause 6:522 imply that structures subject to fatigue loading should normally be assigned to Workmanship Class GA or GB.
### Table 8:12 Workmanship Classes

<table>
<thead>
<tr>
<th>Workmanship Class</th>
<th>Lowest Cutting Class in accordance with Table 8:13</th>
<th>Lowest Welding Class in accordance with Table 8:14</th>
<th>Conditions regarding external shape and discontinuities&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA</td>
<td>Sk3</td>
<td>WB</td>
<td>Discontinuities, such as rolling defects, hammer marks, indentations due to hoisting devices, pittings etc. are not allowed. There shall be no geometrical stress concentration factors which interfere with the intended stress flow. Changes in thickness or cross section shall have a smooth transition.</td>
</tr>
<tr>
<td>GB</td>
<td>Sk2</td>
<td>WC</td>
<td>Sharp discontinuities are not allowed. There shall be no major geometrical stress concentration factors which interfere with the intended stress flow. Changes in thickness or cross section shall have a smooth transition.</td>
</tr>
<tr>
<td>GC</td>
<td>Sk1</td>
<td>WC</td>
<td>Same as for GB, paragraph one, but minor discontinuities such as minor surface scaling, scratch marks, marks made by hoisting devices, need not be removed.</td>
</tr>
</tbody>
</table>

<sup>1</sup> For surfaces which are to be given corrosion protection treatment, reference should be made to Subclauses 8:31 and 8:32.

#### 8:13 Cutting Classes

Thermally cut surfaces are assigned to three Cutting Classes Sk1, Sk2 and Sk3 in accordance with Table 8:13.
**Table 8:13 Cutting Classes**

<table>
<thead>
<tr>
<th>Cutting Class</th>
<th>Greatest surface roughness, mm(^1)</th>
<th>Requirements for free edges(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sk1</td>
<td>1.0</td>
<td>Edges shall be free from slag and spatter</td>
</tr>
<tr>
<td>Sk2</td>
<td>0.3</td>
<td>Edges shall be free from slag and spatter and shall be deburred</td>
</tr>
<tr>
<td>Sk3</td>
<td>0.2</td>
<td>Edges shall be chamfered to (s \geq 2) mm</td>
</tr>
</tbody>
</table>

\(^1\) The roughness is the difference in level between a crest and an adjacent trough. For cutting defects, cracks etc, see also Subclause 8:32.

\(^2\) Regarding the preparation of edges to surfaces which are to be given corrosion protection treatment, reference should be made to Subclause 8:31.

### 8:14 Welding Classes

Welds are assigned to Welding Classes WA, WB or WC in accordance with Table 8:14.

**Table 8:14 Welding Classes**

<table>
<thead>
<tr>
<th>Welding Class</th>
<th>Requirements(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA</td>
<td>In accordance with SS–ISO 5817(^2,3), Welding Class B, with the requirement that the toes of the weld shall be appropriately prepared, e.g. polished or TIG treated, to a very smooth transition to the parent material as well as between weld faces. The expression very smooth refers to a rounded transition with a radius corresponding to at least 4 mm.</td>
</tr>
<tr>
<td>WB</td>
<td>In accordance with SS–ISO 5817(^2,3), Welding Class B, with the requirement that the toes of the weld shall have a smooth transition to the parent material as well as between weld faces. Appropriate measures shall be taken to adjust any irregularities in or adjacent to the toes of the weld, e.g. polishing or TIG treatment so that the requirement for a smooth transition is met.</td>
</tr>
<tr>
<td>WC</td>
<td>In accordance with SS–ISO 5817(^2,3), Welding Class C. However, (\theta \geq 110^\circ) is acceptable for the toes of welds in Figure 8:14.</td>
</tr>
</tbody>
</table>

\(^1\) Regarding surfaces which are to be given corrosion protection treatment, see also Subclause 8:31.

\(^2\) Requirements regarding excessive asymmetry of fillet welds (imperfection no 20) need not normally be considered, on condition that the throat of the weld is sufficiently large and that the toes of the weld meet the requirements in the table.

\(^3\) In summing up the different imperfections of the cross section (imperfection no 26) only the largest of the undercuts need normally be considered. Furthermore, the excessive convexity of the fillet weld need not normally be added to the sum of the imperfections.
8:15 **Bolted Connection Classes**

Bolted connections are assigned to Bolted Connection Classes S1 (fine), S1F (fine), S1, S1F, S2, S2F, S3 and S3 (coarse), with the modes of action and hole tolerances in accordance with Table 8:15.

**Table 8:15 Bolted Connection Classes**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Mode of action</th>
<th>Hole tolerances</th>
<th>Approximate clearance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 (fine) and</td>
<td>Bearing-type connection</td>
<td>Clearance hole in accordance with SS-ISO 273, fine series</td>
<td>1</td>
</tr>
<tr>
<td>S1F (fine) ^1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1 and S1F ^1</td>
<td>Bearing-type connection</td>
<td>Clearance hole in accordance with SS-ISO 273, medium series</td>
<td>2</td>
</tr>
<tr>
<td>S2 and S2F ^1</td>
<td>Bearing-type connection</td>
<td>H12/h13 in accordance with SS 2111</td>
<td>0.3</td>
</tr>
<tr>
<td>S3 ^1</td>
<td>Friction-type connection</td>
<td>Clearance hole in accordance with SS-ISO 273, medium series</td>
<td>2</td>
</tr>
<tr>
<td>S3 (coarse) ^1</td>
<td>Friction-type connection</td>
<td>Clearance hole in accordance with SS-ISO 273, coarse series</td>
<td>3–4</td>
</tr>
</tbody>
</table>

^1 Bolts in S1F (fine), S1F and S2F differ from S1 (fine), S1 and S2 only by being highly preloaded. Bolts in S3 and S3 (coarse) are also highly preloaded, see Subclause 8:542.
8:2 Handling of materials

*BKR 99, Subclause 8:51, first paragraph*

Plates, sections, hollow sections, filler metal for welding, fasteners and similar shall be stored and handled in such a way that different materials cannot be confused, and so that the intended properties do not deteriorate to a harmful extent.

With regard to identification and tracability of materials, see Clause 7:3.

8:3 Surfaces, preparation

8:31 General

*BKR 99, Subclause 8:52*

General recommendation:

In conjunction with the preparation of materials, Clause 8:3 of *BSK 99* should be taken into consideration.

Materials of Corrosion Grade D in accordance with SS 05 59 00 should not be used.

Cut surfaces should be free from cracks, burrs etc. and should also in other respects meet the requirements for the appropriate Workmanship Class, see Table 8:12.

Re-entrant corners should be rounded to a radius which is at least equal to the material thickness, and not less than 10 mm.

Surfaces which are to be given corrosion protection treatment should have sufficient regularity and the edges should be deburred.

8:32 Thermal cutting

Thermally cut surfaces should be free from cutting defects, cracks etc. and should meet the requirements for the appropriate Cutting Class in accordance with Table 8:13.

Cutting defects and other surface defects may be removed by dressing or by repair welding followed by grinding.

Cut surfaces which are to be given corrosion protection treatment should be conform to a Cutting Class not lower than Sk2.

In conjunction with complicated cutting work and where there is a risk of cracking, a cutting trial should be carried out prior to cutting.
8:33 Plastic working

Plastic working, for instance straightening and bending of materials, should be carried out in such a way that the material is not damaged, due regard being also paid to long term effects. The method and temperature should be selected in view of e.g. the properties of the material and the magnitude of strain in the material. In conjunction with hot forming and flame straightening of steel in accordance with SS–EN 10 113-3 and SS–EN 10 137-2 the limitations given in the relevant standard should be taken into account. The risk of strain ageing and stress corrosion should be given special consideration.

In conjunction with cold bending, a check should be made to ensure that the steel has the bending characteristics required. The bending characteristics should be demonstrated if the intended internal bending radius is less than three times the material thickness. For plates in accordance with SS–EN 10 137-2 the bending radius may be taken as four times the material thickness if the axis of bending is along the rolling direction of the plate.

Bending characteristics may be demonstrated by testing in accordance with SS 11 26 26 prior to bending, the test being performed using the method and the bending radius which most closely represent the intended process. Alternatively, a check can be made after bending to ensure that the steel has not been damaged. Cracking or extensive contraction will be regarded as damage.

8:4 Welded connections

8:41 General

_BKR 99, Subclause 8:531, first paragraph_

Welding in a steel structure shall be carried out only where welding is specified on the drawings.

Regarding welding procedure sheets see Subclause 1:42.

_BSK 99_ is above all adapted to the following welding methods

– metal arc welding with covered electrode, 111 in accordance with SS–ISO 4063
– self-shielded tubular-cored arc welding, 114 in accordance with SS–ISO 4063
– submerged arc welding, 12 in accordance with SS–ISO 4063
– MIG welding, 131 in accordance with SS–ISO 4063
– MAG welding, 135 in accordance with SS–ISO 4063
– Tubular cored metal arc welding with active gas shield, 136 in accordance with SS–ISO 4063
– TIG welding, 141 in accordance with SS–ISO 4063.
8:42 Joints

Joints should be designed in accordance with SS–ISO 9692.

If a single bevel joint is made with a backing strip, the strip should be removed after welding unless instructions to the contrary are given on drawings. In Workmanship Class GC, however, the backing strip need not be removed if the structure is assigned to Corrosivity Category C1 or C2.

8:43 Welding

\textit{BKR 99, Subclause 8:531, second and third paragraphs}

General recommendation:

Examples of guidelines regarding welding are given in Swedish Standards SS 06 40 01 and SS 06 40 25.

The regulations and general recommendations of the Swedish Board of Occupational Safety and Health regarding fusion welding and thermal cutting are set out in AFS 1992:9.

In conjunction with welding on a quenched and tempered constructional steel, the manufacturer of the steel should be consulted. Furthermore, it is stipulated that the welding energy (energy input per unit length of weld) should be selected so that the welded connection attains the intended resistance and ductility, see SS–EN 1011-1 and SS 06 40 25.

8:431 Penetration

If a fillet weld is made by a mechanised welding process, e.g. submerged arc welding that can be demonstrated to provide reliable penetration, penetration may be allowed for in determining the throat size of the fillet weld. The size of penetration may be demonstrated by measuring and documenting deep penetration in accordance with Figure 8:431 in at least two sections situated at least 400 mm from each other in a specimen made under the conditions applied in production. In this case, 0.35 times the mean value of the measured deep penetration may be included in the throat size; however, the value included should not exceed 0.25 times the throat size in accordance with the drawing.

If penetration is continuously monitored during production, a larger proportion of the penetration may be utilised. In this case it is stipulated that the necessary tests are specified in the inspection schedule and are carried out.

Data regarding fillet welds with utilised penetration are to be given in the inspection certificate, see Clause 9:7.
8:432  **Welding of embedded fasteners**

Design, execution and control of welded connections in embedded fasteners with reinforcement as the base material should be carried out in accordance with Clauses and Subclauses 6:3, 8:14, 8:4, 9:63 and 9:73 and in accordance with **Welded connections in embedded fasteners**, BBC and SBS. Regarding strength requirements of welded connections between reinforcement and another steel member, see **BBK 94**, Subclause 7.5.3. Regarding the extent of surface finish in conjunction with the embedding of fasteners, see Subclause 8:72.

8:44  **Heat treatment**

If heat treatment is specified in the design documents, this should to the appropriate extent be carried out in accordance with SS 06 45 10.

8:45  **Qualification of welding co-ordinators**

Welding co-ordinators should have the qualifications set out in SS–EN 719, for example EWS.
8:46 Welders' qualifications

**BKR 99, Subclause 8:533, second paragraph**

General recommendation:

An approved welder's test in accordance with EN 287-1:1992 may be considered to be an example of documented qualifications.

As an alternative to SS–EN 287-1, the older Swedish standard SS 06 52 01 regarding welder's tests may be applied.

8:5 Bolted connections

8:51 Holes for bolts and matching of holes

**BKR 99, Subclause 8:541, first paragraph**

Holes shall be made by a method which provides sufficient accuracy with regard to the size and placing of the hole, and in such a way that the strength and ductility of the parent material do not deteriorate to a deleterious extent.

Holes passing through the separate parts of a connection should match so well that the bolts can be inserted without threads or surface protection being damaged.

**BKR 99, Subclause 8:541, second–fourth paragraphs**

General recommendation:

If the displacement between holes in parts of the same connection is excessive, the holes may be drilled or reamed to the next larger bolt diameter, due attention being paid to the appropriate requirements regarding matching of holes.

Examples of methods which comply with the requirements of the mandatory provision are given in Subclauses 8:511 and 8:512 of BSK 99.

Examples of tolerances are given in Publication No 112, 1992, Tolerances for steel structures, of the Swedish Institute of Steel Construction.

8:511 Bolted Connection Classes S1 (fine), S1, S1F, S3 and S3 (coarse)

Holes are to be drilled or reamed in the separate parts to the final dimension. In Workmanship Class GB the holes may be punched to the final diameter if this is larger than the material thickness. Burrs etc. larger than 0.5 mm are to be removed. For highly prestressed connections the edges of holes should be chamfered at 45° over a distance of 0.5 mm.
8:512 Bolted Connection Classes S2 and S2F

Holes are to be drilled or punched to a diameter at least 3 mm less than the nominal hole diameter, after which the holes are drilled or reamed through all the parts in the connection to the final diameter complying with the hole clearance H12/h13 in accordance with SS 21 11. Alternatively, holes may be drilled to the final dimension in the separate parts if the placing of holes is such that the hole clearance is complied with in all the holes in the connection after the bolts have been inserted. Edges of holes should be chamfered at 45° over a distance of 0.5 mm.

For hot dip zinc coated bolts the hole diameter in accordance with Subclause 8:15 is to be increased by 0.2 mm. However, this does not apply to products in accordance with ISO standards specified in Table 7:142b for which the tread is cut with regard to the coating. If the structure is to be hot dip zinc coated after holing, the hole diameter should be increased by another 0.3 mm.

8:52 Contact surfaces

BKR 99, Subclause 8:542

Contact surfaces in bolted connections shall fit together so that the contact necessary for the function of the connection is achieved.

General recommendation:

Special attention should be paid to fit in preloaded connections in order to prevent losses of clamping force.

Examples of the classification of contact surfaces and the treatment of contact surfaces are given in Clause 8:5 of BSK 99.

Contact surfaces in S3 and S3 (coarse) connections should be treated so that the assumed friction is attained on assembly.

Flame cleaning is to be performed on surfaces with remaining mill scale, on other surfaces shot or grit blasting should be carried out. Shot or grit blasting of contact surfaces in friction-type connections should be carried out to Sa 2 or Sa 2½. Flame cleaning should be performed by a multiflame burner with ca 30% excess oxygen. The flame should be directed towards the surface at an angle of approximately 30° and moved at a rate of ca 1 m/min. Remaining loose mill scale, rust and combustion residues are to be removed after flame cleaning.

Contact surfaces which are hot dip zinc coated or consist of clean mill scale should be thoroughly cleaned and brushed lightly with a steel brush.

In conjunction with bolted connections in painted structures, surfaces between plates and under washers and bolts should be coated with at most each so that the preloading force is not lost. After the bolts are tightened, the surface finish should be supplemented in accordance with Tables 8:72a–f.
8:53 Assembly of bolted connections

**BKR 99, Subclause 8:543, third paragraph**
General recommendation:
In close tolerance connections the unthreaded shank of the bolts should normally terminate outside the parent material.

The bolts used in Sl (fine), S2 and S2F connections which transmit shear force should be such that the thread run-out normally terminates outside the parent material. However, the thread run-cut may terminate inside the parent material by up to one third of the plate thickness, but this distance shall not exceed 5 mm (see Figure 8:53).

**BKR 99, Subclause 8:543, fourth paragraph**
General recommendation:
In preloaded connections washers should be used if without a washer the local pressure under the bolt head and nut due to the preloading force exceeds the design value of the ultimate strength of the parent material.

![Figure 8:53 Thread run-out at surface of parent material.](image)

With regard to washers in bolted connections see Subclause 6:45.

If only one washer is specified on the drawing, this should be placed underneath the nut or the head of the bolt if this is being rotated. If necessary for the purposes of tightening, the number of washers specified on the drawing may be increased. On inclined surfaces tapered washers should be used to ensure that complete contact is achieved between surfaces.

