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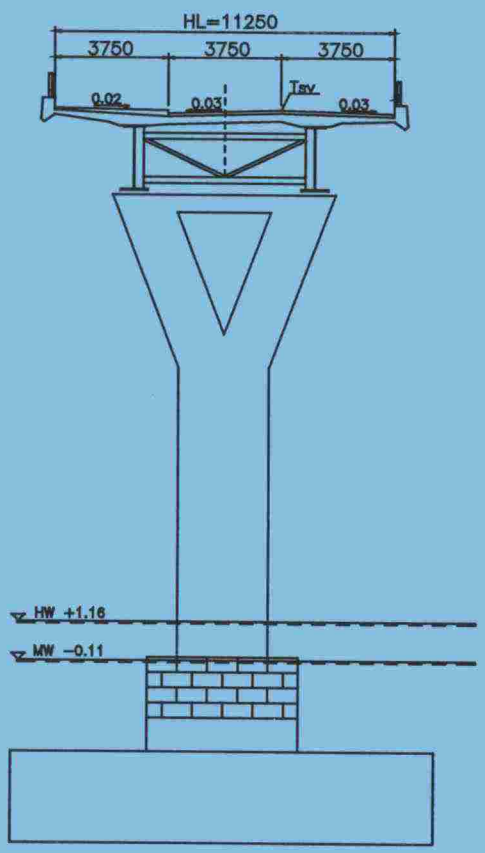
GENERAL QUALITY REQUIREMENTS

FOR BRIDGE CONSTRUCTION

Steel Structures - SYL 4

Finnish National Road Administration



Specifications and quality requirements

Helsinki 1996

Bridge Engineering Unit

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PREFACE

The General Quality Requirements for Bridge Construction are a set of documents comprising the following parts:

General instructions	SYL 1
Ground and foundation construction	SYL 2
Concrete structures	SYL 3
Steel structures	**SYL 4**
Timber construction	SYL 5
Deck surface construction	SYL 6
Equipment and accessories	SYL 7

The production of steel structures calls for the use of both SYL 4 and SYL 1, which presents the general quality requirements for the bridge as a whole and general requirements on quality control and measurements. SYL 2, SYL 3, SYL 5 and SYL 6 also contain quality requirements applicable to steel bridges and the auxiliary structures of steel bridges. SYL 7 presents the requirements relating to bearings and expansion devices.

This document has been supplemented and updated on the basis of the 1992 version by adding, e.g., requirements on acceptability measurements and references to the industry's latest standards on steel structures and surface treatment.

This document has been referred for comment to all the national road districts and bridge contractors, steel structure manufacturers and materials suppliers.

This document has been checked and completed at the Bridge Engineering Unit at Finnra.

Helsinki, August 1996

Bridge Engineering Unit

Contents

4. STEEL STRUCTURES

4.0 A PRODUCT MANUFACTURED IN ANOTHER EUROPEAN COUNTRY

A product which has been manufactured in another Member State of the European Union or in another country in the European Economic Area should be deemed upon application to be in conformity with the quality requirements presented in this publication on the following preconditions:

1. The tests and inspections have been performed in the country of manufacture in accordance with the methods and requirements employed in Finland or ones yielding a corresponding standard of quality and safety, and the results show that the product meets the requirements laid down for it.
2. The body which performed the test and inspections is approved for these tasks by the country of manufacture.

The Finnish National Road Administration is keeping abreast of European standardization in the sector and will amend the guidelines to conform with European standards once they are ready.

4.1 GENERAL

4.1.1 Area of application

These general quality requirements for bridge construction shall be used when building bridges and similar structures from steel. They are also to be followed where applicable when producing structures from a metal other than steel.

Besides the requirements and instructions presented in this document, the requirements and instructions presented in the design and in the General Instructions (SYL 1) of the General Quality Requirements for Bridge Construction shall be followed.

4.1.2 Terms, symbols and abbreviations

This part of the General Quality Requirements for Bridge Construction, Steel Structures, is referred to by the abbreviation SYL 4.

SYL 4 employs the terms and markings defined and used in the regulations and guidelines in the Finnish Code of Building Regulations, primarily in the Directive "B7 Steel Structures" /1/, and in the applicable SFS Standards.
The general terms and abbreviations relating to bridge construction and quality control are defined in SYL 1.

In SYL 4, manufacturer shall refer to a company or production centre which manufactures a steel structure or produces material, accessories or parts for it. The term erector shall be used of a constructor referred to in SYL 1 whose performance obligation in that context is limited to the erection of a steel structure.

The performer of the surface treatment shall be referred to using the term surface treatment worker. The terms relating to surface treatment are also described in detail in Section 4.5.1.2 and in the appendix referred to therein.

4.1.3 Documents

See SYL 1, Section 1.1.4

4.1.4 Technical work plans

Separate technical work plans shall be drawn up for the manufacture, erection and surface treatment of the steel structures in the manner presented in Section 1.3.3.3 of SYL 1.
The work stages shall be planned so that the structural parts, erected structure and the finished bridge meet the quality requirements laid down in the design documents.

The technical work plans shall be submitted to the supervisor for inspection at least a week prior to the start of the work or work stage. Corrections required by the supervisor or emerging in the course of the work shall be made to them. Alterations shall not be made to an inspected work plan without the agreement of the supervisor.

> Manufacturing plans are examined in greater detail in Section 4.3.1.1, erection plans in Section 4.4.4.2 and surface treatment plans in Section 4.5.2.
>
> The technical work plans can be compiled with the aid of the general guidelines for the company's quality system.

4.1.5 Quality plans

In line with the requirements presented in Sections 1.3.2 and 1.3.3.2 of SYL 1, quality plans shall be drawn up for the entire job and for the structural parts and work stages (work stage quality plans).

The quality plans can be compiled with the aid of the general guidelines for the company's quality system or existing quality plans for a certain type of structure. The quality plans can be separate plans or form part of the technical work plans.

4.1.6 Works management and labour force

A foreman managing the manufacture or erection of steel bridges shall have qualifications applicable to the manufacture of steel structures and corresponding to a degree from a technical school or college and experience of the manufacture and erection of heavy steel structures (see also Section 4.4.4.1). A foreman managing the surface treatment work shall have technical qualifications applicable to the sector and at least two years' experience of surface treatment work with steel structures or, in the absence of qualifications, at least five years' experience of surface treatment work.

The labour force shall be professional either in terms of qualifications or work experience. The users of machinery and equipment shall receive guidance from the manufacturer or importer, unless such instruction forms part of their vocational training or the manufacturer arranges competent work guidance.

The qualification requirements for welders and welded joint inspectors are presented in Sections 4.3.3.6 and 4.3.3.9.

Workers engaged in painting work shall possess adequate basic qualifications in corrosion prevention or at least two years' experience of demanding anti-corrosive painting work.

4.1.7 Work premises and equipment

Manufacturers, erectors and surface treatment workers of steel bridges shall have at their disposal premises, tools, machinery and equipment with which the required quality standard can be achieved and demonstrated.

4.1.8 Quality control and proof of acceptability

Production inspections, quality control, proof of acceptability and quality

reporting during the course of the work shall comply with the requirements laid down in Section 1.3 of SYL 1 and hereinafter in this document.

4.2 MATERIALS AND ACCESSORIES

4.2.1 General

Materials or accessories whose quality and acceptability have not been proved beforehand shall not be employed in permanent structures.

The manufacture of the products shall be subject to approved quality control and the results of quality control tests shall be available.

4.2.2 Structural steels

4.2.2.1 Mechanical, physical and chemical properties

The terms and codes for structural steel shall be entered in the design in line with the Standard SFS-EN 10 027-1 /2/. The steel employed shall meet all the requirements for mechanical, physical and chemical properties laid down in the specification standard referred to in the design.

> The requirements apply to the strength properties, quality grade, delivery state, method of compacting and chemical composition of the steels.

The steels can also be delivered in line with some other corresponding approved standard.

> The requirements for hot-rolled, non-alloy, i.e. general structural steels are defined in the Standard SFS-EN 10025 /3/. The general delivery conditions for hot-rolled weldable fine-grain structural steels are given in the Standard SFS-EN 10113-1 /4/. The requirements for normalized / normalized-rolled fine-grain structural steels are defined in the Standard SFS-EN 10113-2 /5/ and for thermomechanical rolled fine-grain structural steels in SFS-EN 10113-3 /6/. The requirements for steels with improved atmospheric corrosion resistance, i.e. weather-resistant steels, are defined in the Standard SFS-EN 10155 /7/.
>
> Comparison data on the current markings for the most common types of steel used in bridges can be found in the aforesaid

standards and in the steel manufacturer's design guide /8/.

The grade for steels used in parts requiring toughness in the direction of the material thickness is Z 25 according to the Standard SFS EN 10164 /9/ unless otherwise stipulated in the design.

4.2.2.2 Other requirements

The dimensions and shapes of rolling products shall conform to the measurement standards defined in the design or similar standards. The permissible deviation of the thickness of hot-rolled steel plates from the nominal thickness is that given for grade A in the Standard SFS-EN 10029 /10/ and the flatness tolerance is that given for grade S in the same standard. Nevertheless a deviation in flatness of more than 3 mm along any measurement length is not permitted when fitting parts together. The precision and other quality requirements of structural parts may also call for precision superior to the standards on which the delivery is based (Cf. 4.2.6.4 and 4.3.1.3).

The surface of a rolled product shall be of such a quality that it can be used to manufacture a structural part conforming to requirements. (Cf. 4.2.6.3). The quality of the surface of hot-rolled steel plates shall meet the requirements for grade A and sub-grade 2 of the Standard SFS-EN 10163-2 /11/.

If the manufacturing method calls for flanging, the steels shall be ordered with a guarantee of flangeability.

Steel plates tensile stressed perpendicularly to the plate level shall meet any ultrasonic testing requirements presented in the design.

The examination grades and quality classification for plates that have undergone ultrasonic examination are shown in the Standard SFS 3294 /12/.

4.2.2.3 Proof of acceptability

The acceptability of structural steels shall be proved by means of purchase inspections and reports based on these. The dimensions and flatness of the steel materials shall be determined during the purchase inspection by means of spot checks, and the quality of the surface by means of visual examination. The inspection is also to involve a check to ensure that all the delivery lot steels have a smelting number or other identification whereby the material certificates conforming to the Standard SFS-EN 10204 /13/ can be found. These show the results of tests performed on the inspection lots in the delivery. These material certificates include the 3.1 A, 3.1 B and 3.1 C certificates of receipt conforming to the aforesaid standard and corresponding

certificates conforming to other norms. The material inspection report shall state the type of steel, manufacturer, dimensions, smelting number and quality of the surface. It shall include at least one typical material certificate for each type of steel in the delivery lot.

> Each piece of material shall be marked permanently and unequivocally with the smelting number or other code indicating the production lot. Cold-worked pipes and other profiles and slender cold-rolled bars can nevertheless be marked and processed in clusters if there is no risk of confusion.
>
> When ordering steels, the 3.1.B certificate of receipt shall be employed unless otherwise agreed for a specific job. If the pieces of material shall be inspected at the steel works, the 3.2 log of receipt shall be employed. The 2.2 test certificate may also be acceptable if the aforesaid certificate of receipt cannot be obtained for reasons relating to the manufacture or delivery of the product. Inspection tests of samples taken from the delivery lot can nevertheless be demanded if justified by the stress state of the structural parts or some other reason.

If the material certificate does not meet the aforesaid requirement but the codes indicating the production lot can be found, the delivery lot can be approved if it is subjected to a sampling and material test in line with the appropriate standard and the test results meet the requirements.

If the markings indicating the production lot are missing or unclear, the pieces of material can be approved only if samples are taken from each product and acceptable test results are obtained from them. If nevertheless it can be demonstrated reliably that a delivery lot belongs to the same production lot, no piece testing is necessary and the approval procedure described in the preceding paragraph can be followed.

4.2.3 Other steel materials

4.2.3.1 General

This section covers materials which due to their strength, composition or method of manufacture are not included among the structural steels examined in Section 4.2.2. These include quenched and subsequently drawn steels, strong structural steels, machine steels, stainless and acid-resistant steels and cast products, cables and thin-plate products.

4.2.3.2 Presentation of quality requirements

The quality requirements for other steel materials shall be defined in the design in the form of a reference to applicable standards or the manufacturer's quality specifications. If the quality requirement is presented in the form of a product name, other similar products which meet the same quality requirements necessary for their intended use are acceptable.

4.2.3.3 Proof of acceptability

Acceptability shall be proved by means of purchase inspections and reports based on them and using the test certificates issued by the manufacturer, provided that each piece of material or product lot is marked permanently and reliably with a code indicating the production lot whereby the materials testing results can be unequivocally located. The smelting number of the production lot shall be found for all hot-rolled steel plates. Thin plates and bars, wires and cables can nevertheless be marked in clusters, coils and reels if they are brought to the place of manufacture in the factory packaging. At least one typical material certificate relating to the steels in the delivery lot shall be attached to the material inspection report for each type of steel material.

The material certificate for special steel, steel casting and forging is a 3.1.A, 3.1.B or 3.1.C certificate of receipt conforming to the Standard SFS-EN 10204 /13/ unless required otherwise. For cast pieces, a certificate of ultrasonic testing is also required, in which at least 10% of the pieces in each smelting lot have been inspected unless the plan calls for anything more or the result of the inspection gives grounds for anything else.

4.2.4 Joint materials and accessories

4.2.4.1 General

The joint materials and accessories referred to here include filler metals, screws, nuts and washers, special bolts and stud pins.

If the products are manufactured under the supervision of an approved inspection body (inspected manufacture), acceptability shall be proved by means of markings found on the packaging and products, which shall be entered in the material inspection report.

4.2.4.2 Filler metals

The quality requirements for filler metals, welding electrodes, wires, powders and gases are defined on the basis of the parent metal, welding method, conditions, the form and proportions of the structure and its intended use.

Products covered by inspected manufacture shall be used as filler metals. Acceptability shall be proved on the basis of the type markings and product names on the packages, which together with the dimensions and production lot codes shall be entered in the material inspection report.

4.2.4.3 Screw accessories

The quality requirements for screws, nuts and washers are defined on the basis of the markings presented in the design and the related standards. The strength properties of screws are defined in the Standard SFS-ISO 898-1 /14/ and the strength properties of nuts in SFS-EN 20898-2 /15/.

In the case of inspected manufacture, acceptability can be proved on the basis of package markings. If this procedure cannot be followed, the screws and nuts shall be subjected to acceptability tests in line with the appropriate standards.

The acceptability of washers shall be proved in a similar manner, e.g., by performing hardness tests. Unless otherwise regulated in the standards, the hardness of the washers shall fall within the following limits depending on the strength grade of the screws:

- strength grade 8.8 200-400 HV
- strength grade 10.9 290-400 HV

The strength grades, standard, dimensions, quality certificate, surface treatment and manufacturer of the screw accessories shall be entered in the material inspection report.

4.2.4.4 Stud pins

Stud pins fastened by arc pressure welding shall meet the following requirements:

- parent metal S235J2G3,
- manufacturing method cold working or machine cutting,
- strength values when welded:
  - ultimate strength R_m = 450-600 N/mm^2

- lower yield point $R_{eL} \geq 350$ N/mm^2
- break elongation $A_5 \geq 15\%$,

- manufacturing precision in line with the requirements laid down by the welding devices,
- accessories to be free of substances hindering welding or adhesion of concrete,
- flash barriers ceramic and suitable for the purpose.

If the manufacture of the stud pins does not involve cold working, the material to be used is S355J2G3 steel.

Stud pins shall be type approved products. Their acceptability shall be proved by means of the purchase inspection of the materials and the report based on it and using a 2.2 material certificate conforming to the Standard SFS-EN 10204 /13/ or similar certificate conforming to another appropriate standard. In the case of inspected manufacture, no material certificates are required. The type, manufacturer, raw material, dimensions and quality of the surface of the stud pins shall be entered in the inspection report. At least one material certificate relating to the stud pins in the delivery lot shall be attached.

The acceptability of other types of stud pin shall be proved in line with the above principles where applicable.

4.2.5 Other materials and accessories

The quality requirements for other materials and accessories shall be presented in the design or they shall be defined in accordance with intended use. These can include rubbers, plastics, adhesives and lubricants. The requirements concerning coating substances are presented in Section 4.5.

The materials and accessories shall be kept fit for use for the planned service life of the bridge ($\geq$ 100 years) unless this part of the bridge is designed to be replaceable.

Products whose manufacture is inspected and for which the findings of quality control tests are available shall be used. The required information consists of product specifications, directions for use, type approval resolutions and the results of quality control and acceptability tests. Test results can be pinpointed to a delivery lot only by means of the codes indicating the production lots.

If an adequate amount of reliable information on quality cannot be obtained or test results cannot be linked to the delivered products, acceptability tests shall be performed on each delivery lot.

