INTERNATIONAL STANDARD

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Steel for the reinforcement of concrete — Headed bars —

Part 1: Requirements

Aciers pour l'armature du béton — Barres avec platine d'ancrage —

Partie 1: Exigences

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15698-1 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 16, *Steels for the reinforcement and prestressing of concrete*.

ISO 15698 consists of the following parts, under the general title *Steels for the reinforcement of concrete — Headed bars*:

— *Part 1: Requirements*

— *Part 2: Test methods*

Introduction

Reinforcing bars with end anchorages have been used for many years, in particular in civil engineering structures, such as marine structures (e.g. offshore platforms), bridges, structures for nuclear power plants, etc. The properties and the requirements for the anchorage products have normally been specified for each separate project. The properties have often been tested individually, due to the lack of standards for the products. Some countries have, however, developed national standards or recommendations for requirements and test methods for such products, e.g. USA.

As a result of the discussions carried out in ISO/TC 17/SC 16, it has been agreed to name these anchorage products “headed bars” as a general term for various types of heads at the bar end.

The advantage of headed bars, as compared to ordinary bond anchored bars, is that the bar can be loaded up to the ultimate capacity of the bar at its end in a very stiff fixing without slip at the end of the bar. In some cases, the head at the bar end is designed such that the end anchorage is combined with a bond anchorage to achieve the ultimate capacity of the bar. The bond length will then be substantially reduced as compared to the bond length without an end anchorage.

The goal of this part of ISO 15698 is to specify requirements to the product in a neutral way, i.e. not to refer to specific types and geometries of heads, and to specify test methods such that the variety of headed bars currently on the market are covered, as well as new types that might be developed in the future.

Steel for the reinforcement of concrete — Headed bars —

Part 1: Requirements

1 Scope

This part of ISO 15698 specifies requirements for headed steel bars to be used as reinforcement of concrete structures.

This part of ISO 15698 is a product standard and not an application standard. It is intended to cover a large variety of products and also to support the development of new products.

This part of ISO 15698 specifies requirements for headed reinforcing bars with heads made of steel. Heads or head-bar connections made using other materials, including metal-filled sleeves, are not covered by this part of ISO 15698.

End anchorages consisting of a steel bar or other steel component positioned orthogonally at the end(s) of a bar and welded on-site to the bar are outside the scope of this part of ISO 15698.

This part of ISO 15698 is intended to cover products which are manufactured in a continuous production that allows the products to be tested in accordance with a defined testing regime.

Requirements and testing for headed bars under impact loading are outside the scope of this part of ISO 15698.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 630-2, *Structural steels — Part 2: Technical delivery conditions for structural steels for general purposes*

ISO 4950-2, *High yield strength flat steel products — Part 2: Products supplied in the normalized or controlled rolled condition*

ISO 4950-3, *High yield strength flat steel products — Part 3: Products supplied in the heat-treated (quenched + tempered) condition*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 6935-1, *Steel for the reinforcement of concrete — Part 1: Plain bars*

ISO 6935-2, *Steel for the reinforcement of concrete — Part 2: Ribbed bars*

ISO 15698-2, *Steel for the reinforcement of concrete — Headed bars — Part 2: Test methods*

ISO 16020, *Steel for the reinforcement and prestressing of concrete — Vocabulary*

ISO 17660-1, *Welding of reinforcing steel — Part 1: Load-bearing welded joints*

ISO 22965-2, *Concrete — Part 2: Specification of constituent materials, production of concrete and compliance of concrete*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16020 and the following apply.

3.1
head
separate piece of steel of any shape firmly attached to the end of a bar or a protuberance of the bar itself at the end, used to anchor a steel reinforcing bar in concrete

3.2
headed bar
steel reinforcing bar that has steel head(s) on one or both ends with the purpose of anchoring the bar in concrete

3.2.1
welded headed bar
headed bar that has the head(s) welded onto the bar

3.2.2
forged headed bar
headed bar that has the head(s) integrally forged from the bar

3.2.3
threaded headed bar
headed bar that has the head(s) attached utilising tapered or straight threads internal to the head or by a separate internally threaded nut or sleeve fixing the head to the threaded bar end(s)

3.2.4
swaged or extruded headed bar
headed bar with the head(s) attached to the bar by swaging or extruding the head directly onto the bar or by using a sleeve

3.2.5
Shear-bolted sleeve-headed bar
headed bar with sleeve(s) attached to the bar by a series of shear bolts which indent into the surface of the reinforcing bar and push the bar against the opposite internal surface of the sleeve