8:54 Securing of bolted connections

**BKR 99, Subclause 8:543, first and second paragraphs**
In preloaded connections each bolt shall be preloaded to not less than 70% of the nominal ultimate tensile strength of the bolt in order that the specified clamping force should be attained. Nuts shall be specially secured where the direction of the force on the bolt alternates.

General recommendation:
Connections in other classes should be tightened normally and the nuts reliably secured.
BKR 99, Subclause 8:543, fifth paragraph

General recommendation:
A bolt which has been preloaded and thereafter undone should be rejected and replaced.

Associated nuts should be handled in the same way.

BKR 99, Subclause 8:543, sixth paragraph

General recommendation:
Examples of appropriate assembly of bolted connections are given in Subclauses 8:53 and 8:54 of BSK 99.

In a connection which is intended to allow movement, for example a hinge, nuts may be secured by tightening two nuts hard against one another.

8:541 Normal tightening

The following procedure is an example of normal tightening and securing.

Zinc coated bolts in Strength Class 8.8 are to be tightened either by manual tightening effort using a spanner of the handle length (lever arm) in accordance with Table 8:541, or by power tool using a torque in accordance with the same table.

<table>
<thead>
<tr>
<th>Bolt dimension (mm)</th>
<th>Lever arm for manual tightening (mm)</th>
<th>Torque for tightening by power tool (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bolts and nuts in as-delivered condition</td>
<td>Waxed nuts</td>
</tr>
<tr>
<td>12</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>350</td>
<td>200</td>
</tr>
<tr>
<td>20</td>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>22</td>
<td>800</td>
<td>500</td>
</tr>
<tr>
<td>24</td>
<td>1000</td>
<td>600</td>
</tr>
<tr>
<td>27</td>
<td>1500</td>
<td>900</td>
</tr>
<tr>
<td>30</td>
<td>2000</td>
<td>1300</td>
</tr>
<tr>
<td>36</td>
<td>2400</td>
<td>2350</td>
</tr>
</tbody>
</table>

1 It is stipulated that nuts are treated with slushing oil.

Nuts are to be secured to prevent loosening, for instance by a heavy punch mark by or a locking nut. Securing by welding should not be adopted. An ordinary spring washer does not provide reliable locking action.
8:542 Preloading

The following procedure is an example of acceptable practice for highly preloaded connections.

If the bolts are hot dip zinc coated, the threads are to be waxed as well as the contact surface on that part of the fastener which rotates during the tightening operation. Waxing is done with e.g. beeswax.

Tightening of bolts should begin at the centre of the connection and proceed alternately towards the ends of the connection. All bolts should first be preloaded to an initial position, with the individual parts of the connection in close contact and with approximately the same preload in each bolt corresponding to normal tightening in accordance with Table 8:542. The relative positions of each bolt and corresponding nut are marked. The bolts are then preloaded by further rotation through one fourth of a revolution (90° with tolerances +10° and -5°). If the grip of the bolt exceeds five times the bolt diameter, the angle of rotation is to be increased in view of the elastic deformation of the bolt during the tightening operation.

Table 8:542 Lever arm and tightening torque at an initial position for highly preloaded connections before the tightening process by rotation starts, zinc coated bolts in Strength Class 10.9

<table>
<thead>
<tr>
<th>Bolt dimension (mm)</th>
<th>Lever arm for manual tightening (mm)</th>
<th>Torque for tightening by power tool (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Waxed nuts</td>
<td>Waxed nuts</td>
</tr>
<tr>
<td>12</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>16</td>
<td>250</td>
<td>125</td>
</tr>
<tr>
<td>20</td>
<td>450</td>
<td>260</td>
</tr>
<tr>
<td>22</td>
<td>650</td>
<td>375</td>
</tr>
<tr>
<td>24</td>
<td>750</td>
<td>450</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>700</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>950</td>
</tr>
<tr>
<td>36</td>
<td></td>
<td>1750</td>
</tr>
</tbody>
</table>

Additional loading of highly preloaded bolts should be observed for connections with thick paint coatings on contact surfaces, see Subclause 8:52.
8:6 Dimensional accuracy in fabrication and erection

8:61 General

BKR 99, Subclause 8:55, first paragraph
Steel structures shall be erected with the intended accuracy with respect to dimensions and shape.

Dimensions specified on drawings apply at a reference temperature, see Subclause 1:41.

BKR 99, Subclause 8:55, fourth paragraph
General recommendation:
Examples of tolerances for fabrication and erection are given in Publication No 112, 1992, Tolerances for steel structures, of the Swedish Institute of Steel Construction.

8:62 Deviations from shape in the finished structure

BKR 99, Subclause 8:55, second paragraph
The deviations from shape in the finished structure shall not exceed the tolerances assumed in design.
Figure 8:62  Normal assumptions regarding permissible inclination and deviation from straightness and flatness.

Unless otherwise specified on the drawings, the following tolerances apply in accordance with Subclause 2:3.

The inclination from the intended direction of a member in compression should not exceed 0.005 times the length, see Figure 8:62a.

The deflection of a member in compression or flexure should not exceed 0.0015 times the length. However, for members of hollow sections the deflection should not exceed 0.002 times the length. These values also apply to a part of the member, see Figure 8:62a and b.

A buckle in the web of a member of I, U or Z section, or in the parts of the cross section of a box section, should not exceed the values given in Figure 8:62c. For a web with a longitudinal stiffener, the limits apply for each panel.

The deflection of a free edge in compression, for instance the compression flange of a member of I, U or Z section, should not exceed the values given in Figure 8:62d.
8:63 Contact surfaces transmitting compressive force

_BKR 99, Subclause 8:55, third paragraph_

If a compressive force is assumed to be transmitted in direct bearing by the contact surfaces of two parts in a welded structure, the parts shall be fabricated so that the contact surfaces have the required fit.

The gap between the surfaces in contact, when fitted together, should not exceed 0.3 mm. In Workmanship Class GC the gap may be increased to a maximum of 1 mm if the weld metal has satisfactory ductility, which under normal conditions can be achieved by e.g. basic electrodes.

8:64 Connection of steel structures to other structural elements

Where a steel structure is connected to some other structural element, for instance a foundation structure, particular care should be taken in execution in order to ensure that erection may be carried out without the steel structure having to be modified.

See also Clause 8:1.

8:7 Corrosion protection

8:70 Introduction

This section is largely based on SS–EN ISO 12944, parts 1–7.

Requirements regarding the durability of structural members and materials in loadbearing structures are given in Subclause 1:23.

_BKR 99, Subclause 8:56, third paragraph_

General recommendation:

Examples of the classification of corrosive environments and appropriate methods of providing corrosion protection are given in Subclause 1:23 and Clause 8:7 of _BSK 99_.

122
8:71 General requirements

**BKR 99, Subclause 8:56, first and second paragraphs**

Steel structures in a corrosive environment shall be provided with the necessary corrosion protection.

General recommendation:

Corrosion protection may be in the form of an appropriate coating, cathodic protection or corrosion allowance.

Environments in Corrosivity Categories C2–C5-M and Im1–Im3 according to Tables 1:23a–c should be considered as corrosive.

Structural members in Corrosivity Category C1 do not normally need corrosion protection. In some cases a simple treatment (surface preparation and painting) may be appropriate on aesthetic grounds.

**BKR 99, Subclause 8:56, fourth paragraph**

General recommendation:

The requirements concerning technical and personnel conditions in conjunction with corrosion protection painting may be considered to have been complied with if the firm in question has been approved by the Authorisation Board for Corrosion Protection Painting.

8:72 Coatings

A corrosion protection system comprises surface preparation and the application of a coating of paint or metal. The coating should comprise a primer, in some cases a second paint, and a finishing coat or a metal coating. A shop primer may normally be included in the corrosion protection system. If the primer in the system is a zinc rich paint, the shop primer should be removed unless this is also a zinc rich paint.

For structures exposed to the open air the system with a primer of a zinc paint or a zinc metal normally gives the longest service life in the relevant Corrosivity Category.

Normally, these systems also give corrosion protection at places of damage caused by mechanical damage on the paint coating, scratches etc.

Examples of appropriate corrosion protection systems, S2.02–S9.12, N2.01–N7.02, are given in Tables 8:72a–f. The systems which correspond to SS–EN ISO 12944-5 are designated "S". In addition to these systems there are a number of systems which are quite common in Sweden and which have proved to be practicable and appropriate in the prevailing Nordic climate. These systems are designated N2.01–N7.02. Examples of systems for painting on thermal sprayed, zinc plated and sheradized surfaces are given in SS–EN ISO 12944-5, Table A.10.

The prescribed coat thicknesses are nominal values and should be measured in accordance with SS 18 41 60.

Before wire-brushing or shot or grit blasting is to begin, chlorides, oil and other impurities should be removed for example by high pressure
cleaning. Blasted surfaces should have medium surface coarseness in accordance with SS–EN ISO 8503-2.

The corrosion protection systems are based on the assumption that the surface temperature of steel members during preparation and painting is at least 3°C higher than the dew point of the surrounding air or that the guidelines given in SS–ISO 8502-4 are applied. Furthermore, attention should be paid to the instructions given by the paint manufacturer/supplier, recommendations and directions given in SS–EN ISO 12944-7 and in *Manual for corrosion protection by paint systems*.

The required corrosion protection for a structural element embedded in concrete may be achieved by providing the structural element with corrosion protection to a depth corresponding to the concrete covers given in BBK 94, Table 7.3.2.2b, but not less than 50 mm below the concrete surface. The surface of the concrete should be shaped so that ponding does not occur, and the quality of the concrete and Execution Class should be selected in accordance with *BBK 94*, Subclause 7.3.2.2.

For surfaces which may be exposed to long-term or permanent condensation, hot dip zinc coating or paint systems with a zinc rich primer should be avoided.

Fasteners should be given a temporary protection against corrosion during storage and transport. Electrical dip zinc coating or phosphatizing together with oiling is often sufficient. Fasteners in permanent structures in Corrosivity Categories C2–C5-M and Im1–Im3, should be given the same corrosion protection as the parent material. However, fasteners with hot dip zinc coating Fe/Zn 45 in accordance with SS 3192 are acceptable in Corrosivity Categories C2–C3 without any further treatment.

In Tables 8:72a–f the degree of preparation, type of paint/coatings, coat thicknesses and the number of layers are specified. In addition, an assessment of the durability of the various systems is provided. The durability is expressed as the time up to the point when the treated surface has deteriorated to Ri 3 in accordance with SS 18 42 03 and is given in two grades; medium and high durability. Medium durability corresponds to a time period of 5–15 years and high durability corresponds to a time period of more than 15 years, see also Subclause 10:42.

The assessment of durability for S-systems is taken from SS-EN ISO 12944-5. For the national N-systems, similar assessments have been made.

The estimated values of durability shall not be confused with a manufacturer's guarantee.
### Table 8:72a  Examples of corrosion protection systems in Corrosivity Category C2

<table>
<thead>
<tr>
<th>Corrosivity Category C2</th>
<th>Designation</th>
<th>S2.02</th>
<th>S2.03</th>
<th>S2.04</th>
<th>S2.06</th>
<th>S2.12</th>
<th>S2.14</th>
<th>S2.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Preparation in accordance with ISO 8501-1</td>
<td>Sa 2½</td>
<td>St 2</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td></td>
</tr>
<tr>
<td>Primer Type of paint in accordance with Table 8:72g</td>
<td>AK</td>
<td>AK</td>
<td>AK</td>
<td>AK</td>
<td>AY</td>
<td>AY</td>
<td>EP</td>
<td></td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>40</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Number of layers</td>
<td>1</td>
<td>2</td>
<td>1–2</td>
<td>1–2</td>
<td>1</td>
<td>1–2</td>
<td>1–2</td>
<td></td>
</tr>
<tr>
<td>Finishing coat /second coat Type of paint in accordance with Table 8:72g</td>
<td>AK</td>
<td>AK</td>
<td>AK</td>
<td>AK</td>
<td>AY</td>
<td>AY</td>
<td>EP, PUR</td>
<td></td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>80</td>
<td>40</td>
<td>80</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Number of layers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1–2</td>
<td>1</td>
<td>1–2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total thickness of system</td>
<td>80</td>
<td>120</td>
<td>120</td>
<td>160</td>
<td>120</td>
<td>160</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Total number of layers</td>
<td>2</td>
<td>3</td>
<td>2–3</td>
<td>2–4</td>
<td>2</td>
<td>2–4</td>
<td>2–3</td>
<td></td>
</tr>
</tbody>
</table>

**1** Hot dip zinc coating in accordance with EN–ISO 1461. The minimum thickness of the zinc layer is 70–85 µm depending on the material thickness of the steel.

**2** For fasteners in bolted connections Fe/Zn 45.

**3** The durability only applies to the painting.

**4** Hot dip zinc coated steel should be cleaned and abrasive blast cleaned to surface profile fine in accordance with SS–EN ISO 8503-2 before painting.

**5** The thickness of the zinc coating is not included.
### 8:72b Examples of corrosion protection systems in Corrosivity Category C3

<table>
<thead>
<tr>
<th>Designation</th>
<th>S3.04</th>
<th>S3.05</th>
<th>S3.06</th>
<th>S3.12</th>
<th>S3.13</th>
<th>S3.17</th>
<th>S3.18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Preparation in accordance with ISO 8501-1</td>
<td>Sa 2½</td>
<td>St 2</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
</tr>
<tr>
<td>Primer Type of paint in accordance with Table 8:72g</td>
<td>AK</td>
<td>AK</td>
<td>AK</td>
<td>AY</td>
<td>AY</td>
<td>EP</td>
<td>EP</td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Number of layers</td>
<td>1–2</td>
<td>1–2</td>
<td>1–2</td>
<td>1–2</td>
<td>1–2</td>
<td>1–2</td>
<td>1–2</td>
</tr>
<tr>
<td>Finishing coat /second coat Type of paint in accordance with Table 8:72g</td>
<td>AK</td>
<td>AK</td>
<td>AK</td>
<td>AY</td>
<td>AY</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>80</td>
<td>120</td>
<td>120</td>
<td>80</td>
<td>120</td>
<td>80</td>
<td>120</td>
</tr>
<tr>
<td>Number of layers</td>
<td>1–2</td>
<td>2–3</td>
<td>2–3</td>
<td>1–2</td>
<td>2–3</td>
<td>1–2</td>
<td>2–3</td>
</tr>
<tr>
<td>Total thickness of system</td>
<td>160</td>
<td>200</td>
<td>200</td>
<td>160</td>
<td>200</td>
<td>160</td>
<td>200</td>
</tr>
<tr>
<td>Total number of layers</td>
<td>2–4</td>
<td>3–5</td>
<td>3–5</td>
<td>2–4</td>
<td>3–5</td>
<td>2–4</td>
<td>3–5</td>
</tr>
</tbody>
</table>

---

### Table 8:72b Examples of corrosion protection systems in Corrosivity Category C3 (cont.)

<table>
<thead>
<tr>
<th>Designation</th>
<th>S3.21</th>
<th>S3.22</th>
<th>S3.23</th>
<th>N3.01</th>
<th>N3.02</th>
<th>N3.03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Preparation in accordance with ISO 8501-1</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
</tr>
<tr>
<td>Primer Type of paint in accordance with Table 8:72g</td>
<td>EP (Zn), PUR (Zn)</td>
<td>EP (Zn), PUR (Zn)</td>
<td>EP (Zn), PUR (Zn)</td>
<td>EP (Zn), PUR (Zn)</td>
<td>AY</td>
<td>EN (Zn), EP (Zn)</td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>–</td>
</tr>
<tr>
<td>Number of layers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>Finishing coat /second coat Type of paint in accordance with Table 8:72g</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
<td>AY</td>
<td>AY</td>
<td>OX</td>
<td>OX</td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>120</td>
<td>160</td>
<td>120</td>
<td>160</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Number of layers</td>
<td>1–2</td>
<td>1–2</td>
<td>1–2</td>
<td>2–3</td>
<td>1–2</td>
<td>1–2</td>
</tr>
<tr>
<td>Total thickness of system</td>
<td>160</td>
<td>200</td>
<td>160</td>
<td>200</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Total number of layers</td>
<td>2–3</td>
<td>2–3</td>
<td>2–3</td>
<td>3–4</td>
<td>2–3</td>
<td>2–3</td>
</tr>
</tbody>
</table>

---

1 Hot dip zinc coating in accordance with EN–ISO 1461. The minimum thickness of the zinc layer is 70–85 µm depending on the material thickness of the steel.