Acceptability shall be proved and the material report compiled in line with the principles given in Section 4.2.2.3.

4.2.6 Preparation of the material

4.2.6.1 Cataloguing and markings

Different kinds of materials and accessories shall be prevented from getting mixed up during manufacture.

> Pieces of material shall be registered on being taken into use. The register shall show the intake date, type of steel, dimensions, smelting number or other code for the production lot. When drawing up the register, information shall not be gained from the smelting numbers in the delivery lot. Indistinct markings shall be interpreted together with the supervisor. The register shall be compared with the delivery notes and material certificates.

If more than one type of steel or other materials similar in appearance but with different properties is employed in the structure, their position in the structure shall also be discernible after manufacture.

> The use of material can be recorded by marking the smelting from which each piece has been manufactured in the drawings or sub-registers or in the structural diagrams drawn up for the purpose. The presentation shall be unequivocal with regard to the most important structural parts such as flanges and web plates. The transfer of smelting numbers to structural parts shall be agreed upon separately.

4.2.6.2 Cleaning

Prior to the manufacture of structural parts, roll scale, rust and other impurities shall be removed from the plates and profile bars to the extent to which they impede flame cutting and welding. The cleanliness grade shall be at least Sa 2 in line with the Standard SFS-ISO 8501-1 /16/.

> The cleaned steel substrate may be protected with what is known as shop primer if it is advantageous as regards manufacture or surface treatment and if it is referred to in the approved surface treatment plan.
>
> If shop primer is employed, the weld points shall be left unpainted or the paint shall be removed prior to welding.

4.2.6.3 Removal of surface flaws

Surface flaws on plates and profile bars shall be removed if they undermine strength or corrosion resistance or appearance considerably.

Dents, cracks, breaks and other roughness may be ground smooth in line with the Standard SFS-EN 10163-2 /11/ whereby the grinding depth, size of the ground areas and the residual thickness of areas ground on opposite sides meet the requirements for grade A in the standard. The pit created shall not hinder the fitting of the parts or the appearance of the structure. The repair finish shall be even and have a pitch of 1:10 or less. Following the work, the magnetic particle method shall be employed to check that the fault has been completely removed.

A detailed technical work plan of the repair welding of the flaws shall be drawn up (SFS-EN 10163-2 /11/, sub-grade 2).

> The correction plan shall cover all matters relating to welding (cf. 4.3.3.2) including any required heat treatment. Heat treatment shall be performed in line with the manufacturer's recommendations unless otherwise agreed. All corrective welds on the surface flaws shall be ground to the level of the surface and checked 100% by a method applicable to the nature and extent of the weld.

4.2.6.4 Straightening

Unless structural parts are required to have superior precision (cf. 4.3.1.3), the pieces of material shall meet the following straightness requirements:

- undulation of plates and bars in line with Section 4.2.2.2
- curvature of profiles $\geq$ L:1000.

The steel shall meet the requirements laid down for its mechanical properties after straightening as well.

If straightening is performed cold, the plastic deformation of the steel shall not exceed 5% (ratio of bending radius to material thickness R:t $\geq$ 10), unless heat treatment in line with the steel manufacturer's guidelines is performed after correction.

Straightening shall be performed in line with the applicable standards and the steel manufacturer's guidelines.

When straightening steel pieces hot, i.e. straightening by heating, the steel shall be at hot-working temperature (825-1025 °C).

With thermomechanical rolled steels, exceeding the temperature of 650 °C in straightening by heating may undermine the strength properties of the steel considerably.

4.3 STRUCTURAL PARTS

4.3.1 General

4.3.1.1 Manufacturing and quality plans

Manufacturing plan

The manufacturing plan shall cover all the stages of manufacture of the structural parts. The manufacturing plan and those quality system documents referred to in the plan shall be sent to the supervisor at least a week prior to the start of manufacture. See also SYL 1, Section 1.3.3.3.

If necessary, calculations or corresponding accounts of the strength, stability and deformations of the structures at the various stages of treatment can be attached to the plan. It can consist of several separate plans. For example, the welding plan (see Section 4.3.3.2) can form part of the manufacturing plan or be a separate plan.

The manufacturing plan is also to take account of the requirements imposed by transportation, erection and surface treatment. Separate plans shall be drawn up for erection and surface treatment (see Sections 4.4.4.2 and 4.5.2).

The section of the manufacturing plan concerning machine shop work shall cover the following matters where necessary:

- the ordering, receipt and storage of material
- the preparation of material
- cutting into pieces and shaping
- welding
- fastening the stud pins
- making the bolted and friction joints
- assembling of parts
- mock assembly (trial erection)
- hoisting procedures and transfers
- the work stages of surface treatment
- storage

Site quality plan

A site quality plan shall be drawn up in line with Section 1.3.2 of SYL 1. It shall define the resources employed, i.e. labour management, employees and inspectors and their competence, machinery and equipment and the production and storage premises. Extracts from the documents in the manufacturer's quality system can be attached to the plan. It shall be sent for checking to the supervisor at least one week prior to the date when the production of the structural parts shall commence.

Work stage quality plan

The work stage quality plan shall cover work stage quality assurance measures and proof of acceptability. It can be a single plan embracing the entire production or it can consist of several separate plans (e.g. quality assurance relating to the materials, welding jobs, other joints, welding of stud pins and the dimensions of the structural parts).

The work stage quality plan shall cover the matters presented in Section 1.3.3.2 of SYL 1. The plan or a copy of the corresponding documents in the quality system shall be sent to the supervisor at least two days prior to the start of the work.

4.3.1.2 Alterations to the structural design

The manufacturer shall point out errors and shortcomings observed in the design, and any structural solutions which will not result in the required standard or allow it to be proved by means of inspections.

Deviations in the positions and dimensions of the bridge substructures shall be taken into account in the manufacture of the steel structure by altering the dimensions of the structure given in the plan.

4.3.1.3 Precision of parts

Precision requirements

The permissible deviations at dimensions for girders, piers and other beam-like structural parts in the finished structure are shown in table 1.

The fitting of the parts or requirements given in the plan may call for superior precision.

> The dimensions of the parts are given in the structural design drawings at a temperature of +20 °C unless another measurement temperature has been given. These are theoretical, and so

possible finishing allowances, grooves, deformations caused by welding and other factors relating to manufacture shall be taken into account in the dimensioning.

Table 1. The permissible measurement deviations for structural parts in a finished structure.

Deviation and its symbol	Figure	Length dimension	Permissible deviation 1)			Remarks
			Minimum mm	Proportional	Maximum mm	
Web height Δh	1	h	± 3	± 0,2%	± 5	2)
Width of flange or web stiffener Δb	1	b	± 2	± 0,5%	± 5	
Web eccentricity v1	1	b	± 3	± 1,0%	± 10	2)
Web bending v2	1	h or l	± 3	± 0,5%	± 20	3)
Positioning of horizontal web stiffeners h1	1				± 10	2)
Positioning of vertical web stiffeners Δl	1	l			± 10	
Flange undulation f3	2	l	± 2	± 0,5%	± 3	4)
Undulation of web stiffeners v4	2	l	± 3	± 0,3%	± 10	5)
Flatness of bearing contact area					0,5	6)

1) The proportional figure for the permitted value refers to a percentage of the measurement length. A deviation less than the minimum value is not required nor is a deviation greater than the maximum value permitted.
2) Joints between structural parts may call for smaller measurement deviations.
3) h = web height or interval between horizontal stiffeners, l = interval between vertical stiffeners.
4) The maximum value is double if there is elongation strain in the flange or if a concrete deck has been cast on top of it. When the parts are fitted together, the gap between weldable plates may nevertheless be a maximum of 3 mm.
5) l = the interval between the vertical stiffeners or the height of the girder.
6) The requirement applies to the joint surface of the top plate of the bearing and the superstructure. The bearing may call for smaller deviations or call for other requirements on the joint surface. Cf. also SYL 7.

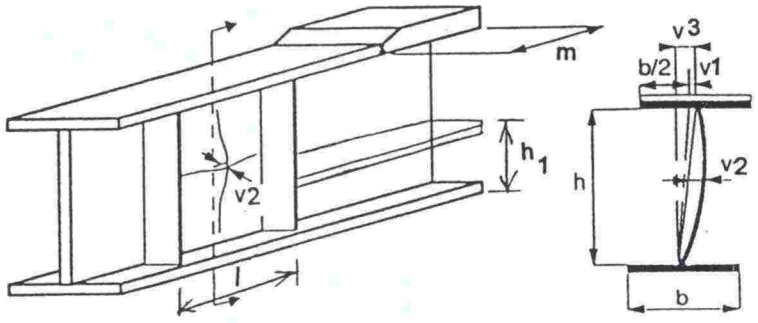


FIGURE 1. CROSS-SECTION DIMENSIONS OF GIRDER

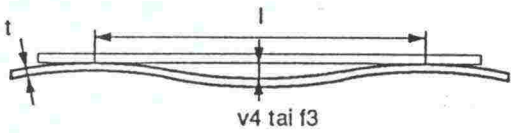


FIGURE 2. UNDULATION OF WEB STIFFENER OR FLANGE RIM, LATERAL CURVATURE OF GIRDER

The standard quality requirements relating to the manufacture of parts are shown in table 2. The manufacturer can employ them in internal quality control to ensure that the precision requirements for the installed steel structure in Section 4.4.1 are met. The fitting of the parts may call for superior precision.

Table 2. The recommended precision requirements for structural parts during manufacture.

Deviation and its symbol	Figure	Length dimension	Permissible deviation 1)			Remarks
			Minimum mm	Proportional	Maximum mm	
Flange length ΔL	3	L	± 2	± 0,1%	± 20	
Flange transverse bending f1	3	L	± 2	± 0,1%	± 20	
Camber Δf	4	L	± 5	±0,05%	± 20	2)
Kink f2	5	L	± 4	± 0,10%	± 20	3)
Flange battering k	6	B	± 2	± 1,5%	± 7	3)and 4)
Web inclination v3	1	H	± 4	±1,0%	± 20	3)
Positioning of vertical web stiffener	1				± 10	3)
Longitudinal position of changes in flange or web dimensions	1	m			± 100	

1) The proportional figure for the permitted value refers to a percentage of the measurement length. A deviation less than the minimum value is not required nor is a deviation greater than the maximum value permitted.
2) In bridges with a single span and in sections as long as an entire span, the maximum deviation may be as shown in table 4.
3) Joints between structural parts may call for smaller measurement deviations.
4) The flange may not gather water.

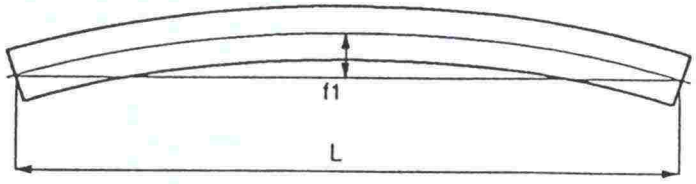


FIGURE 3. LENGTH AND LATERAL BENDING OF FLANGE

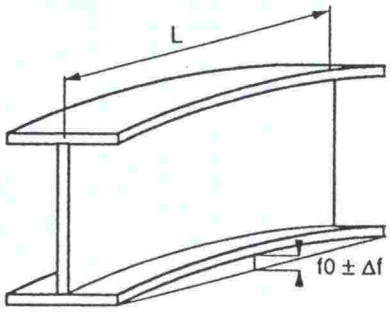


FIGURE 4. CAMBER

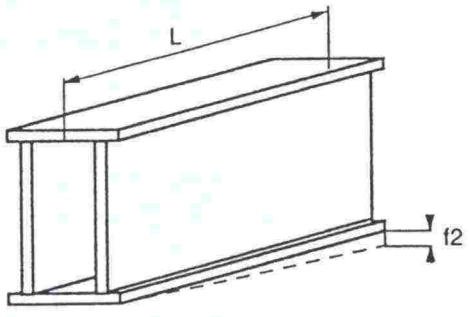


FIGURE 5. KINK

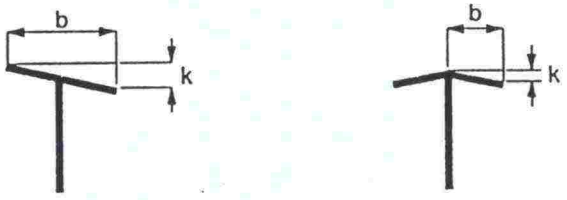


FIGURE 6. FLANGE BATTERING

Checking the dimensions

The builder shall measure and report to the client all the dimensions presented in the design and table 1. The dimensions presented in table 2 shall be reported internally to the next work stage.

The measurement log shall include at least the nominal dimension, permissible deviations or limit values and the dimension measured. If the dimension is checked at several points, at least all dimensions exceeding the limit value or the dimension nearest to the limit value shall be entered in the log. See also SYL 1, Section 1.3.4.

> If the design does not present cross-measures, their specific values shall be calculated and the corresponding measured dimensions shall be entered in the logs.

The widths of the flanges shall be measured from both ends of the girder and whenever the width alters.

The height and eccentricity of the web and position of the web's horizontal stiffeners shall be measured from the ends, middle and quartiles of the girder. The bending of the web shall be measured from in between the vertical stiffeners or, if there are no stiffeners, from the ends, middle and quartiles of the girder.

The undulation of the flange and web stiffeners shall be measured along the entire length of the girder or stiffener.

The flatness of the contact surface of the bearing shall be checked along and perpendicular to the girder. The measurements shall be performed at least from the middle and edge lines of the bearing.

Proving the acceptability of the dimensions of the structural parts is shown in Section 4.3.7.6.

4.3.1.4 Other quality requirements

Closed boxes shall be airtight unless they are coated or protected in some other way from corrosion. (Cf. 4.5.6.3). The method for inspecting the airtightness of boxes is shown in Section 4.3.7.6.

4.3.2 Cutting into pieces and shaping

4.3.2.1 Cutting

Cutting shall not cause cold working or thermal effects which damage the material nor cause cracks.

The quality grade of a flame-cut surface is I and the precision grade A in line with the Standard SFS 4072 /17/ unless a superior standard is required in the plan. The cutting finish can be improved, e.g., by grinding. Flame-cut surfaces that shall be painted shall be roughened throughout by light grinding. The hollows shall be smoothed off to a pitch of 1:10 or less. A detailed plan for welding corrections shall be drawn up (cf. 4.3.3.2).

When cutting mechanically by compression, procedure tests shall be used to demonstrate in advance that the cutting finish is free of cracks and that the material has a maximum hardness of 350 HV in the coverage area of the cutting. In fatigue-stressed structural parts such as the superstructures of road and railway bridges this cutting method is not permitted.

> Cutting into pieces shall be performed by sawing if the requirements laid down for the precision of the parts or for the properties of the cutting surface, or the properties of the material so require.

Unless the shape of the cutting edge has been defined more closely, the rims of the edges left free in the structure shall be rounded by grinding to a radius of about 2 mm.

4.3.2.2 Bending and flanging

When bending cold, the lowest bending radii defined in the material standard or steel manufacturer's product specification shall be reached. Bending with a smaller radius shall be performed at a hot working temperature. (Cf. 4.2.6.4).

> Bending shall not be performed at a temperature between the cold and hot forming temperatures (approx. 100-825 °C).

The parts to be shaped by flanging shall be made of steel, for which the manufacturer shall issue a guarantee of flangeability. The bending radii are defined from the terms of the guarantee.

> When flanging exceptionally a steel which has not been supplied with a guarantee of flangeability, the success of the work shall be

checked by preliminary tests and a 100% fracture verification shall be performed by quality control.

4.3.2.3 Hole-making

The nominal dimensions and tolerances of holes shall be defined on the basis of the design and the applicable standards for the joints.

The holes shall be round, straight, smooth and have an intact surface. Surface quality obtained using a well-maintained drill is adequate unless the plan calls for a smoother (ground) surface. Flashes shall be removed from the rims of the hole by chamfering them to about 1 x 1 mm. The rims of holes left free that shall be surface treated shall be rounded to a radius of about 2 mm.

If the holes shall be made by punching, the applicability of the work method shall be demonstrated beforehand. Fractures shall be verified 100% on test pieces and by spot checks ($\geq$ 10%) as part of the quality control involved in manufacture.

The punching of holes in fatigue-stressed structural parts is not permitted.

4.3.2.4 Machining

The profile depth of machined surfaces may be a maximum of $R_a = 6.3$ µm.

4.3.2.5 Proof of acceptability

The quality of cutting into pieces and shaping shall be monitored and acceptability proved in relation to all the requirements laid down by means of inspections and of reports based on these. The inspections shall determine at least the quality and precision grade of the flame cutting and the roughness of the surface, the rounding of the rims, bending radii and temperature, and the size and quality of the holes. The locations of all the holes marked in the plan shall be checked by measuring the cross-measures as well.