3.3
loose head
head which is not permanently attached to the bar by the head manufacturer, but is attached on-site or in a reinforcement workshop

3.4
head bearing area
area of the head projected onto a plane orthogonal to the longitudinal axis of the bar minus the bar cross-sectional area and minus any area of the head that extends more than one bar diameter from its main face, representing the contact surface between head and concrete where the bar tensile force is transferred to the concrete by compression stress

3.5
head anchorage capacity
maximum force that can be transferred from the head of the bar to the surrounding concrete

3.6
headed bar series
headed bars of identical shape and with the ratio between the head bearing area and the bar cross-sectional area within specified maximum and minimum values, produced from identical materials, by the same production method, but with different nominal bar diameters

3.7
qualification test
test designed to verify the anchorage capacity (category) of a headed bar series

3.8
manufacturer
organization which manufactures headed bars for concrete reinforcement

3.9
batch of headed bars
quantity of headed reinforcing bars that is represented by the specimens which have been tested

3.10
affected zone
portion of the reinforcing bar where any properties of the bar, including the physical, metallurgical or material characteristics, have been altered by fabrication of the headed bar, such as the heat-affected zone for forged and welded headed bars, the location of threads for threaded headed bars, or the location of a sleeve

4 Symbols

For the purposes of this document, the symbols in Table 1 apply.

Table 1 — Symbols

Symbol	Unit	Designation
$D_{H,max}$	mm	Major dimension of head (see 5.2)
$D_{H,min}$	mm	Minor dimension of head (see 5.2)
α_A	-	Aspect ratio between the minor and the major head dimension (see 5.2)
d	mm	Nominal diameter of the reinforcing bar
$R_{eH,spec}$	MPa	Specified characteristic (or nominal) yield strength value of the reinforcing bar. For reinforcement steel without a distinct yield plateau, the characteristic $R_{p0,2,spec}$ may be used
$R_{p0,2,spec}$	MPa	Specified characteristic (or nominal) 0,2 % proof stress of the reinforcing bar
$R_{p0,2,act}$	MPa	Actual 0,2 % proof stress of the reinforcing bar
$R_{m,spec}$	MPa	Specified characteristic (or nominal) tensile strength value of the reinforcing bar
$R_{m,act}$	MPa	Actual tensile strength value of the reinforcing bar to be tested
$(R_m/R_{eH})_{spec}$	-	Specified characteristic tensile strength to yield strength ratio
A_{gt}	%	Percentage total elongation of the reinforcing bar at maximum force
A_5	%	Percentage total elongation after fracture by a gauge length of $5d$
A_{10}	%	Percentage total elongation after fracture by a gauge length of $10d$
$A_{B,nom}$	mm^2	Nominal cross-sectional area of the reinforcing bar
$A_{B,act}$	mm^2	Actual cross-sectional area of the reinforcing bar
F_b	N	The portion of the reinforcing bar's force intended to be anchored by bond (see 7.2.2, Category B1)
$2\sigma_a$	MPa	Stress range for high-cycle elastic fatigue loading test
σ_{max}	MPa	Maximum stress in axial load fatigue test
$\varepsilon_{y,act}$	%	Strain at actual yield strength of the reinforcing bar. For reinforcement steel without a distinct yield plateau the strain at actual 0,2 % proof stress may be used, taken as $\varepsilon_{p0,2,act} = R_{p0,2,act}/E+2\times10^{-3}$
δ	mm	Anchor head movement
1 MPa = 1 N/mm^2		

5 Requirements

5.1 Materials

5.1.1 Steel for reinforcing bars

Steel reinforcing bars shall comply with ISO 6935-1 and ISO 6935-2 or any other product standard for steel reinforcing bars as specified by the purchaser.

For welded headed bars, the steel reinforcing bars, in accordance with ISO 6935-1 and ISO 6935-2, shall be of the weldable (W) type. Other types of weldable steel reinforcing bars shall be permitted if specified and agreed upon by the purchaser and manufacturer and only if the suitability of the head and bar materials for the welding process specified is demonstrated by a welding procedure qualification according to ISO 17660-1, unless otherwise agreed upon by the purchaser and manufacturer.

For forged bars, threaded headed bars and shear-bolted sleeve-headed bars, any type of reinforcing bars may be used.

For swaged or extruded headed bars, any ribbed type of reinforcing bars may be used.