2 Hot dip zinc coated steel should be cleaned and abrasive blast cleaned to surface profile fine in accordance with SS–EN ISO 8503-2 before painting.
### Table 8:72b Examples of corrosion protection systems in Corrosivity Category C3 (cont.)

<table>
<thead>
<tr>
<th>Corrosivity Category C3</th>
<th>Designation</th>
<th>N3.04</th>
<th>S9.06</th>
<th>S9.07</th>
<th>S9.09</th>
<th>S9.10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>High</td>
<td></td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Preparation in accordance with ISO 8501-1</td>
<td>Sa 2½</td>
<td>Vfz</td>
<td>Vfz</td>
<td>Vfz</td>
<td>Vfz</td>
<td></td>
</tr>
<tr>
<td>Type of paint in accordance with Table 8:72g</td>
<td>AY</td>
<td>AY</td>
<td>–</td>
<td>EP, PUR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>40</td>
<td>80</td>
<td>–</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of layers</td>
<td>1</td>
<td>1</td>
<td>–</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of paint in accordance with Table 8:72g</td>
<td>AY</td>
<td>AY</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of layers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total thickness of system</td>
<td>95</td>
<td>120</td>
<td>160</td>
<td>80</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Total number of layers</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Hot dip zinc coating in accordance with EN–ISO 1461. The minimum thickness of the zinc layer is 70–85 µm depending on the material thickness of the steel.

2. For fasteners in bolted connections Fe/Zn 45.

3. The durability only applies to the painting.

4. Hot dip zinc coated steel should be cleaned and abrasive blast cleaned to surface profile fine in accordance with SS–EN ISO 8503-2 before painting.

5. The thickness of the zinc coating is not included.
### Table 8.72c Examples of corrosion protection systems in Corrosivity Category C4

<table>
<thead>
<tr>
<th>Designation</th>
<th>S4.09</th>
<th>S4.11</th>
<th>S4.13</th>
<th>S4.14</th>
<th>S4.17</th>
<th>S4.18</th>
<th>S4.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Preparation in accordance with ISO 8501-1</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
</tr>
<tr>
<td><strong>Primer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of paint in accordance with Table 8.72g</td>
<td>AY</td>
<td>EP</td>
<td>EP</td>
<td>EP</td>
<td>EP (Zn), PUR (Zn)</td>
<td>EP (Zn), PUR (Zn)</td>
<td>EP (Zn), PUR (Zn)</td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>80</td>
<td>160</td>
<td>80</td>
<td>80</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Number of layers</td>
<td>1–2</td>
<td>1</td>
<td>1–2</td>
<td>1–2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Finishing coat/second coat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of paint in accordance with Table 8.72g</td>
<td>AY</td>
<td>AY</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
<td>EP</td>
<td>AY</td>
<td>EP, PUR</td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>160</td>
<td>120</td>
<td>160</td>
<td>200</td>
<td>160</td>
<td>200</td>
<td>160</td>
</tr>
<tr>
<td>Number of layers</td>
<td>2–3</td>
<td>1</td>
<td>2–3</td>
<td>2–3</td>
<td>2–3</td>
<td>2–3</td>
<td>2–3</td>
</tr>
<tr>
<td>Total thickness of system</td>
<td>240</td>
<td>280</td>
<td>240</td>
<td>280</td>
<td>200</td>
<td>240</td>
<td>200</td>
</tr>
<tr>
<td>Total number of layers</td>
<td>3–5</td>
<td>2</td>
<td>3–5</td>
<td>3–5</td>
<td>3–4</td>
<td>3–4</td>
<td>3–4</td>
</tr>
</tbody>
</table>

### Table 8.72c Examples of corrosion protection systems in Corrosivity Category C4 (cont.)

<table>
<thead>
<tr>
<th>Designation</th>
<th>S4.21</th>
<th>S4.22</th>
<th>N4.01</th>
<th>N4.02</th>
<th>N4.03</th>
<th>N4.04</th>
<th>S9.07</th>
<th>S9.07</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Preparation in accordance with ISO 8501-1</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Vfz 4</td>
<td>Vfz 4</td>
</tr>
<tr>
<td><strong>Primer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of paint in accordance with Table 8.72g</td>
<td>EP (Zn), PUR (Zn)</td>
<td>EP (Zn), PUR (Zn)</td>
<td>AY</td>
<td>EN (Zn), EP (Zn)</td>
<td>EN (Zn), EP (Zn)</td>
<td>–</td>
<td>AY</td>
<td></td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>–</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Number of layers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>–</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Finishing coat/second coat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of paint in accordance with Table 8.72g</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
<td>OX</td>
<td>OX</td>
<td>OX</td>
<td>–</td>
<td>AY</td>
<td></td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>200</td>
<td>240</td>
<td>200</td>
<td>160</td>
<td>200</td>
<td>–</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Number of layers</td>
<td>2–3</td>
<td>3–4</td>
<td>2–3</td>
<td>2–3</td>
<td>2–3</td>
<td>2–3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total thickness of system</td>
<td>240</td>
<td>280</td>
<td>240</td>
<td>200</td>
<td>240</td>
<td>–</td>
<td>160 5</td>
<td></td>
</tr>
<tr>
<td>Total number of layers</td>
<td>3–4</td>
<td>4–5</td>
<td>3–4</td>
<td>3–4</td>
<td>3–4</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

1. Hot dip zinc coating in accordance with EN–ISO 1461. The minimum thickness of the zinc layer is 70–85 µm depending on the material thickness of the steel.
2. For fasteners in bolted connections Fe/Zn 45.
3. The durability only applies to the painting.
4. Hot dip zinc coated steel should be cleaned and abrasive blast cleaned to surface profile fine in accordance with SS–EN ISO 8503-2 before painting.
5. The thickness of the zinc coating is not included.
Table 8:72c  Examples of corrosion protection systems in Corrosivity Category C4 (cont.)

<table>
<thead>
<tr>
<th>Corrosivity Category C4</th>
<th>Designation</th>
<th>Durability</th>
<th>Preparation in accordance with ISO 8501-1</th>
<th>Type of paint in accordance with Table 8:72g</th>
<th>Coat thickness (µm)</th>
<th>Number of layers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S9.08 1⁄2</td>
<td>High 3</td>
<td>Vfz 4</td>
<td>AY, EP, PUR</td>
<td>80</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>S9.10 1⁄2</td>
<td>Medium 5</td>
<td>Vfz 4</td>
<td>EP, PUR</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>S9.11 1⁄2</td>
<td>High 3</td>
<td>Vfz 4</td>
<td>EP, PUR</td>
<td>80</td>
<td>1</td>
</tr>
</tbody>
</table>

1 Hot dip zinc coating in accordance with EN–ISO 1461. The minimum thickness of the zinc layer is 70–85 µm depending on the material thickness of the steel.

2 For fasteners in bolted connections Fe/Zn 45.

3 The durability only applies to the painting.

4 Hot dip zinc coated steel should be cleaned and abrasive blast cleaned to surface profile fine in accordance with SS–EN ISO 8503-2 before painting.

5 The thickness of the zinc coating is not included.
### Table 8:72d
Examples of corrosion protection systems in Corrosivity Category C5-I

<table>
<thead>
<tr>
<th>Corrosivity Category C5-I</th>
<th>Designation</th>
<th>Durability</th>
<th>Preparation in accordance with ISO 8501-1</th>
<th>Type of paint in accordance with Table 8:72g</th>
<th>Coat thickness (µm)</th>
<th>Number of layers</th>
<th>Type of paint in accordance with Table 8:72g</th>
<th>Coat thickness (µm)</th>
<th>Number of layers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S6.03</td>
<td>High</td>
<td>Sa 2½</td>
<td>EP, PUR</td>
<td>80</td>
<td>1</td>
<td>EP, PUR</td>
<td>200</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>S6.05</td>
<td>Medium</td>
<td>Sa 2½</td>
<td>EP (Zn), PUR (Zn)</td>
<td>40</td>
<td>1</td>
<td>EP, PUR</td>
<td>120</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>S6.06</td>
<td>High</td>
<td>Sa 2½</td>
<td>EP (Zn), PUR (Zn)</td>
<td>40</td>
<td>1</td>
<td>EP, PUR</td>
<td>200</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>N6.01</td>
<td>Medium</td>
<td>Sa 2½</td>
<td>EN (Zn), EP (Zn)</td>
<td>40</td>
<td>1</td>
<td>OX</td>
<td>160</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>N6.02</td>
<td>High</td>
<td>Sa 2½</td>
<td>EN (Zn), EP (Zn)</td>
<td>80</td>
<td>1</td>
<td>EP, PUR</td>
<td>240</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>S9.12</td>
<td>Medium ³</td>
<td>Vfz ⁴</td>
<td>EP, PUR</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

1. Hot dip zinc coating in accordance with EN–ISO 1461. The minimum thickness of the zinc layer is 70–85 µm depending on the material thickness of the steel.
2. For fasteners in bolted connections Fe/Zn 45.
3. The durability only applies to the painting.
4. Hot dip zinc coated steel should be cleaned and abrasive blast cleaned to surface profile fine in accordance with SS–EN ISO 8503-2 before painting.
5. The thickness of the zinc coating is not included.
## Table 8:72e Examples of corrosion protection systems in Corrosivity Category C5-M

<table>
<thead>
<tr>
<th>Designation</th>
<th>S7.06</th>
<th>S7.07</th>
<th>S7.09</th>
<th>N7.01</th>
<th>N7.02</th>
<th>S9.11</th>
<th>S9.12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Preparation in accordance with ISO 8501-1</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Vfz ³</td>
<td>Vfz ³</td>
</tr>
<tr>
<td>Type of paint in accordance with Table 8:72g</td>
<td>EP, PUR</td>
<td>EP (Zn), PUR (Zn)</td>
<td>EP (Zn), PUR (Zn)</td>
<td>EN (Zn), EP (Zn)</td>
<td>EN (Zn), EP (Zn)</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>250 ⁵</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Number of layers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Type of paint in accordance with Table 8:72g</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
<td>OX</td>
<td>OX</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
</tr>
<tr>
<td>Coat thickness (µm)</td>
<td>250</td>
<td>200</td>
<td>280</td>
<td>200</td>
<td>280</td>
<td>80</td>
<td>160</td>
</tr>
<tr>
<td>Number of layers</td>
<td>1</td>
<td>3</td>
<td>3–4</td>
<td>2–3</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total thickness of system</td>
<td>500</td>
<td>240</td>
<td>320</td>
<td>240</td>
<td>320</td>
<td>160 ⁶</td>
<td>240 ⁶</td>
</tr>
<tr>
<td>Total number of layers</td>
<td>2</td>
<td>4</td>
<td>4–5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

1. Hot dip zinc coating in accordance with EN–ISO 1461. The minimum thickness of the zinc layer is 70–85 µm depending on the material thickness of the steel.
2. For fasteners in bolted connections Fe/Zn 45.
3. The durability only applies to the painting.
4. Hot dip zinc coated steel should be cleaned and abrasive blast cleaned to surface profile fine in accordance with SS–EN ISO 8503-2 before painting.
5. The coating thickness could easiest be achieved with a solvent-free type of paint.
6. The thickness of the zinc coating is not included.
Table 8:72f Examples of corrosion protection systems in Corrosivity Categories Im1–Im3

<table>
<thead>
<tr>
<th>Corrosivity Category Im1–Im3</th>
<th>Designation</th>
<th>S8.01</th>
<th>S8.04</th>
<th>S8.05</th>
<th>S8.06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Preparation in accordance with ISO 8501-1</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td>Sa 2½</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type of paint in accordance with Table 8:72g</td>
<td>EP (Zn), PUR (Zn)</td>
<td>EP</td>
<td>EP</td>
<td>EP²</td>
</tr>
<tr>
<td></td>
<td>Coat thickness ((\mu m))</td>
<td>40</td>
<td>80</td>
<td>80</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>Number of layers</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Type of paint in accordance with Table 8:72g</td>
<td>EP, PUR</td>
<td>EP, PUR</td>
<td>EP²</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Coat thickness ((\mu m))</td>
<td>310</td>
<td>300</td>
<td>400</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Number of layers</td>
<td>2–4</td>
<td>2</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Total thickness of system</td>
<td>350</td>
<td>380</td>
<td>480</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>Total number of layers</td>
<td>3–5</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

1 Should not be used for structures in constant contact with water.

2 Type free of solvents.
Table 8:72g Types of paint

<table>
<thead>
<tr>
<th>Paint Designation</th>
<th>Type of paint</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK</td>
<td>Alkyd with a passivizing pigment</td>
</tr>
<tr>
<td>AY</td>
<td>Acrylic with a passivizing pigment</td>
</tr>
<tr>
<td>EN (Zn)</td>
<td>One-pack epoxy, zinc rich (^2)</td>
</tr>
<tr>
<td>EP (^3)</td>
<td>Two-pack epoxy</td>
</tr>
<tr>
<td>EP (Zn)</td>
<td>Two-pack epoxy, zinc rich (^4)</td>
</tr>
<tr>
<td>OX</td>
<td>Two-pack oxirane ester with a passivizing pigment (^4)</td>
</tr>
<tr>
<td>PUR</td>
<td>Two-pack urethane with a passivizing pigment (^4)</td>
</tr>
<tr>
<td>PUR (Zn)</td>
<td>Two-pack urethane, zinc rich (^2)</td>
</tr>
<tr>
<td>Primer</td>
<td></td>
</tr>
<tr>
<td>AK</td>
<td>Alkyd</td>
</tr>
<tr>
<td>AY</td>
<td>Acrylic</td>
</tr>
<tr>
<td>EP (^5)</td>
<td>Two-pack epoxy, including those modified with resin</td>
</tr>
<tr>
<td>PUR</td>
<td>Two-pack urethane</td>
</tr>
<tr>
<td>OX</td>
<td>Two-pack oxirane ester</td>
</tr>
</tbody>
</table>

1 When choosing the type of paint, the principle of superposition in accordance with the Act on Chemical Products shall be taken into account, i.e. a product more harmful to the environment and injurious to people’s health shall be replaced by a less harmful and injurious product where this is possible from a technical point of view.

In order to reduce, as far as possible, the discharge of solvents from painting and cleaning, water based paints or paints with a high dry substance should be used where possible.

2 The term zinc rich refers to a paint with a zinc content of at least 90\%, calculated on the basis of the dry substance of the paint and given in percentages of weight.

3 For this type of paint, a product free from solvents is also available as an alternative.

4 On a hot dip zinc coated surface the paint does not need to contain passivizing pigment.

5 Whitens when exposed outdoors, where better hardiness against whitening is required aliphatic PUR should be chosen at first hand.

Only corrosion protection systems which have been subject to initial type-testing at an accredited testing laboratory and have been documented by the relevant paint manufacturer/supplier should be used. The documentation should be available in the form of a testing certificate.

The test methods which are specified in SS–EN ISO 12944-6 are accelerated laboratory methods. The accuracy of these tests is limited. For this reason greater weight should be given to results from field exposure. Testing should be carried out in accordance with Guidelines for testing of anti-rust painting by field exposure, SCI Report No 1993:8, Swedish Corrosion Institute 1993 and in accordance with Evaluating coating systems after testing, SCI Report No 1999:2, Swedish Corrosion Institute 1999. Systems for members in Corrosivity Categories Im1–Im3, which are intended to be used in water or in soil should also be exposed to dipping in de-ionised water in accordance with SS 18 41 62 (ISO 1521).

In the course of the field exposure a certificate from Scab testing in accordance with SS 11 72 11 (ISO/CD 11474:1993-01-22) may replace a testing certificate based on field exposure. The Scab testing should be carried out in the temperate climatic region on a location where the rate of corrosion on unpainted steel (without chloride sprayed surfaces) is at least 5 \(\mu m\)/year during one year’s exposure (single-sided corrosion). In addition,
the testing of corrosion protection systems in Corrosivity Category C2 should be carried out during the summer period.

Conditions of exposure and the corresponding limit values for the above mentioned field tests are given in Tables 8:72h and 8:72i.