4.3.3 Welded joints

4.3.3.1 Weld quality requirements

The quality requirements for welds shall be defined on the basis of the quality grade stated in the plan and the Standard SFS 2379 /18/.

The new Standard SFS-EN 25817 /19/ shall replace SFS 2379 where referred to in designs.

The welds of flange extensions shall always be ground along a width of 50 mm from the edge of the flange to the level of the parent metal.

Regardless of the weld quality grade, the welds of structural parts which shall be coated and their surroundings shall not have any slag, spatter or any gas pores extending into the surface which cannot be reliably covered.

Anti-corrosive painting, metal spraying and hot zinc-coating call for the welds to have the steel work quality grade 05 referred to in the Standard SFS 8145 /20/. (Cf. 4.5.3.1).

The quality requirements for the welds of structural parts made from weatherproof steel are the same apart from the fact that the gas pores extending into the surface shall be repaired by welding.

4.3.3.2 Welding plan

The welding plan includes the following matters where applicable:

- a report on the weldability of the parent metal
- welding conditions
- need for pre-heating
- maximum temperature
- means of gauging the temperature
- order of welding
- shapes of the grooves and finishing work on them
- welding positions
- welding methods and equipment (also welding of stud pins)
- filler metals: welding electrodes, wires, powders and shielding gases
- welding energy: conveying speed, voltage and amperage (or length of welding run obtainable with a welding electrode)
- number and order of welding runs
- welding procedure tests (also in bolt welding)
- welders' competence
- after-treatment of welds
- heat treatment of welded pieces
- finishing work on welds

The plan shall be sent to the supervisor for inspection at least a week prior to the start of the welding work.

The time required for welding procedure tests shall be taken into account when drawing up the welding plan. Acceptable test results shall be available before the welding plan can be checked in its entirety.

4.3.3.3 Grooves

The dimensions and shape of the grooves shall conform to the Standard SFS-EN 29692 /21/ unless other groove shapes can be shown to be more advantageous by means of welding procedure tests.

The grooves are to be fitted with the precision required by the welding method and the weld quality grade.

The grooves shall be free of substances undermining the quality of the weld, such as paint, grease and moisture. They shall not contain cutting blister or flashes, or roughness impeding welding.

The shape of the grooves can be designed using, e.g., the Standard SFS-EN 29692.

In order to facilitate welding and surface treatment, the internal angle of the web braces is to be cut as shown in figure 7.

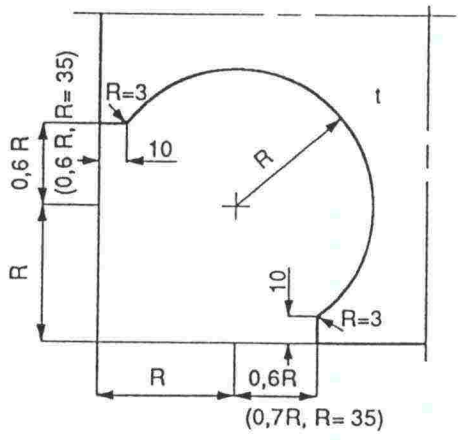


FIGURE 7. "COPE HOLE"

R = 50 when t> 25 mm
R = 35 when t≤ 25 mm

4.3.3.4 Filler metals

The filler metals are to be selected bearing in mind the requirements imposed by the parent metal and welding method so that the welded joint meets the quality requirements laid down for it. The strength and toughness

requirements for the welded joint are the same as for the parent metal unless otherwise specified in the plan. A filler metal considerably stronger than the parent metal shall not usually be employed.

> The selection is generally to be based on the filler metal manufacturer's recommendations and the Technical Inspection Centre's (TTK) licences.

If the ultimate strength of the parent metal is > 400 N/mm^2 and the temperature of the toughness test is $\leq$ - 30 °C, the suitability of the filler metals shall be demonstrated by means of welding procedure tests. The same applies to weatherproof steels regardless of their strength and quality grade. The welding procedure tests shall be performed where applicable in line with the Standard SFS-EN 288-3 /22/.

> Welding procedure tests performed earlier by the same manufacturer on the same parent metal and which are otherwise comparable can be accepted in a new project.

During welding, the filler metals shall be dry and clean. Filler metals shall be stored and dried in line with the storage and drying instructions issued by the manufacturer for each filler metal. Filler metals whose quality cannot be identified shall not be employed.

4.3.3.5 Order of welding

The order of welding shall be selected so that the welded joints meet the quality requirements laid down for them and that no stresses or deformations detrimental to their strength and use are generated in the structural parts and structures.

> The order of welding shall be planned so that the structure reaches its final rigidity at as late a stage as possible, in which case internal stresses caused by the contraction of the welds generally remain small.
>
> Deformations caused by the welding shall be prevented as far as possible by preliminary bending or other suitable means.
>
> The local heating of the structural parts can also be utilized to reduce the deformations and stresses caused by the welding. Heat treatment shall be performed in line with the steel manufacturer's instructions and recommendations. (Cf. 4.2.6.4).
>
> The methods shown in Figure 8 are recommended as the order of welding for a girder extension.

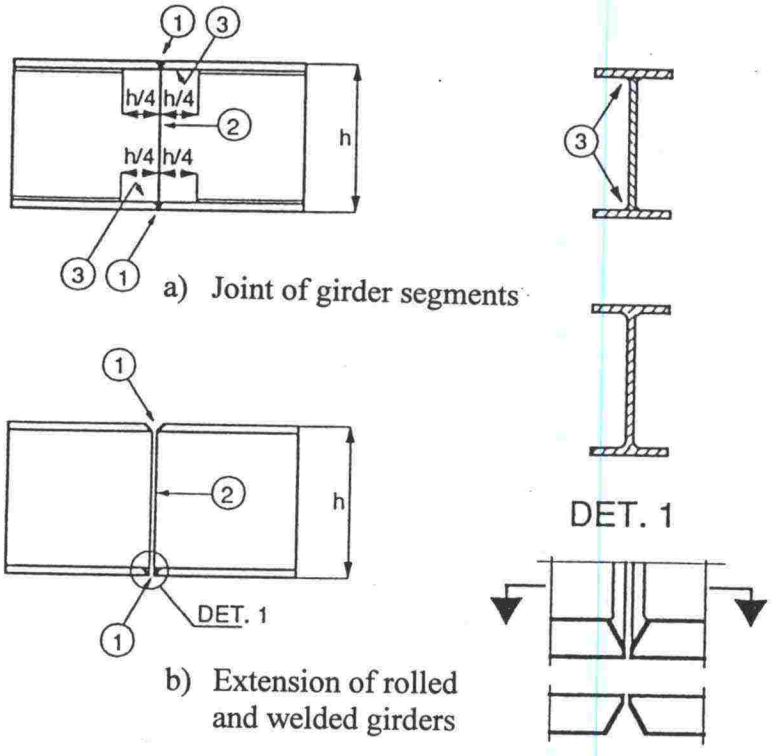


FIGURE 8. EXAMPLE OF ORDER OF WELDING

Welding stage 1 The flanges shall be welded to about 1/3 of the final volume of the weld.
Welding stage 2 The web shall be welded at the same time as the flange extensions are welded up.
Welding stage 3 When the web and flange welds have cooled, the unperformed fillet welds at web-flange joints shall be carried out.

4.3.3.6 Welding

The welder is required to possess competence conforming to the Standard SFS-EN 287-1 /23/. Competence can also be demonstrated in some other approved manner.

The pieces to be welded shall be turned round, if possible, so that the welding can be performed in the most advantageous position.

The welding conditions shall be arranged to facilitate a result conforming to requirements. The grooves shall be prevented from getting wet or soiled if necessary using shields. Air currents having a detrimental effect on the shielding gas at the place of welding shall be eliminated. The welded pieces shall be prevented from cooling down too quickly. Consideration shall

also be paid to the welder's working conditions. If the detrimental factors relating to the conditions cannot be eliminated entirely, the success of the work shall be safeguarded by means of welding procedure tests or comparable trial work.

Welding may only be performed using suitable and reliable equipment with which the required result can be achieved. The equipment shall be maintained in faultless condition throughout the work.

Unless the plan presents requirements for the welding method either directly or indirectly, e.g., via penetration, the manufacturer is free to employ a welding method suitable for the shapes of joint.

4.3.3.7 Heat treatment

The pieces to be welded shall be pre-heated if the parent metal, plate thickness, conditions or welding method so require. The requirements are defined on the basis of the instructions supplied by the steel and filler metal manufacturers.

Heat treatment shall be covered in detail in the welding plan, which shall define the equipment used, temperature measurements, heat retention time, and cooling time and conditions.

The pre-heated area shall be broad enough for the desired deceleration in the cooling rate to be achieved. The temperature stipulated in the welding plan shall reach at least a triple material thickness, nevertheless at least along a width of 80 mm when measured from the middle of the weld along both sides of the seam. Heating shall be performed from the opposite side of the seam. The temperature shall be determined by means of measurements.

Distortions due to welding or other causes can usually be corrected using local heating. (Cf. 4.2.6.4).

If the plan requires it or the quality requirements cannot otherwise be achieved, stress relieving or normalization shall be performed on the welded pieces in line with the parent metal manufacturer's instructions.

4.3.3.8 Correcting welds

The manufacturer of a steel structure has the right to correct a weld. Undersized fillet welds do not need to be reinforced if the undershoot is local (a maximum of 500 mm or 20% of the length of the seam) and the effective throat thickness is no greater than 1 mm less than required when the requirement is in excess of 5 mm, and no more than 0.5 mm less than required when the requirement is $\leq$ 5 mm.

The corrective work shall nevertheless not undermine the strength of the structure nor other properties affecting its serviceability.

If welds are opened up and re-welded during corrective work, a detailed plan covering where applicable the same matters as in the welding plan shall be drawn up. It shall be submitted to the supervisor at least two days prior to the start of the corrective work. A written correction plan is not required if the work is commonplace and straightforward in its effects.

The success of the corrective welding shall be demonstrated if necessary by means of welding procedure tests.

Arc strikes can be removed by grinding the parent metal about 1 mm smooth.

> The flatness, shape and attachment of the weld surface to the parent metal can be improved, e.g., by grinding. TIG treatment is also generally permitted. If the approval of the welding plan calls for welding procedure tests, TIG treatment shall be included in the tests. Excessive effective throat thickness in a weld shall also be eliminated by grinding if it is detrimental as regards the distribution of stresses, fatigue resistance or appearance of the structure.
>
> For corrective purposes, a weld shall be opened to at least 10 times its thickness or nevertheless at least approx. 75 mm along the effective throat thickness. Pre-heating may be necessary in corrective welding even if the actual welding does not call for it. Pre-heating 50 °C higher than during manufacture is recommended for corrections. By heating the area around the correction, the internal stresses caused by welding can be reduced.
>
> If a welding fault is local and is of such a nature and location that the durability of the structure is still adequate, welding faults permitted in the next quality grade down do not usually have to be corrected.
>
> Before the final inspection of the welds, all the slag and spatter

shall be removed from the welds and their surroundings.

4.3.3.9 Proof of acceptability

The inspector shall possess competence for NDT inspections for or equivalent to level 2 of the Standard SFS-EN 473 /24/. Competence shall apply to all the inspection methods used.

The inspection shall be performed using reliable devices suitable for the inspection method. These shall be calibrated at the intervals given in the instructions and on other occasions as well if necessary.

The scope of the inspection shall be as follows unless otherwise fixed in the plan:

a) All the welds shall be inspected visually along their entire length.

b) Ultrasonic testing (UT) shall be performed on 100% of all the butt welds of the flanges and erection welds of the web extensions and on T joints in which there are tension stresses perpendicular to the plate. The same applies to a double-bevel butt weld in between a flange and a web if its quality grade is WA or it has been performed at the erection site. 10% of all the other butt welds and double-bevel butt welds and other rivet-welded joint welds for which the UT method can be used to obtain a reliable test result shall be inspected. Ordinary fillet welds do not need to be inspected unless necessary due to penetration.

   If the material is $\leq$ 10 mm thick, UT testing shall be replaced by radiographic testing.

c) Radiographic testing (RT) shall be used to complement UT testing. If the material is $\leq$ 10 mm thick, the butt welds shall be imaged to the extent shown in section b). Welds 10-40 mm thick shall be imaged if errors are discovered during the UT testing whose nature and scope cannot be determined reliably using the UT method. Welds over 40 mm thick are not to be imaged.

d) Magnetic particle testing (MT) shall be applied to all ground WA grade welds, the ends of WB grade splice welds and the ground edge areas of flange splices.

If an error which is not permitted in the weld grade is detected in 10% of the inspection, the inspection shall be extended so that the extent of the error can be determined with certainty.

The inspections and reporting shall be performed in line with the following

Standards:

- visual inspection SFS 5550 /25/; weld grades and acceptance limits SFS 2379 /18/ or SFS-EN 25817 /19/. The smallest measured effective throat thickness of the weld is also to be entered in the inspection log.

- ultrasonic examination SFS 3290 /26/; acceptance limits SFS 5108 /27/

- radiographic examination SFS 3207 /28/; acceptance limits SFS 5067 /29/ and

- magnetic particle examination SFS 5609 /30/; acceptance limits SFS 2379 /18/ or SFS-EN 25817 /19/.

The results of the inspection or examination shall be submitted to the supervisor before work on repairing the welds is started unless otherwise agreed for a specific job.

The acceptability report shall include information by segment on the inspections performed, a reference to whether the welds meet the requirements, and possible deviations and corrections. The inspection log and deviation reports shall be attached to the acceptability report.

4.3.4 Bolted joints

4.3.4.1 General

Bolted joints are categorized according to their modes as follows:

- In an ordinary bolted joint, the screw hole is loose in relation to the shaft, and so a small shift is required until the forces travel from one part of the joint to another.

- In a fitting bolted joint, the shaft is fitted tightly into its hole, and so the forces travel without any noticeable shift.

The aforesaid modes are functional quality requirements fixed for the joints. Other designations can be employed in the design.

In unclear cases, the planner shall define the mode of the joints.

4.3.4.2 Accessories

When installed, screws, nuts and washers shall be free of substances which

impede tightening, cause corrosion or are otherwise detrimental.

Storage and handling shall be arranged so that the surface treatment carried out for the delivery state or for tightening purposes is preserved. Accessories from different quality grades shall be separated and stored so that there is no risk of confusion.

4.3.4.3 Joint parts

Parts to be joined together shall be shaped and fitted so that the joint surfaces fit tightly opposite each other. Differences in thickness can be evened out by chamfering or using a packing with a maximum combined thickness of 0.15 d or 6 mm, where d refers to the nominal diameter of the screw shaft.

In bolted joints, the screwing force of the screws may be used to force the joint parts. Welding shall not be employed even for the temporary fastening of joint parts.

Unless otherwise stipulated in the design or in the surface treatment plan referred to in Section 4.5.2, the joint surfaces shall be painted with an acceptable zinc-rich paint with a nominal layer thickness of $\geq$ 60 µm. The joint surfaces can also be hot zinc-coated or spray-galvanized. Preparation shall meet the quality requirements laid down for coating.

When the parts are joined together, the joint surfaces shall be clean and the coating agent hardened.

4.3.4.4 Clearance holes

Unless otherwise stipulated in the design, the clearance holes of an ordinary bolted joint shall be made in line with the middle series defined in the Standard SFS 3898 ISO 273 EN 20273 /31/. Unless a washer is used on the side of the screw-head, the edge of the hole shall be chamfered to correspond to the rounding between the head and shaft of the screw (see also 4.3.2.3).

After the joint parts have been assembled, the holes shall not have an offset greater than 1 mm and the screws shall fit without forcing. If necessary, the fit of the holes in an ordinary bolted joint can be improved by enlarging the clearance hole by a maximum of 1 mm.

The clearance holes of a fitting bolted joint may be a maximum of 0.3 mm larger than the screw shaft.

The holes on a fitting bolted joint shall be made about 3 mm smaller than their nominal dimension at the manufacturing stage. They shall be enlarged to their final dimension after the joint

parts have been fitted into their final position and pressed tightly together during the mock assembly or erection stage. The holes shall be finished off by reaming.

The coating of the screws shall be taken into account when measuring the clearance hole.

4.3.4.5 Tightening the screws

Unless otherwise stipulated in the plan, after tightening, the stress calculated for the stress cross-section of the threaded part of the screws shall be about 50% of the screw's yield stress and there shall be the same degree of tightening in all the screws in the joint.

With lightly oiled threads, this requirement can be achieved with the values for the tightening torque moment given in table 3. The corresponding standard values for tightening for bolts treated in another way shall be determined by means of tests to demonstrate that the prestressing force shown in table 3 is achieved.

Table 3. The prestressing forces required for the bolts (strength grades 5.6, 8.8 and 10.9) in an ordinary bolted joint and fitting bolted joint and the tightening torque moment for lightly oiled screws.