5.1.2 Steel for heads

Heads shall be forged, machined or cut from casts of steel identified by a mill certificate. The chemical composition of heads for welded headed bars shall comply with a standard for weldable structural steel, such as quality C and D of ISO 630-2 or quality DD and E of ISO 4950. The impact test energy value shall be minimum 27 J at 0 °C. For headed bars where the danger of lamellar tearing of the head plate material exists, laminations and lamellar tearing in the steel plate shall be avoided by the choice of a suitable parent material. The steel plate shall be controlled by testing or inspection, for example in accordance with EN 10164. The resistance to lamellar tearing shall be specified in the test report, see ISO 15698-2.

NOTE Steels of class Z15, Z25 or Z35 according to EN 10164 are examples of steels resistant to lamellar tearing.

The welding shall be carried out according to ISO 17660-1, unless otherwise agreed upon by the purchaser and manufacturer.

5.2 Head shape and dimensions

The head may have any shape.

The size of the concrete contact area is described by the major dimension $D_{H,max}$, see Figure 1, and the aspect ratio which is the ratio between the minor and the major dimension: $\alpha_A = D_{H,min}/D_{H,max} \leq 1$.

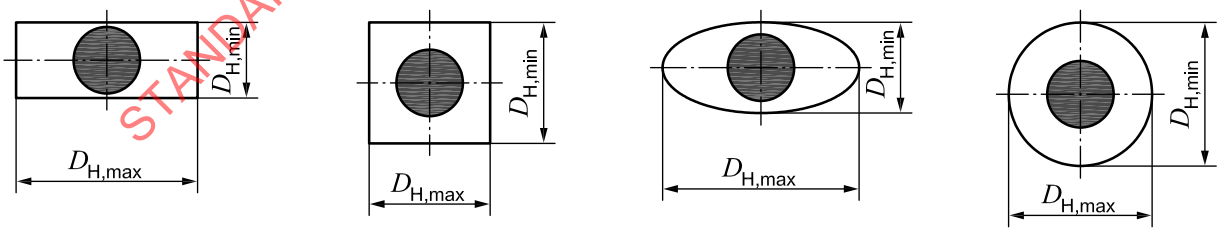

Figure 1 — Definition of head geometry

The head thickness may be constant or variable as indicated in Figure 2. The thickness variation along the head's main axis is determined by the thickness profile, i.e., the section given by the plane spanned by the head's main axis and the bar axis.

5.3 Head bearing area

If part of the head bearing area is not in the same plane as the bearing area of the head itself, this shall be stated in the test report.

In some cases, such as when the head is attached to the bar using a sleeve, some of the bearing area will be at the sleeve-to-bar intersection, at some distance from the head itself. This may be of importance in the structural design and should, thus, be stated in the test report.

The suitability of the head bearing area and head thickness shall be verified by qualification tests according to ISO 15698-2.

5.4 Anchorage capacity

The anchorage capacity is specified for three categories of loading:

— Category B: Anchorage capacity under static loading (Basic)

— Category F: Anchorage capacity under high-cycle elastic fatigue loading (Fatigue)

— Category S: Anchorage capacity under low-cycle elastic-plastic loading (Seismic)

NOTE 1 Categories B and F are subdivided into subcategories (B1, B2 and B3, F1 and F2), see 7.2.2, 7.2.3 and Annex A.

The anchorage capacity shall be verified by testing according to ISO 15698-2 for the relevant category. Categories F and S shall be tested for bars intended for use in structural members exposed to fatigue and earthquake, respectively, or on the purchaser's request.

NOTE 2 The anchorage capacity of the head depends on the strength of the head-to-bar connection, on the compressive strength of the concrete and on the net head bearing area. For ribbed bars, the bond between steel and concrete may contribute to the anchorage capacity, but this is only taken into account in Category B1 (see 7.2.2). The strength of the head-to-bar connection may also be influenced by the production method of the reinforcing bars, such as hot–rolled or hot–rolled and quenched and self-tempered (QST).

NOTE 3 The concrete under the head is locally confined by the surrounding concrete. The qualification test set-up represents the confinement by the surrounding concrete and reinforcement in a simplified way. Concrete design aspects like embedment depth, concrete cover, spacing and confinement details are, thus, outside the scope of this standard.

NOTE 4 This standard does not cover safety elements introduced by, for example, the application of partial factors for capacity (e.g. γ_m-values) to be applied to the tested values. The safety elements are referred to provisions in national design standards.