### Table 8:72h Conditions of exposure for the testing of corrosion protection systems

<table>
<thead>
<tr>
<th>Corrosivity Category</th>
<th>Field exposure at Bohus-Malmö, station Kvarnvik or at an equivalent location</th>
<th>Exposure to de-ionised water in accordance with SS 18 41 62</th>
<th>Exposure in conjunction with Scab testing in accordance with SS 11 72 11 (ISO/CD 11 474: 1993-01-22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>0.5 (year)</td>
<td>0.5 (year)</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>2 (year)</td>
<td>1 (year)</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>4 (year)</td>
<td>2 (year)</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>4 (year)</td>
<td>2 (year)</td>
<td></td>
</tr>
<tr>
<td>Im1–Im3</td>
<td>4 (year)</td>
<td>1 (year)</td>
<td>2 (year)</td>
</tr>
</tbody>
</table>

1 The corrosivity at the field station Kvarnvik corresponds to Corrosivity Category C4 for steel and Corrosivity Category C3 for zinc. The average corrosion on steel during one year's exposure has been measured to $485 \pm 36 \text{ g/m}^2$, and on zinc $8.1 \pm 0.1$.

### Table 8:72i Limit values for the testing of corrosion protection systems with medium or high duration

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Applicable standard</th>
<th>Limit value at the end of the field exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Corrosivity Categories C2 and C3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corrosivity Category C4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corrosivity Categories C5-I, C5-M, Im1–Im3</td>
</tr>
<tr>
<td>Degree of corrosion</td>
<td>SS 18 42 03 (ISO 4628-3)</td>
<td>Ri 0</td>
</tr>
<tr>
<td>Blistering</td>
<td>SS 18 42 02 (ISO 4628-2)</td>
<td>0</td>
</tr>
<tr>
<td>Cracking</td>
<td>SS 18 42 04 (ISO 4628-4)</td>
<td>0</td>
</tr>
<tr>
<td>Flaking</td>
<td>SS 18 42 05 (ISO 4628-5)</td>
<td>0</td>
</tr>
<tr>
<td>Adhesion</td>
<td>SS 18 41 71 (ISO 4624: 1978)</td>
<td>2 MPa, 2 MPa, 2 MPa</td>
</tr>
<tr>
<td>1-pack paint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-pack paint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spread from a scratch and a exposed edge</td>
<td>SS 18 42 19, but with a scratch of 1 mm</td>
<td>Max 4 mm, Max 4 mm, Max 4 mm</td>
</tr>
<tr>
<td>Systems with a primer containing zinc</td>
<td>SS 18 42 19, but with a scratch of 1 mm</td>
<td>Max 10 mm, Max 10 mm, Max 10 mm</td>
</tr>
</tbody>
</table>
8:73 Cathodic protection

Cathodic protection can be provided by means of
– a sacrificial anode of a metal less electropositive than the metal to be protected
– impressed direct current.

Protection is arranged so that all parts of the structure attain a potential of $-0.85 \text{ V}$ or lower relative to a copper/saturated copper sulphate electrode.

The cathodic current density required to attain this potential is above all dependent on whether the steel is unpainted or painted and the type of paint applied. In water, the current requirement for unpainted steel may be higher than $100 \text{ mA/m}^2$ but with an appropriate paint only a few mA/m$^2$. The current requirement is also affected by the rate of the flow of water. With regard to these circumstances the protective current density should be determined in each specific case.

Painting which is being used in combination with cathodic protection should be alkali-proof and also be able to resist the development of hydrogen gas which in some cases may appear on the surface of the protected structure. As an example of paints which are useful in conjunction with cathodic protection epoxy paint could be mentioned.

8:74 Corrosion allowance

A corrosion allowance, i.e. an increase in material thickness over and above that required in view of the requirements in the ultimate and serviceability limit states, may replace corrosion protection if
– the service life of the structure is limited,
– the environment is well defined,
– the risk of pitting is negligible,
– the risk of crevice corrosion is negligible and
– the effect of corrosion with respect to fatigue is taken into consideration.

The corrosion allowance should be determined in view of the expected maximum loss of material due to corrosion during the service life of the structure. The values in Table 8:74 may be used in determining the corrosion allowance in Corrosivity Categories C2, C3 and C4. For structures in Corrosivity Categories C5-I and C5-M, the size of the corrosion allowance should be determined in each individual case. Pitting in these environments may be as much as 2–3 mm annually.
### Table 8:74 Typical loss of material\(^1\) in constructional and slow rusting steels (values refer to one face only)

<table>
<thead>
<tr>
<th>Corrosivity Category</th>
<th>Constructional steel</th>
<th>Slow rusting steel</th>
<th>Constructional steel</th>
<th>Slow rusting steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First 10-year period (mm)</td>
<td>Subsequent 10-year periods (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>0.05</td>
<td>0.02</td>
<td>0.015</td>
<td>0.01</td>
</tr>
<tr>
<td>C3</td>
<td>0.12</td>
<td>0.08</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>C4</td>
<td>0.30</td>
<td>0.15</td>
<td>0.20</td>
<td>0.10</td>
</tr>
</tbody>
</table>

\(^1\) The values for loss of material due to corrosion are taken from SS–ISO 9224. The table gives upper limit values for each interval.

### 8:75 Fire protection painting

In conjunction with fire protection painting the relevant parts of Subclause 8:72 should be taken into account.

Fire protection paint and finishing coat, if any, should not be considered to possess any corrosion protective qualities. The paints in the corrosion protection system must be chosen so that they can be combined with the fire protection painting.

### 8:8 Transport and handling

During transport, storage and handling, a structural member should not be stacked or loaded in such a way that damage, stress or deformations occur which may deteriorate the properties of the material or result in non-compliance with the quality requirements for the Workmanship Class concerned (see Clause 8:12).

Strengthening or attachments for hoisting devices, erection holes etc. for the transport or handling of a structural member should be made in consultation with the designer. With regard to welding, reference should also be made to Subclause 8:41.

### 8:9 Erection

*BKR 99, Clause 2:5, fourth paragraph*

Temporary bracing necessary to provide stability during the period of erection shall be provided.
… Work shall not begin until an erection schedule is available.

With regard to erection schedules and the qualifications of the staff, see Subclauses 1:43 and 8:11 respectively.
9 SUPERVISION AND CONTROL

**BSK 99, Clause 8:6**

The values of the partial factors $\gamma_m$ and $\gamma_{mp}$ set out in this section presuppose that the supervision and control specified in Section 2:6 is carried out.

General recommendation:

For structures in Safety Class 1 the scope of inspections and tests may be assessed in view of circumstances.

Acceptance inspection on delivery, apart from identification and visual examination, may be carried out as spot checks if the materials or products delivered are likely to comply with the stipulated requirements, e.g. due to the availability of acceptance certificates from previous tests. Acceptance certificate Type 3.2 in accordance with SS–EN 10 204 should be used.

**BSK 99, Subclause 2:621**

The term basic inspection in these mandatory provisions refers to the general control of materials, products and workmanship.

General recommendation:

Material-specific regulations regarding basic inspection are set out in the sections for each material.

The term additional inspection in these mandatory provisions refers to the specific control which shall be carried out regarding

- constructional details which are of critical importance for the resistance, stability or durability of the structure,
- structural details of unconventional design, and
- environmental effects.

A scheme shall be drawn up for additional inspection.

General recommendation:

Material-specific regulations regarding additional inspection are set out in the sections for each material.

Rules for basic inspection and additional inspection are given in Subclauses 9:6 and 9:7 respectively.

With regard to the additional inspection scheme, see Subclause 1:44.

All visual control and non-destructive tests of heat affected parts should be carried out after the hydrogen diffusion has stabilised, and the time is directed for example by the maximum material thickness, type of steel and the amount of hydrogen.
9:1 Design supervision

*BKR 99, Subclause 2:61*

The term control of design in these mandatory provisions refers to checks on design assumptions, construction documents and calculations.

General recommendation:

This control should be undertaken by a person not previously engaged in the project.

9:2 Acceptance inspection

*BKR 99, Subclause 2:62, first paragraph*

The term acceptance inspection in these mandatory provisions refers to checks to ensure that materials and products have the specified properties, which implies that on delivery to the construction site, materials and products shall be

– identified,
– examined and
– tested unless they have received type approval or been subjected to factory production control.

The results of tests in conjunction with the acceptance inspection should be entered in an acceptance certificate.

Tests in conjunction with acceptance inspection in accordance with Subclause 9:61 should be carried out at an accredited testing laboratory. The results of the tests should be entered in a test report.

9:21 Type approved or production controlled materials and products

*BKR 99, Subclause 2:62, third and fourth paragraphs*

Materials and products which have received type approval or have been subjected to factory production control in accordance with Section 1:4 need not undergo further testing or inspection in those respects which are covered by the type approval or factory production control.

General recommendation:

For products referred to in the last paragraph, acceptance inspection may be confined to identification, checks on markings and visual inspection.
9:22 Workshop products which are not production controlled in accordance with BKR 99, Clause 1:4

If products from a fabricating shop, which have not been subjected to production control, are being used, the production should be inspected by an independent expert appointed by the building owner or the commissioner of the building project. The inspection should include an assessment of the qualifications of the fabricating shop with respect to fabrication of the steel structure in question, e.g. an assessment of the machinery, procedures for production and control, and the competence of the personnel. It is assumed that the expert prepares a concluding report of the inspection.

It is stipulated that the production control in the fabricating shop comprises the same control measures that apply for control at the building site.

9:221 The competence of the independent expert

In addition to the qualifications in accordance with Subclause 8:11 the independent expert should have theoretical knowledge and practical experience of construction and inspection and special competence relevant to the nature of the project.

9:3 Supervision of construction

*BKR 99, Subclause 2:62, second paragraph*

The term supervision of construction in these mandatory provisions refers to checks to ensure that
– the design assumptions which were not previously verifiable and which are significant for safety are satisfied, and
– the work is carried out in accordance with the most recent drawings and other documents.

9:4 Documentation

*BKR 99, Subclause 2:63*

The results of checks and supervision, inclusive of deviations if any and action taken because of these, as well as other information which is significant for the quality of the finished structure, shall be documented.
The documentation should be kept available for the inspector.

The results of inspections and the actions taken should be summarised in an inspection certificate.

The inspection certificate should contain at least the following information:

- confirmation that basic inspection in accordance with Clause 9:6 has been carried out,
- the results of additional inspection in accordance with the inspection schedule,
- data concerning any deviations from the design documents, for instance utilisation of deep penetration in fillet welds in accordance with Subclause 8:43, and
- data concerning defects or damage and actions taken.

Documentation for the verification of actions taken may consist of consignment notes and test reports, control records, entries in the site diary, as well as records and certificates relating to inspections and checks.

9:5 The building owner's responsibilities according to the Planning and Building Act

The building owner's responsibilities are set out in Chapter 9 of the Planning and Building Act, PBL. With respect to PBL, a building owner is a person who on his own account carries out or gets someone else to carry out building, demolition or earthworks.

The building owner shall arrange for sufficient inspection and testing to be carried out and see to it that work is carried out in accordance with PBL and its associated regulations. Construction works shall be planned and carried out with care so that people and property are not injured or damaged and so that the least possible inconvenience occurs.
9:6 Basic inspection

BKR 99, Subclause 8:61
General recommendation:
Basic inspection should comprise the following areas:
– materials,
– dimensions and shape,
– welded connections,
– bolted connections, and
– surface finish for fire and corrosion protection.

Examples of the measures to be taken in conjunction with basic inspection are given in Section 9 of BSK 99.
If the scope of basic inspection is not specified in detail, it may be confined to sampling inspection. In such a case the inspection measures should have a scope such that there is a satisfactory degree of certainty that the structure as a whole complies with the requirements.

The inspection should be carried out by a person who has not carried out the work and who has the relevant qualifications specified in Subclause 9:221.

9:61 Material – not subject to production control

An inspection lot for the testing of material in conjunction with acceptance inspection should comprise a material lot of not more than 40 tonnes. The lot should be uniform with respect to fabricator, type of steel, charge, state on delivery and material thickness for yield strength in accordance with the relevant standard. Larger material lots should be broken down into several inspection lots.

Each inspection lot should be inspected to the extent specified in the sampling schedules in Table 9:61a.

If a material lot does not comply with the conditions specified for an inspection lot or if there are defects in documentation or marking, sampling schedule H in accordance with SS 11 01 03 should be applied unless it can be shown in some other reliable way that the lot complies with the stipulated requirements.

Material which in conjunction with sampling inspection does not comply with the specifications should be rejected unless it can be reclassified as some other type of steel.

The testing of standardised steel in conjunction with acceptance inspection should be carried out in accordance with Tables 9:61a and b.
Table 9:61a  Scope of tests on steel material

<table>
<thead>
<tr>
<th>Steel</th>
<th>Chemical analysis</th>
<th>Tensile test</th>
<th>Impact test</th>
<th>Bending test</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS–EN 10 025+A1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>–</td>
</tr>
<tr>
<td>SS–EN 10 113</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>–</td>
</tr>
<tr>
<td>SS–EN 10 137</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>–</td>
</tr>
<tr>
<td>SS–EN 10 149</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>SS–EN 10 210</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>–</td>
</tr>
<tr>
<td>SS–EN 10 219</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>–</td>
</tr>
<tr>
<td>Sampling schedule in accordance with SS 11 01 03</td>
<td>E</td>
<td>D</td>
<td>E</td>
<td>D</td>
</tr>
</tbody>
</table>

¹ Impact test may be left out for S235JRG2.

Table 9:61b  Prescribed standards for the sampling and testing of steel material.

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Sampling</th>
<th>Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical analysis</td>
<td>SS 11 01 05</td>
<td></td>
</tr>
<tr>
<td>Tensile test</td>
<td>SS 11 01 20</td>
<td>SS–EN 10 002–1</td>
</tr>
<tr>
<td>Impact test</td>
<td>SS 11 01 51</td>
<td>SS–EN 10 045–1</td>
</tr>
<tr>
<td>Bending test</td>
<td>SS 11 01 80</td>
<td>SS 11 26 26</td>
</tr>
</tbody>
</table>

Tests on material properties other than those set out in Table 9:61b should be carried out if special requirements are stipulated for the material.
Examples of such tests are tests to establish Poisson's ratio in the thickness direction or tests on hardness.

9:62  Dimensions and shape

Basic inspection of dimensions and shape should comprise checks that
– thermally cat surfaces comply with Subclause 8:32,
– dimensional accuracy, straightness and flatness comply with the specifications in the design documents and in Subclauses 8:61 and 8:62,
– surfaces that transmit compressive force comply with Subclause 8:63, and
– workmanship conforms to the appropriate Workmanship Class as specified in Table 8:12 and in all other respects to Section 8.

Checks on the dimensions, straightness and flatness of continuous materials should be made by measurement and comparison with the appropriate standard for the continuous material.
9:63 **Welded connections**

Basic inspection of welded connections should comprise

– visual inspection of joint preparation,
– visual inspection of the surfaces and shapes of welds,
– measurement of the throat size of fillet welds,
– checks that workmanship in other respects conforms to Clause 8:4, and
– check on the competence of the person who carries out welding, see Subclause 8:46.

9:631 **Filler metal**

Inspection of filler metal for welding should comprise checks on strength properties, elongation at rupture and impact strength.

Tests on filler metal should be carried out in accordance with SS 06 01 01.

Filler metals which are listed in the schedule of type approved electrodes, issued by the Swedish Welding Research Commission, need not normally be further tested in conjunction with acceptance inspection.

9:64 **Bolted connections**

Basic inspection of bolted connections should comprise checks that

– the types, numbers and placing of the bolts agree with the design drawing,
– in high strength friction grip connections, Classes S3 and S3 (coarse), the parts of the connection, after the preliminary tightening, have the required flatness and are in proper contact, and
– workmanship in other respects complies with Clause 8:5.

9:641 **Bolts and nuts**

Inspection of bolts and nuts should comprise checks on strength properties, tolerances and, where applicable, surface treatment.

It should be possible to document the strength class of bolts and nuts by a test certificate, type 3.1.B in accordance with SS–EN 10 204, for the lot concerned issued by the manufacturer. If such a test certificate does not exist, tests are carried out as part of the acceptance inspection.

In conjunction with the acceptance inspection of bolts and nuts, checks on strength and, where applicable, zinc thickness should be carried out by tests on at least one bolt and one nut per 100, but at least three bolts and three nuts for each strength class and dimension in the lot.

The ultimate tensile strength of bolts and nuts should be tested in accordance with SS–ISO 898-1 and -2. In highly preloaded connections, however, bolts and nuts should be tested together in accordance with SS-ISO 898-1: 8.2, where the test nut is the nut in the connection. Tests on zinc thickness should be carried out in accordance with SS 3192.
It is stipulated that reinforcing bars, for instance for threaded structural elements, have been inspected in accordance with the inspection rules in *BBK 94*.