Nominal diameter mm	Prestressing force kN			Tightening torque moment Nm		
	5.6	8.8	10.9	5.6	8.8	10.9
12	16	27	38	39	65	91
16	30	50	70	96	160	224
18	37	61	85	133	221	309
20	47	78	109	188	314	440
22	58	97	136	256	427	598
24	67	112	157	325	542	759
27	88	147	206	476	793	1110
30	107	179	251	646	1077	1508

After tightening, the nuts shall be locked. Welding shall not be employed.

If the design places precision requirements on the tightening or on the prestress of the bolt, the dependence between the tightening torque moment and the prestressing force shall be determined empirically. The angle of rotation method described in Section 4.3.5 can also be employed to ensure adequate tightness.

Experience has shown that in the delivery state (lightly oiled) the

internal friction of the bolt varies considerably. A smaller scatter can be achieved by treating the threads with suitable lubricants. If the threads of the nuts are treated with beeswax, a roughly double prestress can be obtained with the same tightening torque moment compared to bolts in the delivery state. (Cf. Table 3.) The scatter of the test results is also smaller.

In joints with several bolts or where the joint parts have to be forced using the bolts, the tightening shall be performed in two stages starting from the middle of the group of bolts.

4.3.5 Friction joints

4.3.5.1 General quality requirements

In friction joints, such a large compression force shall be created between the joint parts by the bolts or other connectors that the shearing forces in the joint are transferred from one part to another via the friction.

The aforesaid functional requirement calls for there to be the precompression required in the design or applicable standard between the joint parts in the finished friction joint and for the friction coefficient of the joint surfaces to meet the requirements laid down in Section 4.3.5.4 or the design.

Pretensioning shall be performed using the connectors defined in the design. A change in the type of connector calls for an alteration to the design.

4.3.5.2 Holes

Unless otherwise required in the design, the clearance holes of the screws shall comply with the middle series defined in the Standard SFS 3898 ISO 273 EN 20273 /31/. The screw shall fit into place without forcing. There shall be no borings or flashes in the holes or joint surfaces. There shall be bevelling of about 1.5 x 1.5 mm at the edge of the hole on the side of the screw-head if a washer is not employed under the head. The other requirements laid down for the rims of the holes are as described in Section 4.3.2.3.

If the holes are drilled during the mock assembly or erection stage, they shall be made a maximum of 1 mm larger than the nominal diameter of the screw unless the functioning of the joint imposes other requirements.

When drilling or reaming, no drilling fluid shall be allowed to get onto the treated friction surfaces.

4.3.5.3 Fitting the joint parts

The joint parts shall fit together throughout the joint so that no more than 10% of the prestressing force of the connectors needs to be employed for achieving close contact. If the thickness of extendable plates differ, the difference in thickness shall be levelled either by smoothing the end of the thicker plate or by employing packing. Connecting plates shall be bent before the joint is made. The packing shall be have the same strength and friction properties as the joint parts.

The fitting precision of the friction joints shall be taken into account in the manufacturing accuracy of the parts and when planning the order of welding and assembly.

The differences in thickness of extendable parts shall be levelled in the manner shown in diagrams 9a and 9b.

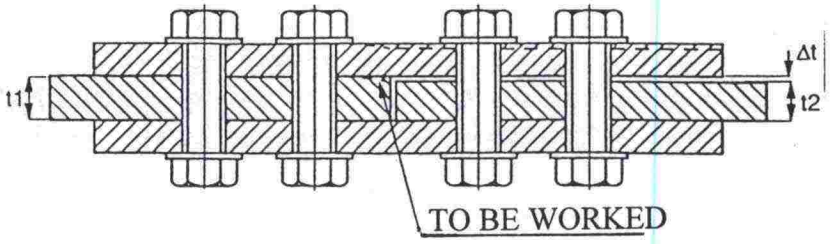
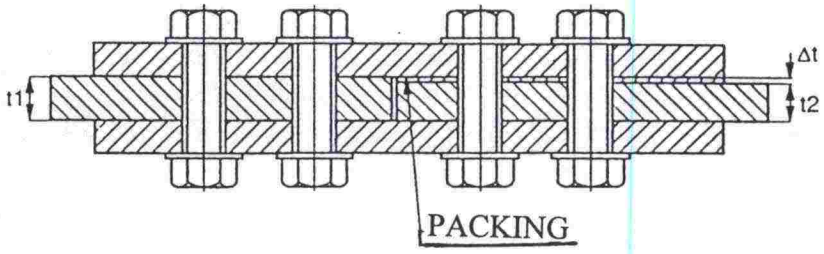


FIGURE 9a FITTING A FRICTION JOINT, $\Delta t < 2$ mm



PACKING TO BE EMPLOYED IF $\Delta t \geq 2$ mm

FIGURE 9b FITTING A FRICTION JOINT, $\Delta t \geq 2$ mm

4.3.5.4 Treating the joint surfaces

When the joint surfaces are fastened together, they shall have the required friction and anti-corrosive properties.

The friction coefficient shall be $\mu \geq 0.5$ unless other requirements are presented in the design.

> This can be achieved with a sharp surface profile 30-40 µm deep, either without coating or coated with a thin zinc silicate paint.
>
> Unless the friction coefficient is determined by means of a procedure test, the cleaned surfaces shall be finished by sand-blasting. The grain size of the quartz sand shall be 1-1.5 mm and the air pressure $\geq$ 7 bars.

The sand-blasted joint surfaces (Sa 2.5/SFS-ISO 8501-1 /16/) shall be coated with zinc silicate paint in order to achieve an even layer of paint with a nominal thickness of 40-60 µm. At least 80 percent by weight of the dry film of the paint shall be metallic zinc. Other coatings can be approved on the basis of procedure tests.

> The test series in the procedure tests shall be sufficiently extensive (generally at least 6) so that the scatter can also be defined.

When the parts are fitted together, the joint surfaces shall be clean and the coating hardened.

> In order to prevent the formation of zinc salts undermining the friction, the friction joint shall be tightened during the same work shift as the zinc-rich painting. If the interval is longer, the zinc salts shall be removed by light shot-blasting (see Section 4.5.3.2). In order to dry, zinc silicate paint requires a relative humidity of at least 50%. If necessary, surfaces can be moistened with a thin jet spray or damp cloth. The hardening of the zinc-rich paint can be checked using a paint solute.

4.3.5.5 Tightening the connectors

The connectors of the friction joint shall be tightened using methods and equipment which can achieve the required precompression between the joint surfaces reliably.

The screws of the friction joint shall be tightened in line with the following

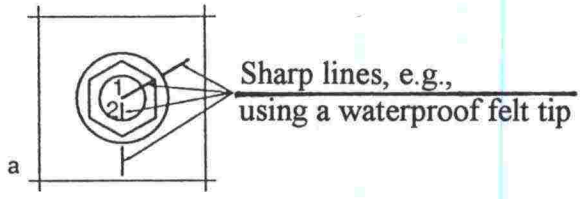
instructions unless another method is shown to be more advantageous as regards the result.

All the screws shall be pre-tightened from the middle of the joint so that 62% of the prestressing forces (about 50% of the yield strength) in the design are achieved. These are shown in table 3.

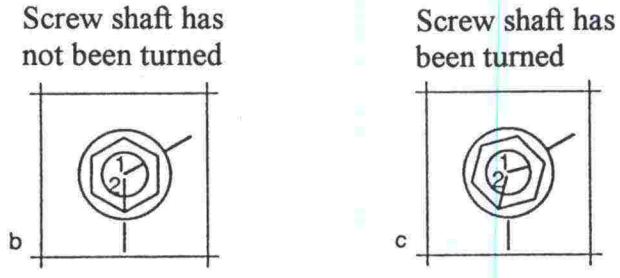
After pre-tightening, the screws shall be prestressed by twisting the nut or head so that the nut turns 120° in relation to the shaft of the screw. The positions of the nut shall be marked so that the angle of rotation can be determined reliably.

The values for the tightening torque moment in table 3 are for screws and nuts whose threads have been lightly oiled, which corresponds to the normal delivery state. Other suitable lubricants can also be employed in the threads, in which case the moments required for pre-tightening will be smaller and the scatter of the bolts' prestressing force will decline. (Cf. 4.3.4.5). The correct tightening moment shall then be determined by means of tests to measure the dependence between the tightening torque moment and the prestressing force of the bolt.

It is recommended that the angles of rotation be marked as shown in Figure 10.



MARKINGS AFTER PRE-TIGHTENING



MARKINGS AFTER FINAL TIGHTENING

FIGURE 10 ANGLE OF ROTATION MARKINGS

4.3.5.6 Finishing the joint

All the gaps between and surrounding the joint parts and between the different parts of the connectors and the parent metal shall be sealed so that moisture cannot penetrate in between the joint parts.

Sealing shall be carried out using paints and putties suitable for the anti-corrosive coating on the structure.

Well-fitted joints can be sealed by brushing primer on them. Open gaps, e.g., in between the ends of extended plates, shall be filled with putty after the priming coat.

If the conditions and schedule so require, sealing shall be performed with a temporary coating, which shall be entirely removed when the final surface treatment is carried out.

When removing grease from the screw-heads and nuts, solvent shall not be used to such an extent that it penetrates in between the joint parts.

The sealing of the friction joints shall be taken into account in the surface treatment plan. (Cf. 4.5.2).

4.3.5.7 Proof of acceptability

During tightening, the prestressing force generated in the connector shall be measured either directly or indirectly.

The prestressing force of pre-tightened screws can be gauged with a calibrated torque spanner. The final tightening of the screws shall be checked from the angle of rotation markings.

Acceptability shall be proved using the inspection logs, which shall be attached to the acceptability report.

4.3.6 Stud pins

4.3.6.1 General quality requirements

A stud bolt fastened by means of arc flash welding shall be welded along its entire cross-section. The bolt shall not be more than 2 mm longer than its recommended dimension.

Recommended dimension refers to the length of the fully welded bolt. It is stated by the manufacturer of the stud bolts in the product specification or is defined on the basis of type approval or procedure tests.

Stud pins which have been proven intact after a beating test can be left askew unless the work methods or functioning of the stud pins in the structure calls for them to be rectified.

The same quality requirements apply to stud pins fastened with a fillet weld as to flash welded bolts. The fillet weld shall entirely surround the bolt. (Cf. 4.3.6.3)

Quality requirements applying to other stud pins depend on the type of stud pin and the fastening method.

4.3.6.2 Welding

Welding may only be performed using flash welding devices developed for welding bolts, whose reliability has been demonstrated by the manufacturer's own procedure tests. The welding gun and control unit shall be tested together with the power source.

The parent metal of the bolts, guard rings and welding point shall be clean. The parent metal shall be shot-blasted to a cleanliness grade of Sa 2.5. The welding point shall be dry.

The hardness of the parent metal at the welding point shall not exceed 400 HV. If the temperature of the parent metal during welding is less than 0 °C, the hardness shall be determined by means of procedure tests.

The parent metal, conditions and equipment shall be the same in the welding procedure tests as in the actual work.

When starting to weld bolts at a new point, a test work shall be performed where at least 10 bolts are welded to the same parent metal used in the bridge. All the bolts shall undergo a ringing and beating test. If bolts break off, the trial shall be repeated until the correct welding values and working methods are found.

In order to ascertain the cause of loosening, procedure tests shall be performed if necessary, and these include tension, bending and hardness tests and the testing of the welded joints by means of NDT methods and specimens for macrographic examinations.

The standard or other directive to be applied in the procedure tests shall be fixed at the start of the work (e.g., DIN 8563 or BRO 94).

4.3.6.3 Corrections

A weld that has remained defective or has proved poor in some other way may be corrected with a fillet weld whose effective throat thickness is $\geq$ 5 mm if the diameter of the bolt is 20 mm, and $\geq$ 6 mm if the diameter is 22 mm. The welding plan referred to in Section 4.3.3.2 shall be drawn up for the welding.

The marks of fractured bolts shall be levelled by grinding. A new stud pin shall be welded alongside the point of fracture.

Those stud pins which went askew in the beating test and which shall not be left askew for the reasons defined in Section 4.3.6.1 shall be corrected by slowly bending them (Cf. Figure 11).

4.3.6.4 Proof of acceptability

All the welded stud bolts shall be checked visually.

The length of the welded bolts shall be checked by measuring at least 5% of the bolts. The bolts to be measured shall be selected visually. If deviant bolts are discovered, the number of inspections shall be increased in order to obtain a reliable picture of the number of raised bolts.

All the bolts which are over 2 mm longer than their recommended dimension shall be inspected by means of a beating test or their fastening shall be reinforced with a fillet weld. (Cf. 4.3.6.3)

All the bolts shall be subjected to a ringing test in which the bolt is made to vibrate by tapping it with a hammer. All the bolts found suspect on the basis of the ringing shall undergo a beating test unless they are reinforced with a fillet weld.

At least one out every 200 bolts found satisfactory in the ringing test and reinforced with a fillet weld shall be subjected to beating tests. In addition, two extra beating tests shall be performed for each broken bolt.

During the beating test, the bolt shall be struck with a hammer with a single blow at least 30 askew (cf. Figure 11). A bolt is not to be accepted if breaks or fractures appear in it or the fastening weld.

All the bolts bent upright after the beating test shall be checked visually and by means of a ringing test.

The results of the inspection shall be entered in an inspection log which shall be attached to the acceptability report.

The beating test and bending shall be performed as shown in Figure 11.

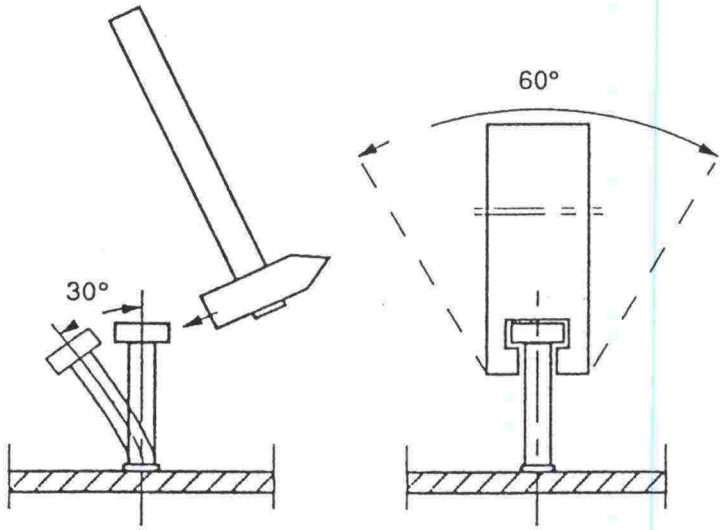


FIGURE 11 BEATING TEST AND BENDING

4.3.7 Assembly

4.3.7.1 General

The assembly of the parts to form the structure shall be planned so that all the parts can be fitted in a controlled manner and so that the joints can be made in line with the quality requirements applying to them. (Cf. 4.1.4)

If the assembly of the structure in line with the aforesaid requirements is impossible or unreasonably difficult, the manufacturer shall point this out in the manner described in Section 4.3.1.2 and make a proposal for altering the design.

4.3.7.2 Measurement

The design contains the theoretical dimensions of the structures at a temperature of + 20 °C unless stated otherwise. Deformations due to the jointing method shall be anticipated when fixing the assembly dimensions.

The measurements shall be made with such precision that the

possible measuring error is a maximum of 1/10 of the precision requirements laid down for the structures or structural parts.

4.3.7.3 Fitting the parts

The parts shall be fitted together so that the assembly and erection joints and the finished structures meet the quality requirements laid down for them.

The fitting precision of the parts affects, e.g., the quality grade of the welds (cf. SFS 2379 /18/ or SFS-EN 25817 /19/).

The butt joints entered in the plan shall be fitted so that the joint surfaces are in close contact. A local gap up to 0.30 mm wide, whose length shall not exceed 1/10 of the length of the contact surface, is permitted between the joint surfaces.

No weld shall be welded into a butt joint until the fitting precision of the joint has been determined.

4.3.7.4 Temporary fastenings

All the temporary fastenings required in the assembly of the structural parts shall be presented in detail in the manufacturing plan.

Temporary fastenings shall not undermine the strength properties of the structure nor its usability. Holes or welds not included in the design shall not be made in the steel superstructures of the bridges without the designer's consent. Welded fastenings shall not be employed in structures assembled with bolts unless there is a reference to this in the plan.

The welds on the fasteners shall be removed so that they have no detrimental effect on strength, appearance or surface treatment. Fasteners shall not be placed on visible surfaces.

Hoist brackets and other parts facilitating transfers and transportation may be attached permanently to erection segments only if they are positioned in places having no detrimental effect on appearance and if a fatigue examination is performed to study their effect on the strength properties of the structure.