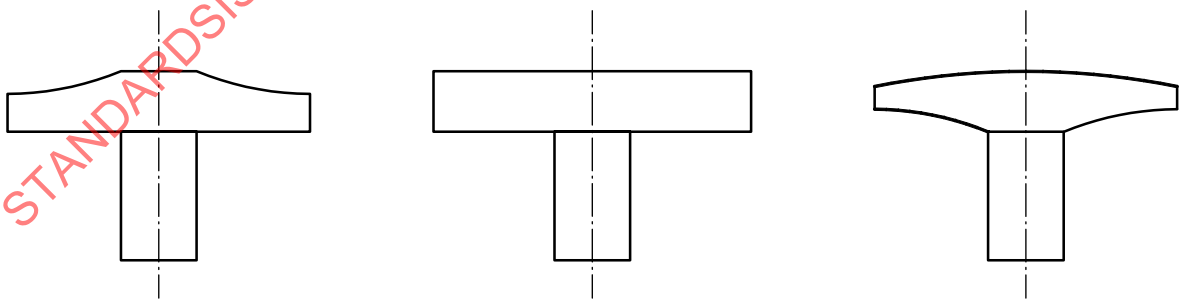

Figure 2 — Examples of head thickness variation

5.5 Tolerances

Geometric tolerances for the head shall be within the limits given in Table 2. Tolerances for the reinforcing bars and for material properties for the head are given in the product standards.

Table 2 — Geometric tolerances

Geometric characteristic	Maximum acceptable deviation
Major head dimension $D_{H,max}$	± 5 %
Aspect ratio α_A	± 10 %
Thickness profile	± 5 %

6 Classification of headed bars

6.1 General

Headed bars are distinguished by the characteristics of three main elements:

— Head

— Bar

— Method of attachment

The main characteristics of these three elements are:

Head:

— Major head dimension $D_{H,max}$ in mm (see 5.2)

— Aspect ratio $\alpha_A = D_{H,min}/D_{H,max} \leq 1$ (see 5.2)

— Thickness profile (see 6.2)

— Nominal yield strength $R_{eH,spec}$

— Geometry of head-to-bar transition

— Method of production (cut from plate material, cut from bar material, forged or cast)

Bar:

— Nominal diameter d

— Nominal yield strength $R_{eH,spec}$

— Ductility class (according to ISO 6935-1 and ISO 6935-2)

— Relative rib area (relevant for Category B1 only)

— Method of production (micro-alloyed, quenched and self-tempered)

Method of attachment:

— Forging

— Welding

— Threading

— Swaging

— Shear bolts

6.2 Series of headed bars

A headed bar may represent any combination of the characteristics listed in 6.1. Headed bars may be divided into series representing a specific combination of the characteristics and where only the bar diameter and the head size vary. The head size shall be characterized by the major head dimension $D_{H,max}$. Within one series, the headed bars shall be classified according to the nominal bar diameter.

Within one series, the nominal values of the characteristics shall be within the limits given in Table 3.

For heads with variable thickness, the thickness profile shall be similar for all head sizes within a series in the sense that the deviation between the normalized profiles ($t/D_{H,max}$) shall not, at any point, be more than the limits given in Table 3.

Table 3 — Accepted deviations of nominal values of characteristics within one series

Head characteristics	
Major head dimension $D_{H,max}$	± 5 %
Aspect ratio α_A	± 5 %
Thickness profile	± 5 %
Material strength	Stay within one grade
Bar characteristics	
The bars in one series shall be limited to one steel grade according to ISO 6935-1 and ISO 6935-2 or to one steel class as specified in national standards. For Category B1, the relative rib area in one series shall be larger than or equal to the relative rib area of the test specimens.	

7 Qualification testing

7.1 General

Unless otherwise agreed with the purchaser, qualification testing shall be performed:

a) at the commencement of the production of a new or modified product;

b) at the commencement of a new or modified method of production if this may affect the characteristics specified in this part of ISO 15698.

The purpose of the qualification testing is to verify the load transfer from the reinforcing bar to the head and into the concrete.

NOTE 1 The test set-up is designed to subject the headed bar to simplified but realistic conditions, in order to avoid detailed and specific requirements for the head geometry and for the connection between the head and the bar. The intention is to enable the development of new products that can meet the requirements of this part of ISO 15698 for the behaviour of headed bars.

For each series of headed bars and for each category, a number of qualification tests, as specified in 7.2 and 7.3, shall be performed. Each test shall consist of three specimens.