### 9:642 Washers in highly preloaded bolted connections

Inspection of washers should comprise checks on hardness, tolerances and, where applicable, surface treatment. It should be possible to document the hardness of washers by a test certificate, type 3.1.B in accordance with SS-EN 10 204, for the lot concerned issued by the manufacturer. If such a test certificate does not exist, tests are carried out as part of the acceptance inspection.

In conjunction with the acceptance inspection of washers, checks on hardness, tolerances and, if applicable, zinc thickness should be carried out by tests on at least one washer per 100, but at least three washers for each dimension in the lot.

The hardness of washers should be tested in accordance with ISO /R81. Tests on zinc thickness should be carried out in accordance with SS-EN ISO 1463 or as an alternative SS–EN ISO 2178.

### 9:65 Corrosion protection

Basic inspection of corrosion protection should comprise

- checks on environmental conditions, and that the surface temperature of steel members during preparation and painting is at least 3°C higher than the dew point of the surrounding air in accordance with the guidelines given in ISO 8502-4,

- checks that prepared steel surfaces which are to receive corrosion protection treatment have the required degree of cleanliness, assessment in accordance with ISO 8501-1 (SS 05 59 00) and the required surface coarseness, assessment in accordance with SS–EN ISO 8503-2,

- measurement of the thickness of the protective coating in accordance with SS 18 41 60, and

- checks that the corrosion protection treatment in all other respects complies with the provisions of Clause 8:7.

Examples of inspection measures in conjunction with corrosion protection are given in SS–EN ISO 12944-7. See also *Recommendations for inspection of corrosion protection painting*, Bulletin No 104, Swedish Corrosion Institute.

### 9:66 Fire protection coating

In conjunction with fire protection coating, applicable parts of Subclause 9:65 should be taken into account.
9:7 Additional inspection

Additional inspection should comprise the following areas:

- inspection measures relating to the specific structure in question,
- elements of structure subject to tensile force in the thickness direction,
- welded connections, and
- cathodic protection.

Examples of inspection measures in conjunction with additional inspection are given in Section 9 of BSK 99.

Additional inspection should be carried out by an independent expert, see Subclause 9:221.

9:71 Structure related inspection measures

Examples of inspection measures which should be included in additional inspection are:

- visual inspection of surfaces in Workmanship Classes GA and GB, 100%
- checks that the tolerance requirements for the cross sectional dimensions of members are complied with if $\gamma_m = 1.0$ in accordance with Subclause 3:42, one cross section for each dimension
- measurement of the deviation from straightness and inclination in highly utilised members subjected to compression
- checks on the fit between bolts and holes in close tolerance connections, sample tests
- checks on preloading force in highly preloaded connections,

for corrosion protection systems in Corrosivity Categories C3, C4, C5 and Im1–Im3

- visual inspection of surface coarseness and cleanliness in accordance with SS–ISO 8503-2 and SS 05 59 00 respectively, sample tests
- measurement of the total coat thickness of corrosion protection treatment in accordance with SS 18 41 60, 10% of the scope of the standard.

Other examples may be:

- non-destructive tests on welds with coefficients of utilisation even lower than specified in Subclause 9:732
- checks on homogeneity when a member is subjected to tensile forces in the thickness direction, in conjunction with coefficients of utilisation even lower than specified in Subclause 9:72, or for structures in Safety Class 1
– checks on bond for the total corrosion protection treatment in accordance with SS 18 41 71 in Corrosivity Categories higher than C2
– checks on the porosity of organic coatings for systems S8.05 and S8.06.

9:72 Structural elements subject to tensile forces in the thickness direction

Additional inspection of structural elements should be carried out
– in accordance with Subclause 7:22, items a–f
– in conjunction with coefficients of utilisation $0.2 \leq \eta_{ULS} \leq 0.5$ and $\eta_{FLS} \leq 0.5$

The inspection may be confined to structures in Safety Classes 2 and 3 and should include all the affected structural elements. Inspection should be carried out after welding; for material thickness $\leq 25$ mm at the earliest 16 hours and for material thickness $> 25$ mm at the earliest 40 hours after welding is completed.

It is stipulated that inspection is carried out by ultrasonic testing of those parts of the parent material which are affected by tensile force in the thickness direction. The parent material should be free from non-homogeneities such as cracks, cleavages and clusters of elongated inclusions.

9:73 Welded connections

Additional inspection of welded connections should comprise:
– visual inspection in accordance with Subclause 9:731,
– non-destructive testing in accordance with Subclause 9:732, and
– other checks in accordance with Subclause 9:733.

9:731 Visual inspection of welds

In Workmanship Classes GA and GB, the welds should be checked along their entire length by visual inspection. In Workmanship Class GC the scope of visual inspection may be confined to sampling inspection, the extent of which should be specified in the inspection schedule, quality requirements in accordance with Subclause 8:14.

If visual inspection gives rise to doubt whether the specified quality requirements are satisfied, visual inspection should be supplemented by non-destructive testing, for instance by crack detection.

Visual Inspection in Workmanship Class GC should be directed by the inspection schedule towards those welded connections which are of major significance for the safety, performance and durability of the structure. Appropriate typical values of the scope of sampling inspection are 25% of the length of weld in Safety Class 3 and 10% in Safety Class 2. Recommendations for the realisation of visual inspection of welds are given
in SS–EN 970. It is stipulated that a written report is prepared, e.g. with contents in accordance with the forms given in MNC 1120.

Visual inspection should be carried out by an independent expert with certifying competence in accordance with ASNT or Nordtest/SS–EN 473.

9:732 Non-destructive testing

Non-destructive tests on welds should be carried out at the earliest 16 hours after welding is completed. For welds in members with a thickness \( \geq 25 \text{ mm} \) non-destructive tests are carried out at the earliest 40 hours after welding is completed.

Non-destructive tests on welds should be carried out in connections with coefficients of utilisation higher than 0.70 in structures not subject to fatigue loading and in connections with coefficients higher than 0.50 in structures subject to fatigue loading. Even if non-destructive tests are not prescribed at least one sample should be taken out. For the above coefficients of utilisation, the scope of non-destructive tests should be as specified in Table 9:732. The values given in the table are the lengths of weld inspected, as a percentage of the length of weld with the specified coefficient of utilisation. For welded connections produced at the building site the scope should be doubled.

It is assumed that in deciding which welds should be included in the inspection schedule the designer takes account of the Safety Class, coefficient of utilisation, the weld geometry and the risk of defects and errors in the welded connection with respect to welding method, accessibility etc.

Non-destructive testing should be carried out in accordance with one of the following methods:

– radiography, in accordance with SS–EN 1435, Class B, with the image quality in accordance with SS–EN 462-3. For welds in Workmanship Class GC, image quality Class A may also be applied. Radiograms should be interpreted in accordance with SS–EN 1435 with quality requirements in accordance with SS–EN 12 517 and Table 8:14.

– ultrasonic testing in accordance with SS–EN 1714. Quality requirements in accordance with SS–EN 1712 and Table 8:14. For the testing of structures in Workmanship Classes GA and GB Examination Level B or higher should be applied.

– crack detection by the magnetic particle method in accordance with SS–EN 1290, quality requirements in accordance with SS–EN 1291 and Table 8:14. If the magna flux method cannot be used it should be replaced by the dye penetrant method in accordance with SS–EN 571, quality requirements in accordance with SS–EN 1289 and Table 8:14.

Non-destructive testing should be arranged so that the weaker parts of the weld are included in the test, e.g. the beginning and end of the weld. Furthermore, each individual weld should be tested.

Non-destructive tests on welds should be carried out by an independent expert with certifying competence in accordance with ASNT or Nordtest/SS–EN 473.
If there is doubt concerning interpretation of the results obtained in non-destructive tests, additional tests should be carried out by some other method.

**Table 9:732**  Prescribed minimum scope of non-destructive tests on welds expressed as a percentage of the length of weld with coefficient of utilisation in accordance with Subclause 9:732

<table>
<thead>
<tr>
<th>Workmanship Class</th>
<th>Welding Class</th>
<th>Safety Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA</td>
<td>WA</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>WB</td>
<td>25</td>
</tr>
<tr>
<td>GB</td>
<td>WA</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>WB och WC</td>
<td>10</td>
</tr>
<tr>
<td>GC</td>
<td>WA–WC</td>
<td>10</td>
</tr>
</tbody>
</table>

**9:733 Other checks**

Other checks on welded connections should be carried out at the earliest 40 hours after welding is completed and comprise

- checks that the appropriate preliminary tests have been carried out in conjunction with utilisation of penetration in fillet welds, as specified in Subclause 8:43 and

- checks on fluid-tightness if special requirements have been stipulated for fluid-tightness, see also appendix 4.

Other checking may also refer to checks on tests applied for a special welding or cutting procedure. It may also refer to assessment of production control in conjunction with extensive utilisation of deep penetration in fillet welds in accordance with Subclause 8:43.

**9:74 Cathodic protection**

Cathodic protection should, for instance, be checked by measuring the potential of the protected structure in relation to a reference electrode, for instance a copper/saturated sulphate electrode. The inspection should be carried out by a person who has a thorough knowledge of the mode of action of such protection. For instance, it has to be secured that the cathodic protection does not affect other structures in a negative way.
10 MAINTENANCE

10:1 Introduction

According to Swedish building legislation the owner is responsible for the maintenance of the building so that the technical quality of the building on the whole is maintained. Certain facilities e.g. those which shall provide safety shall be kept intact. The exterior of buildings shall be kept in good condition.

Legislation regarding maintenance is given in BVL, 2 § last paragraph and in 13 § and in PBL, 3 Chapter 13 §.

This section gives examples of systems for the maintenance of steel structures which have been deemed to comply with the requirement concerning durability in BKR 99, Subclause 2:13. It should be specially pointed out that the proposed maintenance systems only are given as examples.

Every steel structure shall be subjected to routine inspection in accordance with Clause 10:2.

If there are special reasons for this, a steel structure or part thereof shall in addition be subjected to periodic detailed inspection in accordance with Clause 10:3. Examples of such special reasons are:

– that there is a great risk of corrosion, for instance in Corrosivity Categories C4, C5-I, C5-M and Im1–Im3

– that a structural member forms part of a building which is designed in such a way that failure of the member may give rise to extensive damage comparable to progressive collapse in accordance with BKR 99, Subclause 2:113

– that the structure is subjected to fatigue loading

– that there is a risk of brittle fracture, for instance in the case of a structural member for which a higher Workmanship Class (GA or GB) has been stimulated in accordance with Table 7:21b.

10:2 Routine inspection

10:21 General

Routine inspection comprises regular examination of the steel structure with respect to visible damage, and the action necessitated by such damage.

The inspection shall be carried out by an independent expert familiar with the maintenance of steel structures.
If damage which is of essential significance for the resistance or durability of the structure is discovered, the structure or the structural member concerned shall be subjected to periodic detailed inspection in accordance with Clause 10:3, or appropriate actions in accordance with Clause 10:4 shall be taken to make good the damage. This also applies to other structural members which are under risk of similar damage.

The results of routine inspection shall be documented in accordance with Clause 10:5.

10:22 Structural members

Routine inspection of structural members comprises visual examination with respect to damage and abnormal deformations. Special attention shall be given to members which may be exposed to mechanical action, for instance impact by a vehicle. An examination shall also be made to see whether the structure has been damaged by attachments etc. welded on.

10:23 Welded connections

Routine inspection of welded connections comprises visual examination with respect to damage and abnormal deformations in the connection.

If there is doubt concerning the state of a welded connection, the protective coating on the weld and the parent material affected by the weld shall be removed. If this is necessary, an appropriate test method such as crack detection shall be applied, see Subclause 9:732.

10:24 Connections comprising fasteners

Routine inspection of connections comprising fasteners comprises visual examination with respect to damage and abnormal deformations in the connection. If slip is found in an S3 connection, the preload on the bolts shall be investigated, see Subclause 9:51.

10:25 Corrosion protection

Routine inspection of corrosion protection comprises investigation of whether any corrosion damage has occurred or can be suspected to have occurred in a structural member or in a member which is otherwise important from the point of view of safety. The state of the protective paint system shall be visually examined and the rust grade shall be determined.

The scope of inspection shall be determined in view of the aggressivity of the environment and shall be directed primarily at members which are known by experience to have the greatest exposure.
If corrosion attack is found, the loss of material due to corrosion shall be estimated, and the extent of pitting, and the positions and depths of pits, shall be determined.

The positions of deposits of dirt and pockets of water shall also be noted.

A member of closed cross section which is accessible for inspection shall be checked with respect to drainage and ventilation. A member of closed cross section which is not accessible for inspection shall be checked with respect to fluid-tightness.

10:26 Frequency of routine inspections

The frequency of routine inspections shall be determined in view of the state and use of the structure. For a structure or structural member which is subjected to periodic detailed inspection in accordance with Clause 10:3, routine inspections shall be carried out once every two years, and for other structures at least once every ten years.

If there are special reasons, for instance particularly extensive corrosion attack, the frequency of inspection shall be increased.

10:3 Periodic detailed inspection

10:31 General

Periodic detailed inspection comprises examination of the steel structure and the actions necessitated by such examination.

The inspection shall be carried out by an independent expert who is familiar with the maintenance of steel structures.

The state of the structure shall be surveyed to the extent necessary with the aid of appropriate test methods. The inspection measures and their scope shall be determined in view of the state and use of the structure, maintenance carried out previously, and the inspection measures and their scope specified in the original inspection schedule.

In a structure subjected to variable loading, the mode of action of the structure under load should be noted.

The measures in accordance with Clause 10:4 which are required for continued use shall be determined on the basis of the inspection results. The remaining service life shall be assessed on the basis, for instance, of the state of the structure and its continued use.

The results of periodic detailed inspection shall be documented in accordance with Clause 10:5.
10:32 Structural members

Periodic detailed inspection of structural members comprises inspection in accordance with Subclause 10:22 and any necessary additional testing.

10:33 Welded connections

Periodic detailed inspection of welded connections comprises inspection in accordance with Subclause 10:22 and any necessary additional testing.

10:34 Connections comprising fasteners

Periodic detailed inspection of connections comprising fasteners comprises inspection in accordance with Subclause 10:23 and any necessary additional testing.

Sample checks shall be made by means of a light hammer blow to see whether a fastener has become loose.

Pretensioned ties shall be tension tested by a jack until a gap appears between the nut and the backing. The force required for this to occur shall be compared with the original pretensioning force.

10:35 Corrosion protection

Periodic detailed inspection of corrosion protection comprises thorough investigation with respect to damage etc. in accordance with Subclause 10:25 and any necessary additional testing.

10:36 Frequency of periodic detailed inspection

The frequency of periodic detailed inspections shall be determined in view of the intended remaining service life of the structure and its state and use. The frequency of periodic detailed inspections should be at least once every fifteen years.

The applicable rules in accordance with Subclause 10:26 shall otherwise be taken into account.
10:4 Actions in the event of defect or damage

10:41 General

If at the time of routine inspection, periodic detailed inspection or any other inspection, the structure is judged to be of reduced quality or if damage is found, the necessary action shall be taken to ensure that satisfactory safety and durability is maintained.

Repairs and other measures shall be carried out in a workmanlike manner and shall be checked to the necessary extent, see Section 9.

Rivets which have become loose shall be replaced by bolts in Strength Class 8.8 of the next larger size. The rivet holes shall be drilled out, and Bolted Connection Class S2 shall be applied for hole clearance and tightening.

If the required maintenance is not carried out, the remaining service life and resistance of the structure shall be reassessed.

The action taken shall be documented in accordance with Clause 10:5.

10:42 Corrosion protection

A painted surface shall be maintained when the rust grade has reached Ri 4 in accordance with SS 18 42 03 in a structure subjected to fatigue loading or if there is a risk of brittle fracture. Other structures shall be maintained when the rust grade has reached Ri 5. It may however be economical to maintain the paintwork already when the rust grade has reached Ri 3.

If corrosion attack is found on a steel surface subject to cathodic protection, the protection system shall be inspected.

If the loss of material due to corrosion on a surface with a corrosion allowance in accordance with Subclause 8:74 is expected prior to the next inspection to be larger than the stipulated corrosion allowance, actions as required shall be taken, for instance provision of corrosion protection in accordance with Clause 8:7 as applicable.