The use of welds in fastening shall be restricted. Welds in particular increase the susceptibility of the structure to brittle fractures. This is why the welding of fasteners may call for pre-heating even though assembly welding might not require it. Fasteners shall not be welded to girder flanges or to rod- or beam-like structures subjected to tensile force without the

designer's consent. Braces and the web at least 200 mm from the flange are recommended spots.

The welds on fasteners may be removed by grinding.

4.3.7.5 Assembly joints

The requirements on joints are as described in Sections 4.3.3, 4.3.4 and 4.3.5.

In combined friction and welded joints, the welding shall be performed prior to the tightening of the connectors.

4.3.7.6 Proof of acceptability

Logs shall be kept of the measurement of structural parts, containing at least the measurement results, theoretical dimensions and permissible deviations and their overshoots as referred to in Section 1.3.4 of SYL 1.

If the measurement result exceeds the limit value, the area of occurrence of the deviation in excess of the permitted level shall be investigated and the structural part shall be corrected in an acceptable manner unless a procedure for reducing value has been agreed upon.

As regards the joints, the requirements on proving acceptability are shown in Sections 4.3.3.9, 4.3.5.7 and 4.3.6.4.

The tightness of boxes designed to be airtight shall be determined by means of a pressure test employing an excess pressure of 0.5 bars unless another pressure has been required. A log shall be kept of the test.

The tightness of the beams of bracing trusses and other secondary structural parts can nevertheless be determined by a careful inspection of the welding seams.

4.4. STRUCTURES

4.4.1 Precision of the structure

Precision requirements

When complete, a steel bridge shall meet the general measurement and shape precision requirements laid down in Section 1.2 of SYL 1.

Unless the aforesaid general quality requirements stipulate otherwise or other precision requirements have been laid down in the design, the permissible measurement and shape deviations for the erected steel structure are as shown in table 4.

Table 4. The permissible measurement deviations of the structures

Deviation and its symbol	Figure	Length dimension	Permissible deviation 1)			Remarks
			Minimum mm	Proportional	Maximum mm	
All structural bearers:						
Span length ΔL	12	L or ΣL	± 20	± 0,1%	± 60-30	
Construction depth ΔH	13	H	± 5	±0,2%	± 20	
The vertical shape of the bearer Δf	12	L	± 20	± 0,1%	-100	2)
The lateral bending of the bearer v4	2	I	± 5	± 0,1%	± 30	3)
The batter of the flange k	6	b	± 2	±2,0%	± 10	
The distance between main and secondary bearers ΔB	13	B	± 5	±0,2%	± 20	4)
The deviation in level between main bearers Δh	13	B	10	0,3%	30	
The batter of bearers v6	13	H	± 5	±0,5%	± 20	
The distance from the centroid of the bearing to the end of the bearer Δa	12,15	a			±20	
The position in relation to substructure e0	12,15	L	± 20	±0,05	± 50	
The position in relation to the centroid of the bearing in longitudinal direction e1	15				± 20	
The position in relation to the centroid of the bearing in transverse direction e2	15				± 10	
Truss, arch or other beam structure:						5)
The bending of the axis of the beam f3	14	S	± 2	±0,1%	± 10	
The eccentricity in a joint e3	14				± 10	
The deviation of a joint in relation to the axis of the bearer's centroid e3	14				± 10	

1) The relative figure for the permitted value refers to a percentage of the measurement length. A deviation less than the minimum value is not required nor is a deviation greater than the maximum value permitted.
2) The shape of the bearer refers to the shape as shown in the design of the bottom surface of the bearer between two adjacent supporting lines.
3) l is the spacing between the braces or supports preventing lateral deformations
4) The requirements imposed by the deck structure shall be taken into account.

5) The table values apply to the main bearers. Double deviations are permitted in the bracing trusses.

It shall be noted that the substructure or deck structure of the bridge, e.g., concrete elements and railway sleepers may require precision superior to that shown in the table.

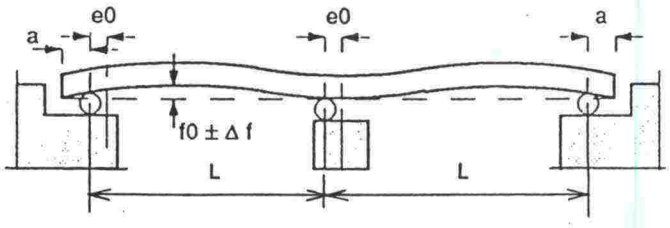


FIGURE 12 PROFILE OF THE BEARER

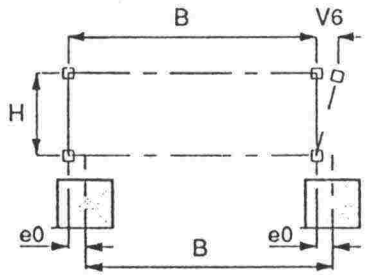


FIGURE 13 CROSS-SECTION OF BEARER

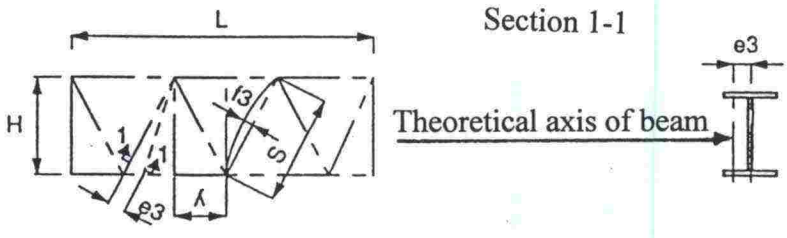


FIGURE 14 TRUSS GIRDER, 1-1 SECTION

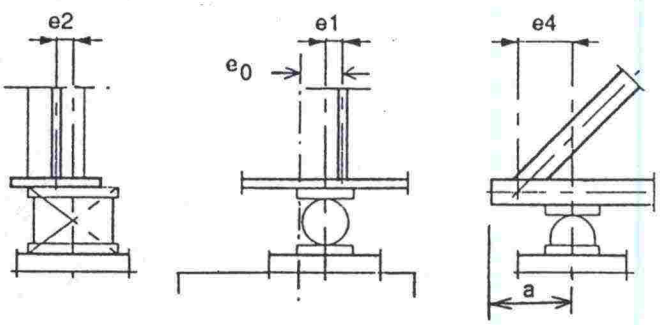


FIGURE 15 POSITION OF GIRDER OR TRUSS IN RELATION TO BEARING

Checking the dimensions

The erector of the steel structure shall measure all the dimensions shown in the design and table 4 and report them to the client. The measurement log shall contain at least the nominal dimension, permissible deviations or limit values and the dimensions measured. If the dimension is checked at several points, at least all the dimensions in excess of the limit value or the dimension nearest to the limit value shall be entered in the record. See also SYL 1, Section 1.3.4.

If no cross-measures are shown in the design, their specific values shall be calculated and their implementation shall be followed up in the course of the work.

The shape of the main girder in a vertical direction shall be checked at the points marked in the design and at least at the ends and middle of the girder and at the quartiles of the span.

The shape is usually to be checked prior to the welding together of the segments, after welding and after the superstructure has been installed.

The measurements shall be performed at the upper and lower flanges of the girder.

The lateral bending, distances and batter of the main girders shall be checked at the transverse girders and/or trusses.

The lateral curvature, intervals and pitch of the girders are usually to be checked prior to and following erection.

The spacing between the transverse girders shall be measured at both ends of the girders and the lateral bending at the middle of the girders. In the case of a truss, the spacing at both the top and bottom chords shall be measured.

The difference in height between the main girders shall be measured at the supports and at the middle of the spans and their quartiles.

The batter of the girder's flange shall be checked at the bearings.

The structural depth of a truss, arch or other beam- or rod-like structure shall be checked at the bearings, the middle of the span and quartiles.

The bending of the beam axis shall be checked at the middle of the beam on the outside surface.

The eccentricity of the beam in the joint and the deviation of the joint from the vertical plane of the girder shall be measured in each joint of the truss.

4.4.2 Mock assembly

4.4.2.1 General

The need for a mock assembly shall be ascertained when drawing up the manufacturing and erection plans unless a mock assembly has been stipulated in the bridge design.

If fitting work on the joints during erection is not possible or useful due to the schedule, prevailing conditions or other cause, the structural parts shall be assembled during the mock assembly into structures or uniform structural parts so that the fit of the erection parts can be ensured. In simple structures, a mock assembly can be replaced by precise quality control measurements.

4.4.2.2 Requirements

During mock assembly, the structure shall be supported into a stress-free state unless the design gives the dimensions and shape in another state of loading.

Detailed requirements on the fitting of the erection joints and on other matters shall be presented in the manufacturing and erection plans.

Unless a stress-free state can be arranged, the deformations in the structure shall be determined at the different stages of the mock assembly and taken into account in measurements and when making joints between structural parts.

The erection joints shall be prepared during the mock assembly so that when they are erected they fit without working. Joints in which there is looseness or other play due to the jointing method shall be marked with locating marks in order to ensure the correct position.

The mock assembly of the structure can also be performed in parts so that only the most important and complicated erection parts are mock assembled and the other erection joints are left with finishing allowance. For example, trusses and arched bearers can be mock assembled horizontally.

4.4.3 Transfers, transports and storage

4.4.3.1 General

Transfers and transports shall be taken into account in the manufacturing and erection plans. Parts of the plan concerning the storage of structural parts are also to be enclosed with them if necessary.

The general requirement is that the quality of structural parts and structures shall not deteriorate during transfers, transports or storage or from the effect of fastenings or supports made for such purposes. Nor shall they undermine the quality level of work stages performed subsequently, such as coating.

> If the division of segments in the design is disadvantageous as regards transfers and transports, the manufacturer or erector can submit an alteration to it. Its effect on manufacture and erection shall be ascertained beforehand.
>
> Damage to the coating during hoisting procedures, storage and transports lowers the quality level and increases costs.

The manufacturer or erector shall ascertain whether supplementary braces or other supportive measures are required in order to ensure stability during transfers and transports or in order to prevent permanent deformations. The need for hoist loops and brackets shall also be investigated. The aforesaid detailed plans for the structures shall be incorporated in the manufacturing plan.

The addition or alteration of permanent structures shall be treated as an amendment to the design.

4.4.3.2 Hoisting procedures

Hoisting procedures shall not cause stresses in the structures detrimental to their strength or permanent deformations undermining bearing capacity, durability, other service characteristics or appearance. This requirement shall be taken into account when planning lifting points and hooks and when using lifting accessory equipment.

The safety level of hooks and lifting equipment is defined in line with official regulations and directives on health and safety in work.

Jolts occurring during hoisting procedures shall be taken into account when determining stresses.

Gripping devices or other accessory equipment causing local contortions or surface faults shall not be used in hoisting procedures. Damage to the coating shall also be kept as limited as possible.

Warning signs as regards structural stresses and deformations include the buckling of slender plate girders and the occurrence of compression stresses in the slender tension bars of arch and truss structures, in which case they can easily buckle.

It is advantageous for the treatment of coated structural parts if hoist loops and similar hooks are fastened permanently. (Cf. 4.3.7.4)

4.4.3.3 Supporting the structural parts

When planning support work, the movements of the base and all the loads and other influences affecting the structures shall be taken into account.

Holes not included in the structural design or manufacturing plans shall not be made nor hooks welded in the structures. (Cf. 4.3.7.4).

High girders with a narrow upper flange (composite girders) can lose their stability by buckling during transports and transfers. This can be prevented by means of supplementary braces employed during transfer or by increasing the width of the compressed flange, which is also to be treated as an amendment to the design.

During transportation, the structures are subjected not only to their own weight but also to wind load and to horizontal and vertical inertial forces.

4.4.3.4 Protection

During transfers and transportation and possible intermediate storage, deterioration in the properties of the structural parts due to the weather, traffic and other detrimental factors to the extent that they cannot be made to meet all the requirements laid down for them even after cleaning and corrective measures shall be prevented, if necessary, using shields.

The accumulation of water in the boxes and joints increases the risk of corrosion, and, in the winter, ice can crack structural parts or cause permanent deformations in them.

During transportation, the structural parts may be soiled, e.g., by dust, mud, salt and bitumen to the extent that the coating for the duration of transportation cannot withstand it or it cannot be cleaned well enough for a coating placed on top to meet the quality requirements.

Friction joints shall be protected carefully so that when they are joined together the joint surfaces meet the requirements laid down for them. If necessary, the effects of transportation and protective measures on the friction properties shall be ascertained by means of tests. (Cf. 4.3.5.4)

4.4.4 Erection

4.4.4.1 General

On the basis of his qualifications and experience, the foreman of the erection work shall understand the performance of the structure to be erected during the various work stages with the precision required by the erection method and shall have a thorough command of the work methods.

The person preparing the erection plan shall be well acquainted with bridge erection and with the functioning of machinery and equipment used in their erection. He or the designer assisting him who performs the design and strength calculations possibly required in the planning of the erection shall also possess experience of planning steel bridges.

The qualifications required of the work force relate to mastery of the erection method and of the use of machinery and equipment. The qualification requirements for welders are defined in Section 4.3.3.6.

4.4.4.2 Erection plan and quality plans

The erection plan

The erection plan shall present the assembly of the bridge parts and their transfer into place as a finished bridge structure together with all the related measures and investigations. It shall be in writing. The plan shall be submitted to the supervisor for inspection at least a week prior to the start of erection.

Standard erection plans can be utilized and followed as they stand, conditions and erection method permitting.

The erection plan shall cover and take into account, e.g.,

- conditions during erection at the bridge site
- oading circumstances and other effects relating to the erection stages
- the requirements of traffic moving in the area of influence of the site and the disturbance caused by it
- the terms imposed by a construction permission issued by the Water Rights Court or another body
- the properties of the structure
- the time schedule
- the available equipment and work force
- health and safety at work.

Information on conditions affecting the erection work includes:

- climate conditions such as windiness
- ground survey findings
- data on waterways and water traffic
- existing structures
- substructure and earth construction work arrangements
- available site areas
- means of communication.

The ground investigations relating to the design shall be supplemented if necessary at points where there is scaffolding or other auxiliary structures.

The erection plan shall show by means of drawings and texts, e.g., the following matters with the precision and to the extent required by the object:

- the arrangement of the erection work and use of the area at the different stages
- auxiliary structures
- the assembly of erection parts
- transfers and the condition restrictions applying to them
- the making of erection joints and the detailed technical work plans relating to them
- mounting of bearings
- the detailed schedule for the work

The structural designer's proposal for the structure erection method presented in the design shall form the basis for the erection plan. It is generally based on conventional working methods and erection equipment. The forces and shifts presented in the erection method proposal are indicative. The person drawing up the erection plan shall check whether they are suitable for the erection equipment even if the erection method

employed is the same as in the erection method proposal. The person drawing up the erection plan can also propose that the structure be erected in another manner which he considers best. If, in this connection, the division of the structure into structural parts or the dimensions of the structure submitted by the structural designer have to be altered, this shall be treated as an amendment to the design.

The erection plan shall include calculations which together with the calculations relating to the design shall be used to demonstrate the safety of the structures and the dominant or measurable shifts and deformations at all the erection stages. The loads in the Publications 'Bridge loading' (Finnish National Road Administration 2172072) /32/ and 'Directives of loading on structures' (RIL 144-1990) /33/ shall be employed. If necessary, the client can issue supplementary guidelines.

The wind loads acting on the structure to be erected and its auxiliary structures shall be calculated in line with the loading directives (RIL 144-1990). If damage possibly caused by the wind is limited solely to economic losses, the wind pressure employed can be 75% of the values in the aforesaid directives.

In a transfer or erection stage of a relatively short duration, a wind velocity of 20-25 m/s may be employed when calculating the wind load provided that changes in the weather conditions can be foreseen with adequate precision. In transfers of a very short duration, the wind load may be determined from an even smaller velocity, nevertheless at least 12 m/s also provided that the structure can, e.g., be supported quickly by guying or reinforced in some other way against a greater wind load.

The wind velocities permitted at the various stages of erection shall be entered in the erection plan.

The permanent loads and cross-section values of the structure shall be obtainable either from the supervisor or with his permission directly from the designer. It shall be noted that the real weight of the structure may differ from the theoretically computed value. Where necessary, the weight of scaffolding, formwork and reinforcement shall be taken into account in erection weights. Their permitted weight shall be entered in the erection plan.

When the structure is transferred, it is subjected to additional stresses caused by vibration and jolts. These shall be taken into account by means of an impulse coefficient, which shall be ≥ 1.1.

The applicable regulations and instructions issued by the authorities shall form the basis for design of the auxiliary structures. The design shall be drawn up in such detail that the auxiliary structures can be manufactured in line with the requirements of the erection work. If the auxiliary structures shall be used in the area of influence of a waterway, railway, road or street, their design shall be submitted for inspection and approval by the relevant authorities.