Advice concerning maintenance painting is given in the Manual of corrosion protection painting.
10:5 Documentation of maintenance

In the case of steel structures which are subject to periodic detailed inspection in accordance with Clause 10:3, the results of both routine inspection and periodic detailed inspection shall be documented in a *maintenance ledger*. The ledger shall be kept by the owner of the structure. The appropriate sections of the design documents and the inspection certificate and maintenance schedule shall be entered in the maintenance ledger.

The records of routine inspection and periodic detailed inspection shall comprise the observations made, the results of tests, the rust grade found, corrosion damage and information concerning changes in the frequencies of routine and periodic inspections. Maintenance measures taken, such as repair painting, repairs to welds and strengthening, shall also be recorded.

The maintenance ledger shall be made available to the person who carries out routine inspection and periodic detailed inspection.
APPENDIX 1

Example of a welding procedure sheet

The following example of a welding procedure sheet refers to fabrication of girders to overhead travelling cranes in Service Class B3. The cross section of the girders consist of a single symmetrical welded runway EST of steel S355J2G3 with a double-bevel butt weld with complete penetration at the upper flange and double fillet welds at the lower flange. Welding Class WB in accordance with Table 8:14.

Further information about the project in question is given in Appendix 2, page 161. Welding procedure sheets may be necessary not only for the fabrication of girders to the overhead travelling cranes but also for other welding procedures in the project, depending on whether or not the welding can be characterised as simple work of routine character. This has to be decided in each individual case taking into account the competence and qualifications of the fabricator of the steel structure.

The welding procedure sheet follows the rules given in Subclause 1:42. Above all the example is intended to show the arrangement of a welding procedure sheet. The example shall not be interpreted as a general recommendation of the most appropriate way to carry out the welding procedure in question.

Only information specific to the project under consideration has been included in the welding procedure sheet. It is presumed that general rules and procedures related to welding are being followed, e.g. the rules and the cited standards and other documents in Subclause 8:14 and Clause 8:4.

If applicable welding data sheets (WPS) in accordance with SS–EN 288-1 are available for the welds under consideration, relevant information on filler metal, welding parameters etc. may instead be given by reference to the welding data sheets which are to be attached to the welding procedure sheet.

The aim of the welding procedure sheet is to plan the work in advance with respect to filler metal, welding parameters, the welding sequence etc., in order to, as far as possible, eliminate e.g. the risk of hardening or some other inappropriate influence on the material, severe induced stresses and unacceptable deformations. Induced stresses can be kept to a minimum by maintaining the mobility of the individual members as long as possible. In composite structures comprising several welded structural components, the components should generally first be welded separately. By this procedure it is possible, where necessary, to straighten and adjust components before they are finally welded together.

The welding procedure sheet should be signed by the person who has prepared the welding procedure sheet, normally the person who is in charge of the welding or by another competent person who has been duly appointed for the task. Consultations with the designer should be confirmed with a signature on the welding procedure sheet. When the welding has been completed and inspected it may be appropriate for the welder to confirm that welding has been carried out in accordance with the welding procedure sheet.
Another example of a welding procedure sheet is given in *Comments on Swedish Regulations for Steel Structures – Inspection and Maintenance, StBK-K3*, The Swedish Committee for Steel Structures, 1979. The welding procedure sheet has in this case been established to give the welder a more complete instruction. It also comprises rules which should be followed at all times, e.g. cleaning of surfaces prior to welding and de-slagging of welds between welded seams.
Welding procedure sheet for welding of girders to an overhead travelling crane runway type EST

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of joint:</td>
<td>See drawing (double-bevel butt weld at upper flange, double fillet welds at lower flange).</td>
</tr>
<tr>
<td>Joint preparation:</td>
<td>See sketch.</td>
</tr>
<tr>
<td>Tacking:</td>
<td>Tack welds are placed with a ∅ 2.5 mm electrode, minimum length of 40 mm. Tack welds are ground down as the welding seam is advancing.</td>
</tr>
<tr>
<td>Temporary arrangements:</td>
<td>No temporary preparations such as clips etc.</td>
</tr>
<tr>
<td>Position of welds:</td>
<td>Horizontal position.</td>
</tr>
<tr>
<td>Welding sequence:</td>
<td>See sketch.</td>
</tr>
<tr>
<td>Type of electrode:</td>
<td>EN 499–E 42 4 B H5</td>
</tr>
<tr>
<td>Dimension of electrode:</td>
<td>∅ 3.25 mm for root beads, ∅ 4 mm for other beads.</td>
</tr>
<tr>
<td>Required measures prior to welding:</td>
<td>Pre-bending of the upper flange about 3 mm with respect to flatness requirements for the top face of the upper flange. Raised working temperature 100°C in welding to the upper flange and 50°C in welding to the lower flange.</td>
</tr>
<tr>
<td>Required measures during welding:</td>
<td>Intermediate weld bead temperature max 250°C.</td>
</tr>
<tr>
<td>Required measures after welding:</td>
<td>Where necessary, straightening of the upper flange to contact with rail. Where necessary, grinding of the face of welds to meet the requirements in accordance with Welding Class WB.</td>
</tr>
</tbody>
</table>

Welding procedure sheet prepared 1999-xx-xx by
Consultation with designer

Responsible for the welding procedure sheet
Responsible for the design

Work carried out according to the welding procedure sheet

Welder Welder
APPENDIX 2

Example of an additional inspection schedule

A form which can be used for the preparation of an additional inspection schedule for steel structures is given in Figure B2:1. The form is intended to function as a checklist for the designer when preparing the schedule. The form may also be used as a checklist for the inspector by ticking the last row in the form when the additional inspection has been carried out. It is presumed that individual inspection measures are recorded in separate protocols or reports which are signed by the inspector.

The additional inspection should normally include a check of the documentation of the basic inspection that has been carried out in the project, to verify that the basic inspection has been adequately carried out and documented.

One example of an additional inspection schedule for the fabrication and erection of a steel structure with crane runways is shown in Figure B2:2. The additional inspection schedule follows the rules in Clause 9:7.

An example of a welding procedure sheet for the welding of girders to the crane runway is shown in Appendix 1, page 157.

The basic and additional inspection that have been carried out should be summarised in an inspection certificate in accordance with Clause 9:4. The inspection certificate should be signed by the person who is in charge of the supervision of the fabrication and erection and by the inspector in charge of the additional inspection.

Further examples of additional inspection schedules and inspection certificates are given in Comments on Swedish Regulations for Steel Structures – Inspection and Maintenance, StBK-K3, The Swedish Committee for Steel Structures, 1979.
## Figure B2:1 Example of a form for additional inspection

**ADDITIONAL INSPECTION SCHEDULE FOR STEEL STRUCTURES**

<table>
<thead>
<tr>
<th>Raw number</th>
<th>Structural member</th>
<th>Coefficient of utilisation</th>
<th>Inspection measure</th>
<th>Visual inspection of surfaces</th>
<th>Visual inspection of joint plates</th>
<th>Ultrasonic examination after welding</th>
<th>Corrosion protection</th>
<th>Other checks</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Performed inspection*
## Figure B2:1 Example of a form for additional inspection

### ADDITIONAL INSPECTION SCHEDULE FOR STEEL STRUCTURES

<table>
<thead>
<tr>
<th>Row number</th>
<th>Structural member</th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
<th>Column 6</th>
<th>Column 7</th>
<th>Column 8</th>
<th>Column 9</th>
<th>Column 10</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Columns supporting the crane runways</td>
<td>0.02</td>
<td>102</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sample test</td>
</tr>
<tr>
<td>2</td>
<td>Base and wind braces</td>
<td>0.70</td>
<td>103</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.3.3</td>
</tr>
<tr>
<td>3</td>
<td>Overhead crane runways</td>
<td>0.89</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Trestles</td>
<td>104</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Other members n Sk 2</td>
<td>105-108</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Whole structure</td>
<td>101-108</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 3

Detail Categories

Table B3:1 Detail Category C for parent material and welded connections

In the figures, ------- marks the regions affected by the stress concentration factor for which the values of $C$ given apply. The arrows indicate the direction of the stress and not the type of stress (normal stress–shear stress, tension–compression).

<table>
<thead>
<tr>
<th>No</th>
<th>Type of connection</th>
<th>$C$</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Parent material, ground surface</td>
<td>(200)</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>Parent material, rolled surface</td>
<td>100</td>
<td>Exposed surface of slow rusting steel.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Workmanship Class GB.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>112</td>
<td>Workmanship Class GA.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>Parent material, sand blasted surface</td>
<td></td>
<td>See No 02 and 04–07.</td>
</tr>
<tr>
<td>04</td>
<td>Parent material, hot dip zinc coated</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>05</td>
<td>Parent material, sawn surface</td>
<td>112</td>
<td>Workmanship Class GB.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>125</td>
<td>Workmanship Class GA.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chamfered edges.</td>
</tr>
<tr>
<td>06</td>
<td>Parent material, sheared surface</td>
<td></td>
<td>See No 05</td>
</tr>
<tr>
<td>07</td>
<td>Thermally cut surface</td>
<td>90</td>
<td>Cutting Class Sk2.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>112</td>
<td>Cutting Class Sk3.</td>
</tr>
<tr>
<td>08</td>
<td>Open circular holes</td>
<td>71</td>
<td>The stress range may be calculated over the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td>gross area. For reamed holes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>with chamfered edges, the values of $C$ may</td>
</tr>
<tr>
<td></td>
<td>$1.5d \leq c &lt; 3d$</td>
<td></td>
<td>be increased by one step.</td>
</tr>
<tr>
<td></td>
<td>$c \geq 3d$</td>
<td></td>
<td>For punched holes, the values of $C$ shall be</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>reduced by two steps.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For values of $C$ for bolted connections, see</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Table A2:2.</td>
</tr>
<tr>
<td>09</td>
<td>Stud</td>
<td>63</td>
<td>Mechanised flash welding with quality</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>requirements in accordance with BRO 94.</td>
</tr>
<tr>
<td>No</td>
<td>Type of connection</td>
<td>Welding Class</td>
<td>$C_{</td>
</tr>
<tr>
<td>----</td>
<td>-------------------</td>
<td>---------------</td>
<td>---------</td>
</tr>
<tr>
<td>10</td>
<td>Butt weld in double V joint</td>
<td>WC</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>112</td>
</tr>
<tr>
<td>11</td>
<td>Butt weld in single V joint</td>
<td>WC</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>112</td>
</tr>
<tr>
<td>12</td>
<td>Butt weld in single V joint</td>
<td>WC</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>90</td>
</tr>
<tr>
<td>13</td>
<td>Butt weld in single V joint with backing strip left in position</td>
<td>WC</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>90</td>
</tr>
<tr>
<td>14</td>
<td>Butt weld with incomplete penetration</td>
<td>WC</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>90</td>
</tr>
<tr>
<td>15</td>
<td>Butt weld at change in plate thickness</td>
<td>WC</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>Butt weld at change in plate thickness</td>
<td>WC</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>112</td>
</tr>
<tr>
<td>No</td>
<td>Type of connection</td>
<td>Welding Class</td>
<td>$C_\parallel$</td>
</tr>
<tr>
<td>----</td>
<td>------------------------------------------</td>
<td>---------------</td>
<td>--------------</td>
</tr>
<tr>
<td>17</td>
<td>Butt weld at change in plate width</td>
<td>WC</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>–</td>
</tr>
<tr>
<td>18</td>
<td>Butt weld at girder splice</td>
<td>WC</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>–</td>
</tr>
<tr>
<td>19</td>
<td>Butt weld at girder splice (rolled girder)</td>
<td>WC</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>–</td>
</tr>
<tr>
<td>20</td>
<td>Butt weld at transverse junction</td>
<td>WB</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>50</td>
</tr>
<tr>
<td>21</td>
<td>Butt weld at transverse junction</td>
<td>WC</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>71</td>
</tr>
<tr>
<td>No</td>
<td>Type of connection</td>
<td>Welding Class</td>
<td>$C_{</td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------------------------</td>
<td>---------------</td>
<td>---------</td>
</tr>
<tr>
<td>22</td>
<td>T-butt weld</td>
<td>WC</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>112</td>
</tr>
<tr>
<td>23</td>
<td>Single V, T-butt weld</td>
<td>WC</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>100</td>
</tr>
<tr>
<td>24</td>
<td>Weld with partial penetration</td>
<td>WC</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>71</td>
</tr>
<tr>
<td>25</td>
<td>T-butt weld at girder splice (welded girder)</td>
<td>WC</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>80</td>
</tr>
<tr>
<td>26</td>
<td>T-butt weld e.g. at beam-column joint</td>
<td>$Sect. \ a-a$</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$Sect. \ b-b$</td>
<td>WC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WA</td>
</tr>
<tr>
<td>27</td>
<td>Continuous single V butt weld at attachment of circular or rectangular hollow section to stiff plate</td>
<td>WC</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>–</td>
</tr>
<tr>
<td>No</td>
<td>Type of connection</td>
<td>Welding Class</td>
<td>$C_{\parallel}$</td>
</tr>
<tr>
<td>----</td>
<td>-------------------------------------------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>28</td>
<td>T-butt weld at transverse junction</td>
<td>WC</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>50</td>
</tr>
<tr>
<td>29</td>
<td>T-butt weld at transverse junction</td>
<td>WC</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>71</td>
</tr>
<tr>
<td>30</td>
<td>Fillet weld</td>
<td>WC</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>100</td>
</tr>
<tr>
<td>31</td>
<td>Fillet weld</td>
<td>WC</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>100</td>
</tr>
<tr>
<td>32</td>
<td>Fillet weld on one side only</td>
<td>WC</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>80</td>
</tr>
<tr>
<td>33</td>
<td>Fillet weld at girder splice</td>
<td>WC</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>80</td>
</tr>
<tr>
<td>34</td>
<td>Intermittent fillet weld between flange and web in I girder</td>
<td>WC</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>56</td>
</tr>
<tr>
<td>No</td>
<td>Type of connection</td>
<td>Welding Class</td>
<td>( C_\parallel )</td>
</tr>
<tr>
<td>----</td>
<td>-------------------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>35</td>
<td>Fillet weld at transverse junction</td>
<td>WC</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>50</td>
</tr>
<tr>
<td>36</td>
<td>Fillet weld at transverse junction</td>
<td>WC</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>71</td>
</tr>
<tr>
<td>No</td>
<td>Type of connection</td>
<td>Welding Class</td>
<td>$C$</td>
</tr>
<tr>
<td>----</td>
<td>---------------------------------------------------------</td>
<td>---------------</td>
<td>-----</td>
</tr>
<tr>
<td>37</td>
<td>Fillet welded longitudinal cleat $^2$</td>
<td>WC</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Diagram of Fillet welded longitudinal cleat" /></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

38 Fillet welded transverse cleat $^2$

| WC | 45  | If the width of the cleat is less than half the plate width, the values of $C$ may be increased by one step. If $l > 100$ mm, No 48 shall be applied. |
| WB | 50  |                                                                        |
| WA | 63  |                                                                        |
| ![Diagram of Fillet welded transverse cleat](image) |              |     |                                                                        |

39 Fillet weld at transverse attachment $^2$

| WC | 45  | Weld not returned at the ends. The values of $C$ given may also be applied to T-butt welds. |
| WB | 56  |                                                                        |
| WA | 80  |                                                                        |
| ![Diagram of Fillet weld at transverse attachment](image) |              |     |                                                                        |

40 Fillet weld at transverse attachment $^2$

| WC | 45  | Weld returned at the ends. The values of $C$ given may also be applied to T-butt welds. |
| WB | 63  |                                                                        |
| WA | 90  |                                                                        |
| ![Diagram of Fillet weld at transverse attachment](image) |              |     |                                                                        |

41 Fillet weld at longitudinal attachment $^2$

| WC | 45  | Where $l \leq 100$ mm the values of $C$ may be increased by one step. The weld is not designed for the transmission of force. |
| WB | 50  |                                                                        |
| WA | 63  |                                                                        |
| ![Diagram of Fillet weld at longitudinal attachment](image) |              |     |                                                                        |

42 Intermittent fillet weld between crane rail and crane girder

<p>| WC | 45  | Good contact between rail and top flange. |
| WB | 56  |                                                                        |
| <img src="image" alt="Diagram of Intermittent fillet weld between crane rail and crane girder" /> |              |     |                                                                        |</p>
<table>
<thead>
<tr>
<th>No</th>
<th>Type of connection</th>
<th>Welding Class</th>
<th>C</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>43</td>
<td>Continuous beam with stiffeners over intermediate support (the figure shows three alternatives)</td>
<td>WC</td>
<td>50</td>
<td>The stress range is calculated at the edge of the stiffener. Weld returned at the ends.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Beam with web stiffeners in span and over end supports (see No. 43)</td>
<td>WC</td>
<td>56</td>
<td>The stress range is calculated at the edge of the stiffener. Weld returned at the ends. The values of $C$ given also apply to single stiffeners.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Box girder with stiffeners</td>
<td>WC</td>
<td>56</td>
<td>Weld returned at the ends. The values of $C$ given also apply to single stiffeners.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Beam with longitudinal web stiffeners</td>
<td>WC</td>
<td>63</td>
<td>Manual welding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Beam with longitudinal web stiffeners</td>
<td>WC</td>
<td>71</td>
<td>Mechanised welding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Beam with a cover plate</td>
<td>WC</td>
<td>–</td>
<td>With or without transverse fillet welds for Class WB. For Class WA, the transverse fillet welds and at least 100 mm of longitudinal fillet welds nearest the corner shall be dressed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Type of connection</td>
<td>Welding Class</td>
<td>C</td>
<td>Remarks</td>
</tr>
<tr>
<td>----</td>
<td>--------------------</td>
<td>---------------</td>
<td>----</td>
<td>---------</td>
</tr>
<tr>
<td>49</td>
<td>Beam with a cover plate</td>
<td>WC</td>
<td>–</td>
<td>With transverse fillet welds. For Class WA, the transverse fillet welds and at least 100 mm of longitudinal fillet welds nearest the corner shall be dressed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Beam with a cover plate</td>
<td>WA</td>
<td>63</td>
<td>Transverse fillet weld shall be dressed to slope of 1:3 or less. At least 100 mm of longitudinal fillet welds nearest the corner shall be dressed to Class WA.</td>
</tr>
<tr>
<td>51</td>
<td>Beam with a cover plate</td>
<td>WC</td>
<td>80</td>
<td>Relates to a section at least one flange width distant from the end of the cover plate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Fillet welded attachment of member</td>
<td>WC</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Fillet welded attachment of member</td>
<td>WC</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>Fillet welded symmetrical lap joint</td>
<td>WC</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Fillet welded symmetrical lap joint</td>
<td>WC</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WB</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Type of connection</td>
<td>Welding Class</td>
<td>C</td>
<td>Remarks</td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------------------------------------------------------------</td>
<td>---------------</td>
<td>----</td>
<td>---------</td>
</tr>
<tr>
<td>56</td>
<td>Continuous single fillet weld at attachment of circular or rectangular hollow</td>
<td>WC</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td>section to stiff plate</td>
<td>WB</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WA</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

1 Where the root of the weld is not given a sealing run, the value of $C$ shall be reduced by one step for $C_{||}$ and by two steps for $C_{\perp}$ in the series of values of $C$ (45, 50, 56, 63, 71, 80, 90, 100, 112 and 125, see Figure 6:523).

2 The connection is capable of transmitting shear force.
Connection factors 01 to 12 relate to parent material with drilled or reamed holes. For punched holes, the values of $C$ shall be reduced by one step. Threaded holes are not dealt with.

Unless otherwise specified, the values of $C$ relate to Bolted Connection Classes S2, S2F, S3 and S3 (coarse).

The arrows indicate the direction of stress, not the type of stress (flexural stress–normal stress, etc.).

<table>
<thead>
<tr>
<th>No</th>
<th>Type of connection</th>
<th>$C$</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Splice or attachment of flat bar by means of a double shear connection</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>Splice or attachment of flat bar by means of a single shear connection</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>Splice or attachment of each part of a member by means of a double shear connection</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>04</td>
<td>Splice or attachment by means of a partly double shear connection</td>
<td>71</td>
<td>Axial force in member.</td>
</tr>
<tr>
<td>05</td>
<td>Splice or attachment of part of a member by means of a double shear connection</td>
<td>71</td>
<td>Axial force in member.</td>
</tr>
<tr>
<td>No.</td>
<td>Type of connection</td>
<td>C</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------</td>
<td>---</td>
<td>---------</td>
</tr>
<tr>
<td>06</td>
<td>Splice or attachment by means of a single shear connection</td>
<td>71</td>
<td>Axial force in member.</td>
</tr>
<tr>
<td>07</td>
<td>Splice or attachment by means of a single shear connection</td>
<td>63</td>
<td>Axial force in member.</td>
</tr>
<tr>
<td>08</td>
<td>Unsymmetrical splice or attachment by means of a single shear connection</td>
<td>50</td>
<td>For $e \leq 2t$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45</td>
<td>For $e &gt; 2t$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$e =$ eccentricity according to the figure.</td>
</tr>
<tr>
<td>09</td>
<td>Cover plate with a single shear connection</td>
<td>63</td>
<td>Relates to a section within one flange width from the end of the cover plate.</td>
</tr>
<tr>
<td>10</td>
<td>Cover plate with a single shear connection</td>
<td>80</td>
<td>Relates to a section at least one flange width from the end of the cover plate.</td>
</tr>
<tr>
<td>11</td>
<td>Flange brace attached by means of single shear connection</td>
<td>80</td>
<td>Relates to effect of hole in the beam for a normally tightened bolt. For design of bracing, see No. 02.</td>
</tr>
<tr>
<td>No</td>
<td>Type of connection</td>
<td>C</td>
<td>Remarks</td>
</tr>
<tr>
<td>----</td>
<td>------------------------------------------------------------------</td>
<td>-----</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>12</td>
<td>Attachment of member to a gusset plate by means of a double shear connection</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Fastener, subjected to a shear force, in a single shear connection</td>
<td>90</td>
<td>The value of C given applies for S2 and S2F connections.</td>
</tr>
<tr>
<td>14</td>
<td>Fastener, subjected to a shear force, in a multi-shear connection</td>
<td>112</td>
<td>The value of C given applies for S2 and S2F connections.</td>
</tr>
<tr>
<td>15</td>
<td>Fastener subjected to a tensile force</td>
<td>45</td>
<td>The value of C applies for a tightened bolt of Strength Class 8.8 or higher. For a non-tightened bolt, No. 16 applies.</td>
</tr>
<tr>
<td>16</td>
<td>Threaded structural member</td>
<td>&lt;45</td>
<td>The design value is 90% of the value for Detail Category 45 for a rolled thread, and 70% for a cut thread.</td>
</tr>
</tbody>
</table>
APPENDIX 4

Leak testing

## APPENDIX 5
### Standards

**Table B5:1 List of standards referred to in BSK 99**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Title</th>
<th>Edition</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS 70</td>
<td>Plain washers – Inch series – Product grade A</td>
<td>5</td>
</tr>
<tr>
<td>SS-ISO 273</td>
<td>Fasteners – Clearance holes for bolts and screws</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 288-1</td>
<td>Specification and approval of welding procedures for metallic materials – Part 1: General rules for fusion welding</td>
<td>2</td>
</tr>
<tr>
<td>SS-EN 440</td>
<td>Welding consumables – Wire electrodes and deposits for gas – Shielded metal arc welding of non alloy and fine grain steels – Classification</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 462-3</td>
<td>Non-destructive-testing of – Image quality of radiographs – Part 3: Image quality classes for ferrous metals</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 499</td>
<td>Welding consumables – Covered electrodes for manual metal arc welding of non alloy and fine grain steels – Classification</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 571-1</td>
<td>Non-destructive testing – Penetrant testing – Part 1: General principles</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 719</td>
<td>Welding coordination – Tasks and responsibilities</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 756</td>
<td>Welding consumables – Wire electrodes and wire-flux combinations for submerged arc welding of non alloy and fine grain steels – Classification</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 757</td>
<td>Welding consumables – Covered electrodes for manual metal arc welding of high strength steels – Classification</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 758</td>
<td>Welding consumables – Tubular cored electrodes for metal arc welding with and without a gas shield of non alloy and fine grain steels – Classification</td>
<td>1</td>
</tr>
<tr>
<td>SS-ISO 898-1</td>
<td>Mechanical properties of fasteners – Part 1: Bolts, screws and studs</td>
<td>3</td>
</tr>
<tr>
<td>SS-ISO 898-2</td>
<td>Mechanical properties of fasteners – Part 2: Nuts with specified proof load values – Coarse thread</td>
<td>3</td>
</tr>
<tr>
<td>SS-ISO 965-1</td>
<td>ISO general purpose metric screw threads – Tolerances – Part 1:principles and basic data</td>
<td>1</td>
</tr>
<tr>
<td>SS-ISO 965-2</td>
<td>ISO general purpose metric screw threads – Tolerances – Part 2:limits of sizes for general purpose bolt and nut threads – Medium quality</td>
<td>1</td>
</tr>
<tr>
<td>SS-ISO 965-3</td>
<td>ISO general purpose metric screw threads – Tolerances – Part 3:deviations for constructional threads</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 970</td>
<td>Non-destructive examination of fusion welds – Visual examination</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 1011-1</td>
<td>Welding – Recommendations for welding of metallic materials – Part 1: General guidance for arc welding</td>
<td>1</td>
</tr>
<tr>
<td>MNC 1120</td>
<td>Non-destructive testing – Visual inspection of welds</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 1289</td>
<td>Non-destructive examination of welds – Penetrant testing of welds – Acceptance levels</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 1290</td>
<td>Non-destructive examination of welds – Magnetic particle examination of welds</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 1291</td>
<td>Non-destructive examination of welds – Magnetic particle testing of welds – Acceptance levels</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 1435</td>
<td>Non-destructive examination of welds – Radiographic examination of welded joints</td>
<td>1</td>
</tr>
<tr>
<td>EN ISO 1461</td>
<td>Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods (ISO 1461:1999)</td>
<td>1999</td>
</tr>
<tr>
<td>Designation</td>
<td>Title</td>
<td>Edition</td>
</tr>
<tr>
<td>------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>SS-EN ISO 1463</td>
<td>Metallic and oxide coatings – Measurement of coating thickness – Microscopical method (ISO 1463:1982)</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 1712</td>
<td>Non-destructive examination of welds – Ultrasonic-examination of welded joints – Acceptance levels</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 1714</td>
<td>Non-destructive examination of welds – Ultrasonic-examination of welded joints</td>
<td>1</td>
</tr>
<tr>
<td>SS 2111</td>
<td>ISO system of limits and fits – ISO tolerances H1 to H18 for holes</td>
<td>2</td>
</tr>
<tr>
<td>SS-EN ISO 2178</td>
<td>Non-magnetic coatings on magnetic substrates – Measurement of coating thickness – Magnetic method (ISO 2178:1982)</td>
<td>1</td>
</tr>
<tr>
<td>SS 3192</td>
<td>Metallic and other non-organic coatings – Hot dip zinc coated threaded components of steel</td>
<td>3</td>
</tr>
<tr>
<td>SS-ISO 3898</td>
<td>Basis for design of structures – Notations – General symbols</td>
<td>2</td>
</tr>
<tr>
<td>SS-ISO 4014</td>
<td>Hexagon head bolts – Product grades A and B</td>
<td>2</td>
</tr>
<tr>
<td>SS-ISO 4032</td>
<td>Hexagon nuts, style 1 – Product grades A and B</td>
<td>2</td>
</tr>
<tr>
<td>SS-ISO 5817</td>
<td>Arc-welded joints in steel – Guidance on quality levels for imperfections</td>
<td>1</td>
</tr>
<tr>
<td>DIN 6914</td>
<td>Hexagon bolts with large widths across flats for high tensile structural bolting</td>
<td>1989-10</td>
</tr>
<tr>
<td>DIN 6915</td>
<td>Hexagon nuts with large widths across flats for high tensile structural bolting</td>
<td>1989-10</td>
</tr>
<tr>
<td>ISO 7412</td>
<td>Hexagon bolts for high-strength structural bolting with large width across flats (short thread length) – Product grade C – Property classes 8.8 and 10.9</td>
<td>1</td>
</tr>
<tr>
<td>ISO 7414</td>
<td>Hexagon nuts for structural bolting with large width across flats, style 1 – Product grade B – Property class 10</td>
<td>1</td>
</tr>
<tr>
<td>ISO 7415</td>
<td>Plain washers for high-strength structural bolting, hardened and tempered</td>
<td>1</td>
</tr>
<tr>
<td>SS-ISO 9224</td>
<td>Corrosion of metals and alloys – Corrosivity of atmospheres – Guiding values for the corrosivity categories</td>
<td>1</td>
</tr>
<tr>
<td>SS-ISO 9692</td>
<td>Metal-arc welding with covered electrode, gas-shielded metal-arc welding and gas welding – Joint preparations for steel</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10002-1</td>
<td>Metallic materials – Tensile testing – Part 1: Method of test (at ambient temperature)</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10025+A1</td>
<td>Hot rolled products of non-alloy structural steels – Technical delivery conditions</td>
<td>2</td>
</tr>
<tr>
<td>SS-EN 10029</td>
<td>Hot rolled steel plates 3 mm thick or above – Tolerances on dimensions, shape and mass</td>
<td>1</td>
</tr>
<tr>
<td>Designation</td>
<td>Title</td>
<td>Edition</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>SS-EN 10034</td>
<td>Structural steel I and H sections – Tolerances on shape and dimensions</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10045-1</td>
<td>Metallic materials – Charpy impact test – Part 1: Test method</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10051+A1</td>
<td>Continuously hot-rolled uncoated, sheet and strip of non-alloy and alloy steels – Tolerances on dimensions and shape (includes amendment A1:1997)</td>
<td>2</td>
</tr>
<tr>
<td>SS-EN 10055</td>
<td>Hot-rolled steel equal flange tees with radiused root and toes – Dimensions and tolerances on shape and dimensions</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10056-2</td>
<td>Structural steel equal and unequal leg angles – Part 2: Tolerances on shape and dimensions</td>
<td>1</td>
</tr>
<tr>
<td>SS-ENV 10080</td>
<td>Steel for the reinforcement of concrete – Weldable ribbed reinforcing steel B500 – Technical delivery conditions for bars, coils and welded fabric</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10113-1</td>
<td>Hot-rolled products in weldable fine grain structural steels – Part 1: General delivery conditions</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10113-2</td>
<td>Hot-rolled products in weldable fine grain structural steel – Part 2: Delivery conditions for normalized/normalized rolled steels</td>
<td>2</td>
</tr>
<tr>
<td>SS-EN 10113-3</td>
<td>Hot rolled products in weldable fine grain structural steels – Part 3: Delivery conditions for thermomechanical rolled steels</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10131</td>
<td>Cold rolled uncoated low carbon and high yield strength steel flat products for cold forming – Tolerances on dimensions and shape</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10137-1</td>
<td>Plates and wide flats made of high yield strength structural steels in the quenched and tempered or precipitation hardened conditions – Part 1: General delivery conditions</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10137-2</td>
<td>Plates and wide flats made of high yield strength structural steels in the quenched and tempered or precipitation hardened conditions – Part 2: Delivery conditions for quenched and tempered steels</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10143</td>
<td>Continuously hot-dip metal coated steel sheet and strip – Tolerances on dimensions and shape</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10149-1</td>
<td>Hot-rolled flat products made of high yield strength steels for cold forming – Part 1: General delivery conditions</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10149-2</td>
<td>Hot-rolled flat products made of high yield strength steels for cold forming – Part 2: Delivery conditions for thermomechanically rolled steels</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10155</td>
<td>Structural steels with improved atmospheric corrosion resistance – Technical delivery conditions</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10164</td>
<td>Steel products with improved deformation properties perpendicular to the surface of the product – Technical delivery conditions</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10204</td>
<td>Metallic products – Types of inspection documents</td>
<td>2</td>
</tr>
<tr>
<td>SS-EN 10210-1</td>
<td>Hot finished structural hollow sections of non-alloy and fine grain structural steels – Part 1: Technical delivery conditions</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10210-2</td>
<td>Hot finished structural hollow sections of non-alloy and fine grain structural steels – Part 2: Tolerances, dimensions and sectional properties</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10219-1</td>
<td>Cold formed structural hollow sections of non-alloy and fine grain steels – Part 1: Technical delivery requirements</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 10219-2</td>
<td>Cold formed structural hollow sections of non-alloy and fine grain steels – Part 2: Tolerances, dimensions and sectional properties</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN 12517</td>
<td>Non-destructive examination of welds – Radiographic examination of welded joints – Acceptance levels</td>
<td>1</td>
</tr>
<tr>
<td>Designation</td>
<td>Title</td>
<td>Edition</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>SS-EN ISO 12944-4</td>
<td>Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 4: Types and surface preparation (ISO 12944-4:1998)</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN ISO 12944-6</td>
<td>Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 6: Laboratory performance test methods (ISO 12944-6:1998)</td>
<td>1</td>
</tr>
<tr>
<td>SS-EN ISO 12944-7</td>
<td>Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 7: Execution and supervision of paint work (ISO 12944-7:1998)</td>
<td>1</td>
</tr>
<tr>
<td>SS 031411</td>
<td>Colours for coding purposes</td>
<td>2</td>
</tr>
<tr>
<td>SS 060101</td>
<td>Welding electrodes – Covered electrodes for manual metal-arc welding and gravity welding of carbon steels, carbon manganese steels and fine grained steels with increased yield stress – Technical requirements for inspection and delivery</td>
<td>1</td>
</tr>
<tr>
<td>SS 064025</td>
<td>Metal arc welding with covered electrodes of carbon, carbon manganese and microalloyed steels</td>
<td>1</td>
</tr>
<tr>
<td>SS 064510</td>
<td>Welded vessels – Heat treatment</td>
<td>2</td>
</tr>
<tr>
<td>SS 110103</td>
<td>Inspection of metallic goods for material characteristics</td>
<td>5</td>
</tr>
<tr>
<td>SS 110105</td>
<td>Sampling for chemical analysis of inspection lot of steel</td>
<td>3</td>
</tr>
<tr>
<td>SS 110120</td>
<td>Non-alloy steels, not for heat-treatment – Sampling for tensile testing</td>
<td>7</td>
</tr>
<tr>
<td>SS 110151</td>
<td>Metallic materials - Sampling for impact testing (V-notch)</td>
<td>6</td>
</tr>
<tr>
<td>SS 110180</td>
<td>Metallic materials – Sampling for bend testing</td>
<td>3</td>
</tr>
<tr>
<td>SS 112626</td>
<td>Metallic materials – Bend testing</td>
<td>3</td>
</tr>
<tr>
<td>SIS 142168</td>
<td>Reinforcing steel</td>
<td>4</td>
</tr>
<tr>
<td>SS 184160</td>
<td>Paints and varnishes – Determination of thickness of a dry film on a metal substrate – Magnetic flux and eddy current methods</td>
<td>3</td>
</tr>
<tr>
<td>SS 184171</td>
<td>Paints and varnishes – Pull-off test for adhesion</td>
<td>2</td>
</tr>
<tr>
<td>SS 184203</td>
<td>Paints and varnishes – Evaluation of degradation of paint coatings – Designation of intensity, quantity and size of common types of defect – Part 3: Designation of degree of rusting</td>
<td>1</td>
</tr>
<tr>
<td>SS 212150</td>
<td>Steel – Flat bar, hot rolled – Dimensions and tolerances</td>
<td>3</td>
</tr>
<tr>
<td>SS 212325</td>
<td>Steels – Square bar, hot rolled – Dimensions and tolerances</td>
<td>3</td>
</tr>
<tr>
<td>SS 212502</td>
<td>Steel – Round bar, hot rolled – Dimensions and tolerances</td>
<td>3</td>
</tr>
<tr>
<td>SIS 212515</td>
<td>Reinforcing steel bar</td>
<td>2</td>
</tr>
<tr>
<td>SIS 212725</td>
<td>Hot-rolled steel channels</td>
<td>3</td>
</tr>
<tr>
<td>SS 271117</td>
<td>Steel structures – Slip resistant bolted joint – Friction-number</td>
<td>1</td>
</tr>
<tr>
<td>Designation</td>
<td>Title</td>
<td>Edition</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>SS 7643005</td>
<td>Cranes – Overhead travelling cranes and portal bridge cranes – Tolerances for cranes and tracks</td>
<td>1</td>
</tr>
</tbody>
</table>
LIST OF REFERENCES