A design shall be drawn up for all auxiliary structures on which the structure to be erected or its parts shall be supported during storage, transfers or erection. A design shall also be drawn up for those auxiliary structures on which machinery or equipment employed for hoisting or transfer are supported. Embankments and other earth structures are also auxiliary structures which shall be planned.

The design for the auxiliary structures shall comprise accounts of the design principles, structural drawings, strength calculations and work commentary or similar manufacturing instructions which may be required.

The Publication 'Scaffoldings' (RIL 147-1993) /34/ and the complementary guide 'Scaffoldings for bridges' (Finnish National Road Administration 2170009) /35/ shall followed in the design.

Site quality plan

The work quality plan shall cover, e.g., the organisation of the site, the qualification requirements laid down for the management and labour force, the special equipment used in the work and its monitoring and provisions for risks and exceptional circumstances relating to the work etc. (Cf. also SYL 1, Section 1.3.2)

Work stage quality plan

The work stage quality plan shall cover, e.g., the following points relating to the various erection stages:

- measuring the shape, shift and deformations of the dimensions of the structure
- measuring the lifting and support forces
- quality control of the erection joints
- measurements and inspections relating to the installation of bearings
- inspections relating to the finishing work and surface treatment (cf. 4.5) (Cf. also SYL 1, Section 1.3.3.2)

4.4.4.3 Hoisting procedures and transfers

Fastenings made for hoisting procedures and transfers relating to erection shall be presented in detail with their joints in the manufacturing and erection plans (Cf. 4.4.3.2). Restrictions applying to these were also covered in Section 4.3.7.4. They shall be removed without damaging the structure unless they have been planned to be permanent.

Hoisting procedures and transfers are only to be performed using equipment which enables the work to be carried out in a controlled and safe manner.

The dependability of the equipment shall if necessary be demonstrated by strength calculations or some other reliable manner. Its usability shall be checked prior to the start of the erection work. The instructions for use shall be exhaustive. All the servicing and adjustments required to ensure reliability shall be performed in the course of the work. As regards critical work stages, provision shall be made for using back-up equipment or for repairing the equipment without delay.

4.4.4.4 Erection joints

The erection joints are covered by the requirements laid down in Sections 4.3.3, 4.3.4 and 4.3.5 and in the design. The working conditions shall be so arranged, if necessary using shielding and auxiliary equipment, that the required quality level of the joints can be achieved with certainty and confirmed reliably by inspections.

The temporary support and fastening of structural parts relating to erection are covered by the same restrictions as in assembly work (Cf. 4.3.7.4)

When making erection joints, provision shall be made for movements of the structural parts, which can be due, e.g., to:

- fluctuations or differences in temperature
- shifting or deformation of auxiliary structures
- movements or deformations of hoisting or transfer devices

Fluctuations in temperature cause not only length changes but also angle changes between the joint parts. The uneven warming of structural parts also results in warping. It may be difficult or even impossible to make erection joints in sunny weather.

When making erection joints, pre-heating may be necessary due to the conditions even though similar welds do not require it at the place of manufacture. When extending the supplementary

plates on the flanges, large welding stresses can be avoided by heating the rest of the girder at the splice so that its thermal elongation corresponds to the contraction of the splice weld of the cover plate.

The inspection of the erection joints shall be fitted into the work stages so that the quality level of the joints is ensured and that possible repairs can be carried out in the most advantageous manner and without undermining the quality of the structure.

If flaws are detected in the erection welds, the causes of the faults shall be ascertained and removed as far as possible before undertaking corrective work. Cracks in a weld always call for a thorough investigation.

When making friction joints, it is important to ensure that the joint surfaces are in the state stipulated in the requirements at the moment of joining. During erection work, the bolts can face attractive forces caused by the forcing together of the parts, which reduce the friction of the joint and thereby correspondingly undermine the strength of the joint. This can be avoided by selecting the order of erection correctly, by arranging temporary supports so that no constraint actions are generated, and by fitting the joints carefully in advance.

4.4.4.5 The finishing work

Traces of the erection work shall be cleared away from the structure and the bridge site. The requirements for the cleaning work depending on the surface treatment are laid down in Section 4.5.

4.4.4.6 Proof of acceptability

The requirements concerning proof of acceptability are given in Section 1.3.4 of SYL 1.

The acceptability of an erected bridge shall be proved by making measurements and visual inspections and by comparing the results to the quality requirements laid down.

Prior to carrying out the acceptability measurements, a check shall be made to see that the structure is correctly supported and that it is not subject to extra loads or other influences. The temperatures of the different parts of the structure and of the air shall be observed and their effect on the dimensions of the structures shall be determined.

The dimensions and shape of the bridge shall be checked in line with Section 1.2 of SYL 1 and Section 4.4.1 of this document.

The dimensions and shape of the steel structure shall be checked prior to making the deck structure.

If the measurement result exceeds the limit value, the area of occurrence of the deviation in excess of the permitted level shall be ascertained and the structural part shall be corrected in an approved manner unless a depreciation procedure is agreed upon.

The same requirements apply to the quality control and demonstration of acceptability of erection joints as to other joints. (Cf. 4.3.3.9, 4.3.4.7, 4.3.5.6 and 4.3.6.4)

The tightness of boxes closed in connection with the erection shall be demonstrated in line with the requirements laid down in Section 4.3.7.6.

The support reactions of the bridge shall be measured prior to the soldering together of the bearings unless it is unnecessary due to the support conditions of the supporting structural bearer or impossible due to the size of the bridge or otherwise to the properties of the structure. The correct positions for the bearings shall be determined on the basis of the measurement results.

> If the main girders are continuous or in the case of a box or grillage structure with torsional rigidity, the support reactions shall generally be measured. When interpreting the measurement results, it shall be noted that differences in temperature between and within the structural parts have an effect on the support reactions. For this reason, measurement is best performed when the differences in temperature have evened out, e.g., in cloudy weather.

Measurement results shall be presented in clear and consistent measurement and inspection records and summary reports.

4.5 SURFACE TREATMENT

4.5.1 General

4.5.1.1 Application

This section of the general work commentary shall be followed in the surface treatment of new steel structures. It may also be applied when old steel structures are being surface treated.

This section lays down quality requirements and provides instructions on the working method, quality control and proof of acceptability: for anti-corrosive painting, hot zinc-coating and metal spraying.

The finishing work on an uncoated steel surface and the internal corrosion protection of the boxes are also covered.

4.5.1.2 Terms and definitions

Besides the terms presented in Section 4.1.2 above and in Section 1.1.3 of SYL 1, the surface treatment industry's terms defined in Appendix 1 are also used.

4.5.1.3 General quality requirements for coatings

The corrosion protection and other properties of the coating shall be durable. Re-coating or a thorough service treatment may become necessary a minimum of 20 years after the surface treatment. Five (5) years after coating, there shall be no signs of rust or other faults in the coating detectable to the naked eye.

As regards its shade and other properties affecting appearance, the coating shall be of a uniform quality especially on the visible surfaces.

> A quality requirement can be defined for the uniform quality of the coating by preparing a comparison surface on the structure at the start of the job, the treatment for which shall be agreed upon and which shall be compared with observations on the coated surface.

The adhesion of the coating to its substrate and adhesion between different layers shall meet the requirements laid down for the type of coating.

The coating shall not have any pores or any other faults not referred to earlier which undermine its anti-corrosive properties.

The coating shall meet the thickness requirements laid down in the design, hereinafter in this general work commentary and in the revised surface treatment plan.

Faults due to a mechanical or other external effect and occurring in the structure following the taking over for service are not to be taken into account when evaluating the quality and durability of the coating.

4.5.1.4 Quality plans and proof of acceptability

Site quality plan

The site quality plan referred to in Section 1.3.2 of SYL 1 shall present with respect to surface treatment, e.g.:

- a time schedule
- the personnel responsible for labour management, surface treatment and quality control and their qualifications
- the measuring equipment to be employed in the work and inspections, and the calibration of the measuring devices
- provisions for risks and exceptional circumstances occurring during the work
- repair measures and
- proof of acceptability

Work stage quality plan

The work stage quality plan referred to in Section 1.3.3.2 of SYL 1 shall refer to, e.g.:

- quality assurance measures and quality control measurements during the work
- proving the acceptability of the work stage. This includes:
  - the matters to be measured and inspected and the related quality requirements and acceptance limits
  - the scope, date and test connections of the inspections
  - the inspection and measurement methods, equipment and person in charge, and
  - the documentation of the inspections and measurements (log models)

The surface treatment work in its entirety can be treated as a single work stage.

Proof of acceptability

The acceptability of the surface treatment shall be proved using the inspection and measurement records by comparing the results of the inspections and acceptability measurements with the requirements laid down (see also SYL 1, Section 1.3.4).

4.5.2 Surface treatment plan

4.5.2.1 The form and content of the plan

The surface treatment plan is a separate technical work plan, referred to in Section 1.3.3.3 of SYL 1 and above in Section 4.1.4, which defines the stages of the surface coating and the coating work and materials.

The plan shall be supplied to the client at least a week prior to the start of the surface treatment. It shall be based on the requirements and instructions on the surface treatment of structural parts presented in the design and in this document.

The surface treatment plan shall be based on the surface treatment of the structural parts defined in the design. It can also propose something other than the surface treatment system approved by the Finnish National Road Administration as presented in the design within the limits given in Section 4.5.2.2. Deviations from the surface treatment defined in the design shall be treated as amendments to the design. The surface treatment plan is then to be submitted to the client for approval a minimum of two weeks prior to the start of the surface treatment work.

The surface treatment plan shall describe in detail the manner and products which shall be used to carry out the surface treatment. It shall define unequivocally the surface treatment system and the quality requirements to be laid down for it. Product specifications and possible other accounts of the composition, properties or use of the products shall be attached to the surface treatment plan.

The quality requirements to be laid down for the preparation of the surface shall be defined in detail. All the cleaning and other measures relating to the intermediate stages are also to be clarified.

When drawing up the plan, a check is also to be made that the quality grade of the steel work (SFS 8145 /20/) defined in the manufacturing plan for the structural parts (cf. 4.1.4, 4.3.1.1 and 4.3.3.1) is adequate for the surface treatment system.

With reference to anti-corrosive painting, the following is also to be presented:

- preparation of steel surfaces and, if necessary, painted surfaces (including the roughness of the surface and blasting material) together with a possible shop primer
- painting system with the Finnish National Road Administration's codes
- products to be used and their shades by layer (with product specifications and shade cards)
- paint layers and the nominal thickness of their dry film together with the permitted fluctuation ranges
- thickness of the wet film
- improvement of painting
- painting of spots which are difficult to paint
- puttying of gaps and pores
- equipment and tools to be used in the painting
- outlines of the paint layers
- surface treatment of the seams between different materials
- requirements laid down for the conditions
- drying and repainting times taking into account condition factors
- instructions for remedying defects in the painting
- site for execution and possible protective measures and structures
- environmental protection and waste disposal and
- surface treatment worker and name of the foreman in charge.

With reference to hot zinc-coating, the following is also to be presented:

- grade according to the Standard SFS 2765 /36/ or the thickness of the zinc layer in some other way
- work stages and materials used in preparation
- temperature, dipping time and cooling method of the zinc
- possible support of the structural units and other measures
- remedying defects and
- treatment plant and name of the foreman in charge.

With reference to metal spraying, the following is also to be presented:

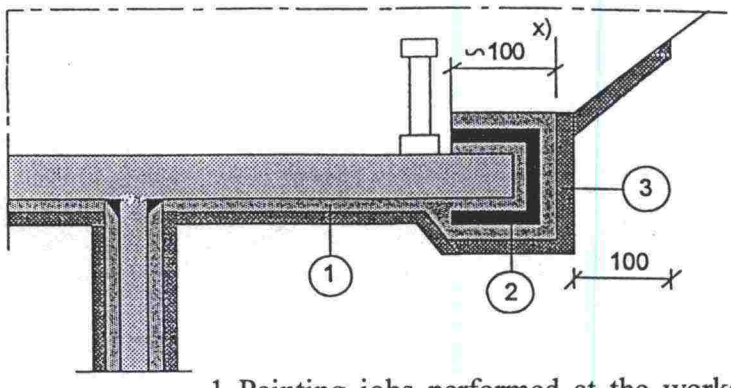
- preparation of the substrate
- composition and state of the metal to be sprayed
- thickness of the layers together with the permitted fluctuation range
- tools to be used
- requirements laid down on the conditions

- site for execution and possible protective measures and structures
- environmental protection and waste disposal
- remedying defects and
- name of the metal sprayer and the foreman in charge.

Steel surfaces coming into contact with concrete shall be treated so that the coating can withstand the special stress caused by the alkalinity of the concrete and that the areas at the boundaries which are difficult to maintain are limited. Only the edge areas of flanges touching the concrete on composite girder bridges shall be coated as shown in Figure 16. If there is no composite effect (stud pins), the flange shall be covered with the layers of primer and undercoat specified in the painting system, which shall be alkali-resistant at least 200 mm downwards from the concrete boundary (cf. Figure 17). The upper flange of wooden decked bridges is also to be painted as shown in Figure 18. Bars and other steel parts cast partly in the concrete shall be painted as shown in Figure 18.

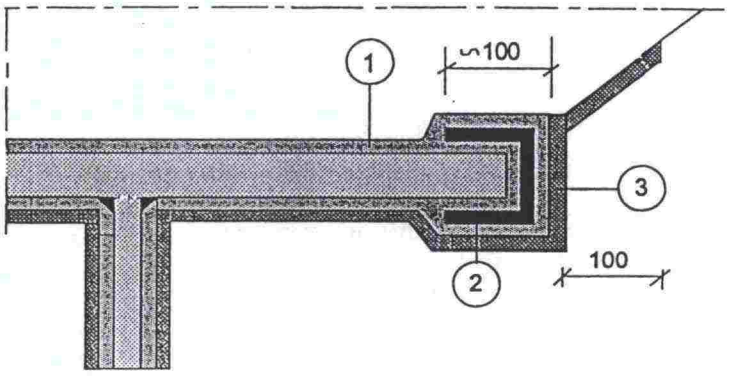
The paints most commonly employed on bridges, which are unable to withstand the alkalinity of concrete or the impregnating agents in wood, are alkyd paints.

The making of the boundaries of the coating layers shall be planned with care. No layers of paint shall be accepted between zinc-rich paint and the steel surface.



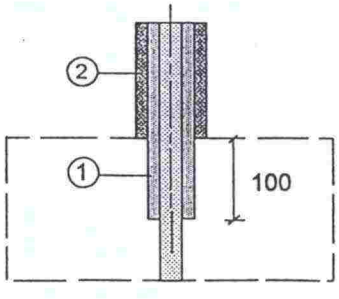
1 Painting jobs performed at the workshop in line with the painting system
2 Reinforcement painting using undercoat
3 The final top coat at the bridge site
x) or until the nearest row of stud pins

FIGURE 16 COATING THE UPPER FLANGE OF A COMPOSITE GIRDER



1 Painting jobs performed at the workshop in line with the painting system
2 Improvement of painting using undercoat
3 The final top coat at the bridge site

FIGURE 17 PAINTING THE BOUNDARY BETWEEN A CONCRETE SLAB AND A STEEL GIRDER



1 Painting jobs performed at the workshop in line with the painting system
2 The final top coat at the bridge site

FIGURE 18 BARS EMBEDDED IN CONCRETE

If the surface treatment system is other than painting, hot zinc-coating or metal spraying, the surface treatment plan shall include references to the materials, layer thickness and fluctuation ranges, the properties of the coating and the working method. Brochures describing the materials and working methods shall be enclosed with the surface treatment plan.

4.5.2.2 Approved bridge coatings

Surface treatment jobs on bridges may only be performed using approved coating systems.

The painting system and the products employed in it shall be approved by the Finnish National Road Administration.

Recommended and other approved painting systems are shown with restrictions on their use in Appendix 2. The systems are defined using the Finnish National Road Administration's numbers (e.g., TIEL 4.12). The list of approved painting systems is updated on the basis of experience and the results of approval tests.

> The approved painting systems and the products to be used in them are presented in SILKO Directive 3.352 /37/ and in letters complementary to it issued by the Finnish National Road Administration.

The manufacture of the paint products shall be supervised. Supervision shall be based on a general approved quality system and meet the requirements laid down by the client.

Other approved coating systems include hot zinc-coating and metal spraying with zinc or aluminium or an alloy of these. Hot zinc-coating shall not be used unless it has been taken into account in the safety level calculations of the structural analysis .

> The design may also contain a requirement concerning the painting of a hot zinc-coated surface.

Requirements and directives concerning other coating methods are shown in Sections 4.5.6.

4.5.3 Anti-corrosive painting

4.5.3.1 The quality requirements for the paint coating

The thickness of the paint film

The paint film shall meet the thickness requirements defined in the design and possibly made more specific in the surface treatment plan.

A maximum of 5% of the paint film measurement results may fall short of the nominal film thickness. The shortfall may be a maximum of 20% of the nominal value. If more than 40% of the measurement results in the measurement range fall short of the nominal value or if the shortfall of an individual measurement result is greater than 20%, the extent of the shortfall shall be determined, marked on the structure and the required improvements shall be made.

The local film thickness of the primer and total paint film (the average of 20 measurements taken in the measurement range) shall not exceed the nominal film thickness by more than 100%. Uniform areas in the measurement range where the thickness of the primer or total paint film is thicker than twice the nominal value shall nevertheless be investigated, marked on the structure and the coating shall if necessary be repaired by repainting.

> The uniform surface of, e.g., a flange, brace or web in the measurement area shall be regarded as a uniform area. The need to repair a coating shall be investigated by means of production control records, visual inspections, supplementary adhesive strength tests and if necessary film thickness measurements performed by cutting methods. In borderline cases and always whenever the production control records are inadequate, a reduction in value shall be made for the overshoot.

The thickness of the paint film shall be measured and reported separately from the primer and finished coating. Corresponding measurements and reporting are also to be made at the site for spots repaired by overlay painting in order to obtain adequate information on the film thickness at these points.

> Film thickness measurements after painting carried out at the workshop shall be utilized in the manufacturer's and erector's internal quality assurance.

Adhesion between the substrate and the layers of paint

The adhesion of the paint coating shall meet the requirements laid down for it.

The average of the results for cohesive fracture measured in a pull-off test performed in line with the Standard SFS-EN 24624 /38/ shall be $\geq$ 2 N/mm^2 for A, SEKK and SSKK systems, $\geq$ 3 N/mm^2 for SEE and SEEH systems and $\geq$ 4 N/mm^2 for SEEPUR and SSEPUR systems unless other requirements have been laid down for adhesion in connection with the approval of the painting system (cf. Appendix 2). Individual test results may fall short of the required average adhesive strength by a maximum of 50%. Adhesion to the substrate and between different layers shall be greater than the cohesion. If peeling in the pull-off test occurs from the substrate or

mainly from in between the layers (adhesive fracture) or if the average for the test results falls short of the required value by > 50% or an individual test result is < 25% of the requirement laid down for the average, the causes of the peeling and the extent of the fault shall be investigated and these areas of poor adhesion shall be repaired by repainting. A depreciation shall be charged for smaller undershoots. Three adhesion tests shall be performed per 1000 m^2 of ready coated structure and at least 6 tests shall be carried out.

Adhesion can also be measured from comparison plates made from the bridge material, which are surface treated at the same time and in the same way as the structure, and which accompany the structure during storage and transportation. There shall be at least one comparison plate in each transport segment.

When performing pull-off tests, the paint films shall be dry and hardened. Unless otherwise due to the properties of the type of paint, a drying time of one month in optimum conditions (temperature of about 23 °C and a relative humidity of about 50%) shall be considered adequate. If the conditions differ from the aforesaid, the paint manufacturer shall state the drying time to be applied in the tests.

Adhesion to the substrate may be undermined if the grains employed in shot-blasting are greasy or if there is grease in the blasting air. Rubber breaking off the blasting pipe may also undermine adhesion.

Adhesion between the layers of paint can be undermined if the structural parts have been painted at the workshop using primers and undercoats and they are soiled during transportation or at other treatment stages. Some types of paint (e.g., epoxy and polyurethane) dry in a manner which impedes adhesion if the painting interval becomes too long.

The adequacy of the adhesion can be determined by procedure tests. Pull-off tests performed at the place of manufacture at the start of the work can be used to ascertain whether adhesion to the substrate is adequate, before the entire structure is prepared and the layers of paint are spread. A test performed on the entire coating combination prior to the transfer of the structural parts to the place of erection provides a good basis for comparison when investigating, e.g., the effect of soiling caused by transportation and the success of cleaning work.

When employing comparison plates for acceptability tests, care shall be taken to ensure that the properties of their coating correspond as far as possible to the coating on the structure.

During storage and transportation, they shall be placed on the most stressed parts of the structure.

Comparison plates can also be used for other purposes relating to the quality control of the coating in the manner defined in the quality plan.

The quality and shade of the surface

The coating shall be of consistent quality with regard to its shade and other properties affecting its appearance.

The quality of the surface shall be evaluated visually. The surface in question shall be examined from a distance perpendicularly of at least 2 m. The lighting shall be the prevailing natural light or in special cases an artificial light shone directly at the surface.

Among the aspects to be evaluated are the imporosity of the surface, the absence of cracks, its gloss, shade and evenness. The last property is also to be checked by feeling the surface with the hand. When the gloss and evenness of the coating are being assessed, the possible unevenness of the substrate shall be taken into account.

Grade of rusting

The quality of the painted surfaces shall be assessed in line with the Standard SFS 3762 /39/. Five years after coating, the grade of rusting of the surface shall be Ri O.

4.5.3.2 Preparation

The quality grade of the preparation shall be 05 as defined in the Standard SFS 8145 /20/ unless the painting system calls for a superior grade. Deviations shall be taken into account when drawing up the surface treatment plan.

Preparation shall be executed in line with the Standard SFS 4957 /40/.

The surfaces to be painted shall be inspected prior to preparation or in the course of it. Unevenness and sharp edges detrimental to the coating shall be removed. If the grade of rusting is even partly D according to the Standard SFS-ISO 8501-1 /16/ the serviceability of the structures shall be investigated prior to coating.

The grade of preparation and the measures forming part of preparation shall be defined on the basis of the properties of the

surfaces to be treated and the requirements laid down by the coating system.

The grade of preparation shall be defined and assessed in line with the Standard SFS-ISO 8501-1 /16/.

No shop primer treatment shall be performed on the bridge materials unless it has been incorporated in the manufacturing or surface treatment plan. Surfaces treated with shop primer shall be prepared prior to final coating in the manner stipulated in the painting system (see the Standard SFS 8145 /20/).

Hot galvanized surfaces which shall be painted shall be prepared in line with the requirements of the painting system. Surfaces painted with zinc-rich paints and spray galvanized surfaces shall be prepared in the same manner as hot galvanized ones, if they are not to be painted with undercoat or sealing varnish, before zinc salts have time to form.

Zinc salts which have formed on a galvanized surface are generally to be removed by light shot-blasting, where the surface is blasted from a distance of about 0.5-1 m and at an angle of 45° with quartz sand with a grain size of 0.5-1.2 mm.

Zinc salts are formed in outdoor conditions in 2-4 hours and indoors within about a single work shift. A hot galvanized surface shall therefore be painted while it is still warm unless the zinc salts shall be removed.

When spreading new layers of paint, the surfaces to be painted shall be free from salt and other dirt. The cleanliness of the surface shall be checked by means of a test where the wet surface is wiped with a white paper cloth over a distance of 10 cm. In the test, only a slight amount of dirt may adhere to the cloth. Cleanliness shall be determined by cleaning the surface again and by repeating the wiping. The results from each inspection shall be compared with each other and with the test result obtained on a clean surface, and the cleanliness of the surface shall be assessed on the basis of the dirt which has adhered to the cloth.

Preparation has a decisive effect on the success of surface treatment. Section 4.5.3.1 contain references to some reasons relating to preparation which may result in poor adhesion. The cleanliness of the grains employed in shot-blasting and of the blasting air shall be examined prior to the start of the work and, if necessary, in the course of the work so that re-cleaning which has to be performed due to poor adhesion can be avoided.

In bolted and friction joints, oil or other lubricant shall be removed from the nuts and screw-heads with solvent prior to shot-blasting. In friction joints, caution shall be exercised with the friction surfaces. (Cf. 4.3.5.6)

If the surfaces to be painted have become soiled, they shall be washed before the next layer is spread. The surfaces shall be moistened with water and washed with a brush and if necessary with a detergent (e.g., alkaline) suitable for the purpose and the environment. After brushing, they shall be cleaned by pressurized washing at a pressure of 100-150 bars from a distance of about 0.5 metres and finally rinsed copiously with clean, fresh water.

4.5.3.3 Materials

The materials shall be delivered to the site in their original packaging, which shall be marked with all the markings required by laws, statutes and other official regulations. It shall be possible to relate the markings to the material manufacturer's quality control.

During storage, the products shall preserve their properties and they shall be unequivocally identifiable.

Storage shall be arranged in line with the manufacturer's instructions.

The different layers of the painting system shall differ distinctly in shade to facilitate monitoring. Thin layers of top coat can nevertheless be of the same shade.

4.5.3.4 Painting work

The painting work shall be executed in line with the requirements on conditions and work laid down in the design, the Standard SFS 4959 /41/ and the paint manufacturer's instructions.

The paint shall be spread in layers whose thickness is within the limits defined in the surface treatment plan. Spots which are difficult to paint such as cope holes, joints, corners, the edges of holes and the heads and threads of screws shall be painted at the start of each coat with a brush or roller and brush prior to the spray painting of the surfaces. The painting of the edges of the upper flange, the heads and threads of the screws and edges of the holes shall be improved with an extra layer of undercoat using a brush or a brush and a roller. All the layers shall be allowed to dry adequately before the next uniform coat is spread.

Gaps and the individual pores opening into the surface and permitted in the weld quality grade, which do not fill with paint, shall be puttied airtight with a putty suitable for the paint combination.

During the painting work, the relative humidity of the air shall conform to the requirements presented in the Standard SFS 4962 /42/ or in the paint product specification. The temperature of the surface to be painted shall be at least 3 °C above the condensation point.

The painting intervals stated by the paint manufacturer shall be complied with. The effects of the thickness of the film, temperature and other conditions on the drying times shall be taken into account. During drying and hardening, conditions enabling the properties of the film to develop favourably shall be maintained, if necessary using shielding.

The equipment used to spread the paint shall be suitable for the type of paint and the object being painted. It shall be used and serviced so as to remain in faultless condition throughout the work. A bridge shall not be painted using a roller apart from when spots which are difficult to paint are improved, and even then the painting shall be completed with a brush.

The erection weld points in the structural parts shall be left unpainted over a sufficiently wide area. The coats shall be stopped at what is known as the gauze limit at intervals of about 200 mm. Paint damaged by the heat of the weld shall be removed from the weld groove and its immediate vicinity as far as the intact paint surface.

Corrective painting shall be carried out in line with the Standard SFS 4961 /43/ and SILKO Directive 1.351 /44/.

4.5.3.5 Quality control and proof of acceptability

Production inspections and inspections of the completed paint surface shall be performed in line with the Standard SFS 4960 /45/ in the manner presented in greater detail in the quality plan.

Thickness measurements shall be performed in line with the Standard SFS-EN ISO 2178 /46/ using approved measuring devices. The meters shall be calibrated on a smooth steel plate. The scope of the measurements shall be in line with the Standard SFS 4962 /42/.

Adhesion measurements shall be carried out in line with the Standard SFS-EN 24624 /38/. The pulling disk shall have a diameter of 20 mm.

Acceptability shall be proved by comparing the results of the visual inspections and measurements with the requirements laid down.

> Prior to the spreading of the primer layer, a visual inspection shall be performed to determine the quality grade of the steelwork and surface cleanness. The surfaces are also to be checked visually after each layer of paint has been applied. The thickness of the paint film shall be checked layer by layer. Acceptability measurements shall be performed on the primer and entire paint film and on overlay painting jobs performed separately at the site. Data on conditions shall be checked at each work shift. The adhesion of the paint film is also to be measured in line with the quality plan. All inspections and measurements shall be entered in a log, which shall be attached to the acceptability report.

Requirements on corrective work are shown in 4.5.3.1

4.5.4 Hot zinc-coating

4.5.4.1 Quality requirements for the zinc coating

The thickness of the zinc layer shall meet the requirement presented in the plan in line with the Standard SFS 2765 /36/. The thickness requirement shall be grade B unless otherwise stated in the plan.

The requirements concerning the other properties of the coating shall be in conformity with the design and/or the Standard SFS 2765 /36/. The colour of surfaces left visible shall be even. The coating shall be so firmly fastened to its substrate that it does not break off when the structural parts are handled in the normal way or during the use of the structure.

Hot zinc-coated pieces shall not have detrimental excessive sagging, layers of slag or what is known as white rust. The functioning of the screws, nuts and other joint parts also places special requirements on the evenness of the zinc coating.

The temperature of the zinc shall not rise above 500 °C.

Hot zinc-coated structural parts shall not be straightened using heating.

4.5.4.2 Preparation

Preparation shall be performed in line with the Standard SFS 4957 /40/ where applicable. Scale, thick layers of rust, welding slag and spatter, oil, grease and other impurities and paint shall be removed from the pieces to be zinc-coated prior to pickling. The quality grade of the steelwork shall be 05 in line with the Standard SFS 8145 /20/. The steel pieces shall be metal-clean prior to being hot-galvanized.

The suitability of the pieces for hot galvanization shall be determined in the course of the preparation. The welds shall be tight, and the joints shall have no gaps in which pickling solution can remain nor closed parts or gaps in which gathering gas pressure may cause an explosion or a detrimental deformation. If necessary, holes shall be made in the structural parts at points agreed upon with the designer of the structures for the purposes of equalizing the pressure and flowing of the zinc.

4.5.4.3 Quality control and proof of acceptability

The galvanization plant is required to have an acceptable quality assurance procedure. Quality shall be controlled in accordance with it. The hot galvanizing worker shall draw up a work plan and quality plans for the galvanization unless the company has a quality system incorporating corresponding guidelines (cf. Sections 4.5.1.4 and 4.5.2.1).

The thickness of the zinc layer shall be measured in accordance with the Standard SFS-EN ISO 2178 /46/ or other acceptable standard.

A certificate concerning the hot galvanizing or the corresponding information in another form shall be issued for the purpose of proving acceptability. The certificate shall cover:

- preparation
- various stages of the pickling and the materials used
- temperature of the zinc and dipping time
- centrifugal treatment or other finishing work
- cooling method
- measurement results for the thickness of the zinc layer
- shape and measurement precision
- undershoots of the quality requirements and their location and repair method and
- treatment plant and name of the person responsible for quality.

4.5.5 Metal spraying

4.5.5.1 Quality requirements for the metal coating

The requirements concerning the coating (incl. the material, requirement on adhesion, thickness and after-treatment) shall be defined in the design. The coating shall have a consistent thickness and tightness. The requirements presented in Section 4.5.3.1 shall be followed where applicable.

4.5.5.2 Preparation

Preparation shall be performed in line with the Standard SFS 4957 /40/.

The surfaces to be sprayed shall be shot-blasted to produce a rough, metal-bright surface. The cleanliness grade shall be Sa3 as given in the Standard SFS-ISO 8501-1 /16/. The requirement for roughness is a rough 3-4 as evaluated in SFS-ISO 8503-2 /47/.

4.5.5.3 Spraying

Metal spraying shall be performed in line with SFS-EN 22063 /48/ and the surface treatment plan drawn up for the job (cf. Section 4.5.2.1).

Conditions for the spraying shall be arranged so that the coating meets the quality requirements laid down for it. The relative humidity of the air shall be less than 70% and the temperature of the air and the structure at least +5 °C.

4.5.5.4 After-treatment

Spray galvanized surfaces shall be sealed with varnish unless the surface treatment plan stipulates that they shall be painted. Varnishing and painting work shall be carried out using acceptable products.

> The sealing work shall be performed immediately after the spraying before dust, dirt or zinc salts have a chance to accumulate. Surfaces spray galvanized earlier shall be prepared in the manner required in Section 4.5.3.2.

The requirements on the after-treatment of a surface sprayed with aluminium shall be defined in the surface treatment plan unless they are presented in the design.

4.5.5.5 Quality control and proof of acceptability

Quality shall be controlled in line with the quality plans referred to in Section 4.5.1.4.

Acceptability shall be proved where applicable in line with Section 4.5.3.5.

4.5.6 Other methods

4.5.6.1 General

Other coating methods such as painting, hot zinc-coating and spray galvanizing can be considered if they have been appointed in the structural design or approved surface treatment plan or if they form part of the normal delivery state of building materials and accessories, or for the purpose of temporary protection.

4.5.6.2 Steel surfaces without coating

Those weatherproof structures made from steel which have not been appointed to be painted in the design shall be shot-blasted to a grade of Sa2.5 in line with SFS-ISO 8501-1 /16/ in order to ensure an even shade. Dirt and other marks caused by concrete casting and other building measures shall be removed from the surfaces of the structure.

Stainless and acid-resistant steels shall be welded using filler metals and the steel surfaces treated so that corrosion cannot take place. Weld seams shall be ground or pickled to ensure corrosion resistance. Preparation shall be performed in line with the Standard SFS 4957 /40/ where applicable.

4.5.6.3 Temporary protection methods

Temporary anti-corrosive methods intended for the construction period or planned for renewal or improvement at prescribed time periods during use can be employed on bridge structures with the consent of the client.