ISSN 0348-7199


ISBN 91-38-12820-9

ISBN 91-524-1066-8

ISBN 91-7332-687-9

ISBN 91-7147-274-6

ISBN 91-7147-394-7

ISSN 1401-9612

ISBN 91-7147-455-2

ISBN 91-7147-124-3

ISBN 91-7196-095-3

ISBN 91-87400-09-X


INDEX

A
abbreviations, 10
acceptance certificate, 139
acceptance inspection, 139
accidental action, 47, 54
action, 8
accidental, 47, 54
additional inspection, 147
additional inspection, 23, 25
cathodic protection, 147
tensile force in the thickness direction, 147
welded connection, 147
additional inspection schedule example, 161
analytical model, 40
ANSI, 10
area, 8
ASNT, 10
assembly bolted connection, 117
ASTM, 10
axial force and bending moment, 69

B
basic inspection, 23
bolted connection, 143
corrosion protection, 143
dimensions and shape, 143
material, 143
welded connection, 143
BBK 94, 10
beam lateral bracing, 66
bearing failure plate, 85
bending characteristic, 112
bending moment, 8, 65
biaxial state of stress, 42
BKR 99, 10
bolt, 50, 99
shank, 85
Strength Class, 99
ultimate strength, 33
assembly, 117
securing, 117
Bolted Connection Class, 83, 99, 110, 115
breathing, 11
fatigue, 96
BRO 94, 10
BSV 97, 11
buckle, 121
BVL, 11

C
C1, 20
C2, 20
C3, 20
C4, 20
C5-I, 20
C5-M, 20
calculation, 140
capacity, 12
carbon equivalent, 33
carbon manganese steel, 15
carbon steel, 15
cathodic protection, 123
certificate, 104
characteristic fatigue strength, 32, 91, 92, 95
modulus of elasticity, 32
Poisson's ratio, 32
shear modulus, 32
characteristic fatigue strength, 90
characteristic strength bolt, 33
characteristic value, 28
characteristic value strength, 28–32
check capacity of the cross section, 70
close tolerance connection, 88
coating, 123
coefficient of friction, 9, 86, 87
cold forming steel, 15
colour coding, 104
compressive force, 60
resistance, 60
concentrated force, 76–77
connection movement, 39
constant stress range, 90, 91, 92, 93
construction document, 140
contact surface, 116
control, 57
corrosion, 19
corrosion allowance, 123, 135
corrosion protection, 19, 23, 122–36
corrosive aggressivity, 18–21
corrosive environment, 122
Corrosivity Category, 98
Corrosivity Category, 18–21, 87, 113
crane, 27
critical moment lateral torsional buckling, 67
Cross Section Class, 57–59, 65
Cross Section Class 1, 59, 60
Cross Section Class 2, 60
cross sectional dimension deviation, 35
curvature, 34
initial, 35, 61
Cutting Class, 108–9
cutting defect, 111

d
deep penetration, 113
deflection, 121
deflection capacity, 38
design service life, 19
design assumption, 140
design check, 17
design section, 79
design value fatigue strength, 89
material property, 45–47
serviceability limit states, 53
Detail Category, 90
detailing bolted connection, 87
welded connection, 82
development cross sectional dimension, 35
development dimensional, 46
size and shape, 34

characteristic fatigue strength, 32, 91, 92, 95
modulus of elasticity, 32
Poisson's ratio, 32
shear modulus, 32
characteristic fatigue strength, 90
characteristic strength bolt, 33
characteristic value, 28
characteristic value strength, 28–32
check capacity of the cross section, 70
close tolerance connection, 88
coating, 123
coefficient of friction, 9, 86, 87
cold forming steel, 15
colour coding, 104
compressive force, 60
resistance, 60
concentrated force, 76–77
connection movement, 39
constant stress range, 90, 91, 92, 93
construction document, 140
contact surface, 116
control, 57
corrosion, 19
corrosion allowance, 123, 135
corrosion protection, 19, 23, 122–36
corrosive aggressivity, 18–21
corrosive environment, 122
Corrosivity Category, 98
Corrosivity Category, 18–21, 87, 113
crane, 27
critical moment lateral torsional buckling, 67
Cross Section Class, 57–59, 65
Cross Section Class 1, 59, 60
Cross Section Class 2, 60
cross sectional dimension deviation, 35
curvature, 34
initial, 35, 61
Cutting Class, 108–9
cutting defect, 111

d
deep penetration, 113
deflection, 121
deflection capacity, 38
design service life, 19
design assumption, 140
design check, 17
design section, 79
design value fatigue strength, 89
material property, 45–47
serviceability limit states, 53
Detail Category, 90
detailing bolted connection, 87
welded connection, 82
development cross sectional dimension, 35
development dimensional, 46
size and shape, 34
dimension  
  erection, 23  
  fabrication, 23  
 dimensional accuracy, 120  
 dimensional deviation, 46  
 dimensional tolerance, 98  
 DIN, 11  
 distance between centres  
  bolts, 87  
  distortion, 12  
 documentation  
  maintenance, 156  
  Ductility Class, 12, 101  
 durability, 18, 139  

E  
  eccentricity, 84  
  load, 35, 61  
  unforeseen, 61  
  edge distance  
  bolt, 87  
  effective cross section, 12, 60  
  effective length, 61  
  effective thickness, 12  
  effective weld length, 81  
  effective width, 12  
  elastic theory, 60  
  fatigue action, 38  
  section modulus, 8  
  electrode, 33  
  embedded fastener, 114  
  EN, 11  
  environment  
  typical, 20  
  environmental effects, 139  
  erection  
  dimension, 23  
  erection schedule, 24, 137  
  execution, 57, 107–37  

F  
  fabrication  
  dimension, 23  
  factory production control, 140  
  fastener, 99  
  fatigue, 89–96  
  breathing, 96  
  fatigue action, 38  
  fatigue crack, 96  
  fatigue limit, 91  
  fatigue load, 27  
  fatigue strength  
  characteristic, 90, 91, 92, 95  
  design value, 89  
  filler metal, 24, 98–99  
  fillet welded connection, 79  
  fire, 17, 47, 54  
  Fire Resistance Class, 23  
  first order theory, 72  
  flame cleaning, 116  
  flame straightening, 112  
  flange curling, 12, 39, 40, 48  
  flange curling and shear deformation, 38  
  flexural buckling, 62, 69, 72  
  slenderness parameter, 62  
  flexural torsional buckling, 69, 73  
  flexural-torsional buckling, 61  
  flexure  
  shape factor, 65  
  force, 8  

G  
  GA, 90  
  GB, 90  
  general recommendation, 7  

H  
  heat treatment, 114  
  high strength friction grip bolted connection, 88  
  hole  
  bolt, 115  
  hole tolerance, 110  
  hot forming, 112  
  hydrogen cracking, 98  

I  
  identification, 104, 139  
  IKH, 11  
  Im1, 20  
  Im2, 20  
  Im3, 20  
  inclination, 121  
  initial  
  inclination, 35  
  initial curvature, 35  
  initial curvature, 61  
  initial inclination, 61  
  inspection scheme, 25  
  interaction in connection, 82  
  ISO, 11  

J  
  joint, 113  
  joint preparation, 24  
  joint type, 24  

K  
  K18, 11  

L  
  lateral bracing  
  beam, 66  
  lateral torsional buckling, 66, 69, 73  
  critical moment, 67  
  reduction factor, 67  
  slenderness parameter, 67  
  lifting point, 25  
  limit state theory, 38, 59  
  limiting value  
  slenderness, 58–59  
  limiting values for slenderness, 43, 44  
  load, 27  
  fatigue, 27  
  load eccentricity, 35, 61  
  structural detailing, 61  
  loadbearing structure, 15, 18  
  local buckling, 38, 39, 41, 42, 57, 60  
  local compression, 77  
  local reduction in cross section, 42  
  local stress concentration, 17  
  locally reduced, 60  
  loss of material, 136  

M  
  MAG welding, 112  
  maintenance  
  BVL, 151  
  documentation, 156  
  maintenance ledger, 156  
  mandatory provision, 7  
  manual tightening, 118
marking, 104
material, 57, 97
requirements, 97
material property
design value, 45–47
metal arc welding with covered electrode, 112
microalloyed steel, 15
MIG welding, 112
modulus of elasticity, 8
characteristic, 32
moment, 66
moment of inertia, 8
movement
collection, 39
point of restraint, 39
support, 39
multiaxial stress
fatigue, 90
multiaxial tensile stress, 101

N
NAD(S), 11, 28
nominal area
bolt, 85
nominal throat thickness, 80
normal force, 8
normal stress, 9
normal stress range, 96
notch, 32
notch action, 32, 50
nut, 99

O
overhead cranes, 27

P
Palmgren-Miner cumulative damage hypothesis, 93
partial factor, 17
load, 9
material property, 9
Safety Class, 9
PBL, 11
penetration, 113, 114
pitting, 135
plastic deformation, 53
plastic flow, 42, 57, 60
plastic hinge, 12
plastic theory
section modulus, 9
torsional modulus, 9
plastic working, 112
point of restraint
movement, 39
Poisson's ratio
characteristic, 32
preloaded connection, 116, 117
preloading, 119
preloading force, 88
preparation, 111–12
principal stresses, 9
production control, 11
production controlled, 105
progressive collapse, 47, 54
properties in the thickness direction, 103
prying force, 83

Q
qualification
welder, 115
Quality Class, 12
quenched and tempered steel, 15

R
radius of gyration, 9
rapid increase in stress, 17
recommendation
general, 7
reduction factor
shear buckling, 9
reduction factor
instability, 9
lateral torsional buckling, 9, 67
residual stress, 48, 53, 62
resistance, 40, 139
compressive force, 60
restraint
loss of, 61
routine inspection, 151

S
Safety Class, 16, 101, 103
section modulus
elastic theory, 8
plastic theory, 9
self-shielded tubular-cored arc welding, 112
serious injury, 16
service life, 19
service temperature, 13
serviceability limit states, 18, 47, 53, 54
shank
bolt, 85
shape
deviation, 34
shape factor, 9
flexure, 65
shape tolerance, 98
shear
bolt, 85
shear deformation, 39, 41, 48
shear failure
bolt, 85
shear force, 8, 74–76
shear modulus, 8
characteristic, 32
shear stress, 9
shearing stress range, 96
SIS, 11
size
deviation, 34
slenderness, 57
limiting value, 58–59
limiting values, 43, 44
slenderness parameter, 61, 62
flexural buckling, 62
lateral torsional buckling, 67
slenderness ratio, 9
SMS, 11
square butt weld, 13
SS, 11
stability, 139
stainless steel, 15
standardised stress spectra, 94, 95
standards, 181
state of stress
biaxial, 42
triaxial, 42
uniaxial, 41
StBk-N5, 11
strain, 9
strain ageing, 112
strain distribution, 40, 41
strength
characteristic value, 28–32
Strength Class
bolt, 83, 99
strength value, 9
strength, design value
  bolt, 50
stress area
  bolt, 85, 86
stress concentration, 101
stress concentration effect, 90
stress cycles, 90, 91, 93
stress range, 89
  constant, 90, 93
stress spectra, 93
  standardised, 94
  standardised, 94
stress spectrum, 50, 90, 92
stress variation, 32
stress-strain curve, 47
structural element
  threaded, 100
submerged arc welding, 112
support
  movement, 39
symbols, 8

T
T-butt weld, 13
temporary anchorage, 25
temporary brace, 25
tensile force, 60
tensile force in the thickness direction, 103
tension and shear
  bolt, 86
terminalogy, 11
thermal cutting, 111
thermomechanically rolled steel, 15
thread run-out, 117
threaded structural element, 100
TIG welding, 112
tightening
  manual, 118
  power tool, 118
TNC, 11
toes of weld, 110
tolerance, 23, 61
tolerance limit, 46
torsional buckling, 61
torsional modulus
  plastic theory, 9
torsional moment, 8, 77–78

U
ultimate limit states, 37
ultimate strength
  bolt, 33
ultrasonic testing, 103
unforeseen eccentricity, 61
uniaxial state of stress, 41

V,W
variable stress range, 93
warping, 34
washer, 88, 100
wear, 19
web crippling, 76–77
weld length, 80
welded connection, 23, 33, 51, 79, 112–15
detailing, 82
welder
  qualification, 115
  welding, 113
Welding Class, 108, 109–10
welding energy, 113
welding position, 24
welding procedure sheet, 23
example, 157
welding process, 24
welding sequence, 24
wind action, 27
visual examination, 139
workmanship, 32, 107–37
Workmanship Class, 90, 107–8

Y
yield region, 12
yield strength value, 9