Temporary film-forming anti-corrosive agents include:

- emulsifying anti-rust agents
- anti-rust oils
- anti-rust fluids which form a waxy, varnish-like, oily or fatty film

- anti-rust greases and
- solid anti-rust agents spread when warm, such as vaselines, waxes and hot-melt plastics.

Spreading methods include:

- spraying
- trowelling
- dip application
- coating or brushing and
- internal filling.

Vapour phase inhibitors (VPI or VCI) are gaseous anti-corrosive agents. These are suitable for use in box-shaped structures. The gas evaporating from them binds itself to the metal surface and prevents corrosion. They can be spread onto the metal surface by powdering or spraying, or bags or belts containing inhibitors and placed inside the structures can be used.

Vapour phase inhibitors are manufactured for a variety of purposes. They can also have harmful properties. They may damage certain organic compounds such as paints and varnishes. Welded pieces to be protected shall not have any welding slag or, in particular, acidic impurities on them.

When using temporary anti-corrosive methods, the surface treatment plan shall be based on the directions for use obtained from the manufacturer of the agents. Their applicability, bearing servicing in mind, shall be demonstrated with test certificates or similar certificates of applicability and with accounts of the composition and method of effect of the agents.

The agents as well as work and quality assurance methods used shall be documented.

Detailed documentation of the agents and of the work and quality assurance methods is necessary for the planning and timing of service treatments.

4.5.6.4 Protecting the boxes

Boxes which cannot be painted using ordinary methods and which are not to be made airtight shall be treated by spraying the inside surfaces with temporary anti-corrosive agents suitable for the purpose or by using a vapour phase inhibitor.

The boxes to be protected shall be manufactured from shot-blasted parts (cleanliness grade at least Sa 2 in line with SFS-ISO 8501-1 /16/) so that the surfaces to be coated are left clean. The cleanliness grade depends on the products used for coating. It shall be defined in the surface treatment plan. Protection shall be performed before rusting has started.

The treatment holes shall be closed so that they can be opened for inspection and servicing. Apertures designed for ventilation shall not be closed or reduced in size.

In box-shaped structures, the anti-corrosive coating or other protection can be substituted or its durability and protective effect can be increased by drying arrangements which keep the relative humidity below the critical humidity (<40%), in which case corrosion does not occur or is very slow.

Boxes found to be hermetically tight (cf. 4.3.7.6) are not usually protected.

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4.7 APPENDICES

1 TERMS USED IN THE SURFACE TREATMENT SECTOR

2 PAINTING SYSTEMS FOR STEEL BRIDGES

TERMS USED IN THE SURFACE TREATMENT SECTOR

Corrosion, general terms

Corrosion
Corrosion is the physical and chemical reaction of a metal with its surroundings which causes changes in the properties of the metal and can often result in damage to the metal, its surroundings or technical system.
N.B. The reaction is normally an electrochemical one.

Corrosive substance
A substance which reacts with a metal when in contact with it.

Corrosive environment
An environment containing one or more corrosive substance.

Stress grade
A definition of the environmental conditions based on the corrosion stress they cause to steel and cast iron surfaces.

Corrosion system
A system consisting of one or more metal and all the parts of the environment which affect the corrosion. N.B. A coating, surface layer, supplementary electrode etc. can also be part of the environment.

Corrosion effect
A change in part of the corrosion system, which has led to corrosion.

Corrosion damage
Damage caused by corrosion which undermines the strength, durability or other properties of the structure.

Corrosion product
A reaction product formed as a result of corrosion.

Blister, scale
A solid layer of corrosion product formed on the surface of a metal at a high temperature.

Rust
Visible ferrous metal corrosion product consisting primarily of hydrated iron oxides.

Corrosion depth
The perpendicular distance between the bottom of the corrosion and the original surface of the metal.

Corrosion resistance
The capacity of the metal to resist corrosion in a specific corrosion system.

Corrosiveness
The capacity of the environment to cause corrosion in a specific corrosion system.

Critical humidity
The relative humidity of the air or other gaseous environment above which there occurs a steep rise in the corrosion rate of a specific metal.

Corrosion protection
Alteration to the corrosion system to reduce corrosion damage.

Temporary protection
Corrosion protection intended solely for a limited period.

Protective coating (corrosion protection coating)
A layer of material produced on the surface of a metal designed to protect the surface from corrosion.

Corrosion inhibitor
A chemical which reduces corrosion when present in suitable concentrations in the corrosion system without altering fundamentally the concentration of any other corrosive substance.
N.B. A corrosion inhibitor is usually effective in small concentrations. In commercial applications, filler metals are sometimes referred to as inhibitors.

Passivation
Reduction in the corrosion rate due to corrosion products forming on the metal surface.

General surface treatment terms

Surface treatment
A general term for treatment involving alteration to a surface.

Surface treatment system
The entity consisting of the preparation and coating of a surface and possible after-treatment of the coating.

Coating
The covering of a basic material with another substance or also the same substance.

Anti-corrosive painting
The purpose of the painting is to protect the metal substrate from the corrosive effect of the environment, i.e. corrosion, and to give the surface of the structure the desired appearance. Paint film belongs to the category of what are known as thin organic coatings. The films vary in thickness between 100 and 500 µm.

Painting system
The painting system consists of the preparation and the paints used to protect the surface.

Paint combination
The paint system is a film of paint of a specific thickness consisting of one or more defined layer(s) of paint. The paint combination can consist of just one paint which is applied on one or more occasion, but the combination normally includes several paints with complementary tasks.

Hot immersion
Covering a piece by immersing it in molten metal, zinc, aluminium, tin or lead.

Metal spraying
Spraying a molten metal usually by means of compressed air. Zinc, aluminium or copper are the metals most commonly employed for spraying.

Zinc coating
Coating with zinc by dipping into molten zinc, spraying or electrolytic precipitation from a solution containing zinc salts.

Hot galvanizing
Coating a piece by immersing it in molten zinc.

Spray galvanizing
Spraying zinc onto a cleaned steel surface in the form of small molten particles.

Aluminium spraying
Spraying aluminium when hot either as a pure metal or as a compound onto a cleaned steel surface.

Preparation
The cleaning or other preparation of a metal surface or coating for the purposes of coating or other treatment.

Grade of rusting of an uncoated substrate
The state of an unprotected steel substrate prior to the removal of rust, expressed by a code (A, B, C or D/SFS-ISO 8501-1:1988) defined by means of a colour photograph scale.

Grade of rusting of a painted substrate
A state expressed by a code defined by means of a colour photograph scale (RiO-Ri5/SFS 3762).

Grade of preparation
Defined by assessing the surface compared to a colour photograph scale following steel-wire brushing (St), flame-cleaning (FI) or shot-blasting (Sa) (SFS-ISO 8501-1:1988).

Surface roughness (surface profile)
The roughness of a steel surface after, e.g., shot-blasting. The surface profile of the shot-blasted surface is described using the words 'round' (round shot-blasting grain) or 'sharp' (edged shot-blasting grain). The surface profile is classified as 'fine', 'medium-rough' or 'rough'.

Alkaline wash
A cleaning method where substrates are washed with an alkaline detergent in order to remove organic impurities such as oils and fats.

Scraping
A rust removal method where rust is removed by hand using a metal scraper.

Steel-wire brushing
A rust removal method where rust is removed by brushing either with a hand tool or by machine.

Flame-cleaning
Cleaning a surface by means of an oxyacetylene gas flame and brushing.

Shot-blasting
Cleaning a surface either by hurling or blowing round or sharp blasting grain onto it.

Sand washing
Light shot-blasting in order to roughen the surface.

Pickling
A chemical metal preparation method where scale, rust, oxides and other layers preventing the coating from fastening are removed chemically.

Shop primer treatment
A measure forming part of preparation whereby the cleaned steel substrate is protected for the duration of transportation, storage and manufacture.

Adhesion treatments
Measures forming part of preparation whereby layers promoting paint adhesion and preventing corrosion underneath the paint film are formed on the clean metal substrate.

Coating

Painting
Spreading of paint with a brush, roller, spray or by immersion.

New painting
Painting of a structure during the manufacturing stage.

Overlay painting
Painting of a damaged part of a paint surface using an appropriate paint combination.

Re-painting
Painting where earlier paint is removed and the surface is completely re-painted.

Service painting
The overlay or re-painting of a previously painted paint surface that has been in use.

Corrective painting
The overlay and re-painting of painted surfaces that are in use and also the correction of damage to new paint surfaces caused by transportation and erection.

Gauzing
Spraying of paint as a thin adhesive layer that does not cover the entire surface.

Paint
A liquid or powdery product which when spread in an even film onto a metal surface dries out or reticulates into a solid film adhering to its substrate.

Pigment
A fine-grained anti-corrosive or coloured powder which does not dissolve into the paint vehicles.

Hardener
The part of a twin-component paint which when mixed with the plastic part reacts chemically with the molecules in the plastic part, binding them to each other.

Plastic part
The part of a twin-component paint which contains the actual vehicle.

Solute
An evaporating liquid used to dissolve the bonding agent of the paint and to make the paint suitable for spreading.

Diluent
A liquid used to reduce the viscosity of the paint and clean the painting equipment and which is not necessarily a paint solute.

The pot life of the paint
The time during which twin-component paints shall be applied following mixing (plastic part + hardener).

Dry film
The paint film when dry.

Wet film
The paint film immediately after the paint has been spread prior to the evaporation of the solvents from the film.

Re-painting dry
The drying stage of the paint film when the painted surface withstands the application of the next layer without crinkling or breaking off.

Dust-dry
The drying stage of the paint film when pellets poured onto the paint film can be brushed off without leaving marks on the film.

Dry for use
The drying stage of the paint film when the painted piece can be put to the intended use without damaging the paint film.

Touch dry
The paint film is touch dry when no damage occurs to it when touched.

Handling dry
The paint film withstands the mechanical stress caused by the handling and movement of the painted object.

Gloss
The paint surface's varying capacity to reflect light falling upon it. The relative gloss of a paint film is defined at angles of 20 , 60 and 85 . The gloss of a paint film can be described using the words gloss, semi-gloss, semi-matt and matt.

Chalking
Normally the partial destruction of the bonding agent in the surface of the paint film caused by the weather, a loose staining layer of pigment being left in the paint surface.

Cracking
The cracking of the paint surface in the form of a surface crack, deep crack or through crack.

Peeling
The loosening of a layer of paint from the previous layer of paint.

Bubbling
The rising of the paint film from its substrate in the form of blisters.

Swimming
The creeping of the dyes in the paint film.

Bleeding
The change in the shade of the paint film due to the effect of colouring agent released from the substrate.

Synthetic
An artificial rather than natural product.

Temporary protective coating
Protection intended to prevent corrosion for a shorter or longer period, characterised by the fact that the surface of the protected object is kept in its original state or that it can readily be restored to its original state, e.g., by removing the protecting material.

Putty
A mass used for filling holes, cavities or seams which adheres to its substrate, does not shrink or age and can be painted over.

Terms and definitions relating to measurements

Relative humidity
The ratio of the quantity of water contained in the air to the quantity of water contained in air saturated with vapour at the same temperature.

Condensation point
The temperature at which the relative humidity of the air is 100%.

Coating thickness
The thickness of the paint film either when wet or dry.

Nominal coating thickness
The thickness of a dry paint film stipulated in the plan or standards. (The requirement has been met when a maximum of 5% of the measurement values in a coating thickness measurement fall short of the requirement by a maximum of 20%.)

Visible surface
The part of the surface which is fundamental to the appearance or use of the piece. (For example, the flanges, webs, braces, transverse and horizontal braces of the steel structure of a bridge.)

Measurement range
The part of the visible surface from where the agreed number of separate measurements are performed. (Approx. 100 m^2 in bridges.)

Measurement point
The point in the measurement range from where an individual coating thickness measurement is performed.

Individual coating thickness
The average value of three measurement readings taken from a measurement point.

Minimum coating thickness
The lowest individual coating thickness in the measurement range obtained during measurement.

Maximum coating thickness
The greatest individual coating thickness in the measurement range obtained during measurement.

Average coating thickness
The individual average value for coating thickness values in the measurement range.

Calibration standard
The film or coated piece used for calibrating coating thickness meters.

Surface profile
The micro-roughness of the surface, usually expressed as the ratio of the height of the principal peaks to the principal valleys.

Adhesion
The capacity of the coating to stick by adhesive forces to its substrate, itself or to another coating. Another aspect of adhesion measurement is the internal strength, i.e. cohesion, of the coating.

PAINTING SYSTEMS FOR STEEL BRIDGES

1. RECOMMENDED PAINTING SYSTEMS ACCORDING TO PLACE OF USE

Object to be painted	Painting system	
New painting		
- New steel bridges	TIEL 4.12	SEEPUR 310/5-FeSa2½
- Bearings, expansion joints	TEIL 4.8	SEEPUR 240/4-FeSa2½ or equivalent
- Railing when hot-dip galvanizing cannot be applied	TIEL 3.4	SEEPUR 180/4-FeSa2½
- Hot-dip galvanized surfaces (also railings)		EPUR 120/2-FeZnSa1 1)
- Interior of box girders and pylons, subsurface structures	TIEL 4.3	ET 250/2-FeSa2
Re-painting		
- Steel structures of rust grade A-C and when old painting may be totally removed to cleanliness grade Sa2½	TIEL 4.12	SEEPUR 310/5-FeSa2½
- Steel structures of rust grade C and when old painting or rust may not be totally removed, or grade D	TIEL 4.9 or TIEL 3.1	EPUR 250/3-FeSa2 A 160/4-FeSa2 2)
Overlay painting		
- Primarily old painting		

1) Light shot-blasting if the hot zinc-coating is over 4 h old. Epoxy paint same as with system TIEL 3.4. In structures which will be subsurface structures and at the root of a railing post TIEL 4.3, (ET 250/2-FeSa 1).

2) Alkyd paints lead-free. They cannot withstand the alkalinity of concrete nor the salt and creosote impregnation substances in wooden structures.

2. APPROVED PAINTING SYSTEMS ACCORDING TO STRESS GRADE

2.1 Painting systems suitable for stress grades M2 and M3 (Primarily recommended systems shown in bold letters, see page 1)

Painting system (SFS 4962)	Type of paint	Nominal thickness of film µm
TIEL 3.1 (A 160/4-FeSa2 or FeSt2 for minor correction work)	**Alkyd primer**	**2 x 40**
	Alkyd top coat	**2 x 40**
		160
TIEL 3.2 (SEKK 200/4-FeSa2½	Zinc epoxy primer, twin composite	40
	Chlorinated rubber primer	2 x 60
	Chlorinated rubber top coat	40
		200
TIEL 3.3 (SSKK 180/4-FeSa2½)	Zinc silicate primer, twin composite	60
	Etching primer (epoxy-chlorinated rubber or vinyl paint)	20
	Chlorinated rubber primer	60
	Chlorinated rubber top coat	40
		180
TIEL 3.4 (SEEPUR 180/4 FeSa2½)	**Zinc epoxy primer, twin composite**	**40**
	Epoxy primer, twin composite	**2 x 50**
Suitable also for railing	**Polyurethane top coat, twin composite**	**40**
		180

Certain water-dilutable painting systems have also been approved.

2.2 Painting systems suitable for stress grade M4

Painting system TIEL/NRO (SFS 4962)	Type of paint	Nominal thickness of film µm
TIEL 4.1 (SEE 200/3-FeSa2½)	Zinc epoxy primer, twin composite.	40
	Epoxy primer, twin composite	80
	Epoxy top coat, twin composite	80
		200
TIEL 4.2 (SEEH 200/3-FeSa2½)	Zinc epoxy primer, twin composite	40
	Resin-modified epoxy paint, twin composite	2 x 40
		200
TIEL 4.3 (ET 250/2-FeSa2½)	**Epoxy-pitch or epoxy-tar paint, twin composite**	**2 x 125**
		250
TIEL 4.8 (SEEPUR 240/4 FeSa2½)	**Zinc epoxy primer, twin composite**	**40**
	Iron mica-pigmented epoxy undercoat, twin composite	**2 x 75**
	Polyurethane top coat twin composite,	**50**
		240
TIEL 4.9 (EPUR 250/30 FeSa2½) *)	**Iron mica- and/or aluminium-pigmented epoxy primer, twin composite**	**100**
	Iron mica- and/or aluminium-pigmented epoxy undercoat, twin composite	**100**
	Polyurethane top coat, twin composite	**50**
		250
TIEL 4.12 SEEPUR 310/5-FeSa2½)	**Zinc epoxy primer, twin composite**	**40**
	Iron mica-pigmented, epoxy undercoat, twin composite	**2 x 85**
	Polyurethane top coat, twin composite	**2 x 50**
		310

*) If repair painting is performed as re-painting, the Sa2 cleanliness grade is also adequate.