The qualification testing shall comprise two series of tests:

— Load transfer test: A test with the head embedded in concrete for the verification of the head geometry and its capacity for load transfer to the concrete. The various tests are related to categories according to the intended application of the headed bar (see 5.4). The qualification testing shall verify to which category the actual headed bar system belongs. Under certain conditions, the testing in concrete may be replaced by special tests in air for Categories B2, B3, F1 and F2, see 7.2.1.

— Robustness tests of head-to-bar connection: Tests in air with the purpose of testing the robustness of the bar-to-head connection, e.g., with respect to skew loading.

NOTE 2 Skew loading may be introduced in a structural concrete member, e.g. if the head is bearing on a transverse bar on one side, generating a stiffer support than the surrounding concrete on the other side.

The manufacturer shall specify the concrete strength and type of concrete (e.g. normal-density concrete, lightweight aggregate concrete or fibre-reinforced concrete) of the test specimen. The chosen concrete strength shall represent the minimum concrete strength in which the head can be used to achieve its ultimate anchorage capacity.

NOTE 3 A concrete of at least grade B30 (ISO 22965-2) is recommended. Lower concrete grades may be permitted according to national standards and regulations.

The qualification test is valid for the concrete grade of the test specimen and all higher grades. However, for lightweight aggregate concrete, very high strength concrete, fibre-reinforced concrete and other special types of concrete, additional qualification tests should be considered. In this context, concrete of higher grade than B90 (ISO 22695-2) should be considered “very high strength” concrete.

NOTE 4 The limit for “very high strength concrete” may be specified by the purchaser. Very few tests on headed bars with concrete above Grade B60 have been executed.

The tests shall be performed according to ISO 15698-2.

The failure mode and load shall be clearly stated in the test report.

The manufacturer shall furnish documentation to the purchaser, in the form of independent certification or test reports that confirms the suitability of head dimensions and shape for the intended application.

7.2 Load transfer tests

7.2.1 General

For each series of headed bars, a representative number of bar diameters shall be tested. If a series consists of two bar diameters, both diameters shall be tested. If the series consists of more than two diameters, the smallest and the largest diameter shall be tested. Intermediate diameter qualification shall be tested in steps of not more than 10 mm.

For bars within one series and within a step of not more than 10 mm, the qualification testing may be omitted.

For Categories B2, B3, F1 and F2, the load transfer tests, both tensile and fatigue, may be performed in air according to ISO 15698-2 if the following conditions are fulfilled:

1) Net head bearing area of at least nine times the bar cross-section;
2) Entire head bearing area in one plane, perpendicular to the bar axis. It shall be permissible that 10 % of the bearing area be located within one bar diameter from the main bearing plane;
3) The maximum specified yield strength of the bar is 500 MPa;
4) The headed bar is intended for use in concrete of at least Grade B30 (ISO 22965-2);
5) The headed bar is intended for use in concrete of not more than Grade B60 (ISO 22965-2);
6) The head support by testing in air is according to the special provisions given in ISO 15698-2.

NOTE 1 The static load transfer from head to concrete of headed bars fulfilling the above conditions is considered to be sufficiently documented by tests similar to those in this part of ISO 15698 and by extensive experimental research during past years.

NOTE 2 In some cases, information about the anchorage stiffness may be required. If so, tests need to be performed in concrete. The anchorage stiffness is given by the load-deformation curves.

NOTE 3 The head bending stresses transverse to the bar axis may have a significant effect on the capacity of the bar-to-head connection. The provisions for head support given in ISO 15698-2 ensure approximately the same bending stresses in the head, perpendicular to the bar axis, when testing in air (item 6) as for a head which is embedded in concrete.

If the conditions 1 to 6 are not fulfilled, the load transfer tests for Categories B2, B3, F1 and F2 shall be performed with the specimen embedded in concrete.

Categories B1 and S shall always be tested in concrete.

Testing in concrete is made to verify the head bearing stresses and the anchorage stiffness, as well as the head-to-bar load transfer.

The requirements in 7.2.2 and 7.2.3 are valid for both testing in concrete and in air. For tests with the specimen in air, only relevant requirements apply.

7.2.2 Anchorage capacity under static loading — Category B

This test is the basic test, which is obligatory for all types of headed bars. Three subcategories of headed bars fall under Category B, where the subcategory is related to the capacity of the head to achieve a portion of the bar's specified or actual yield strength or specified or actual tensile strength, respectively. The requirements for each category are as follows.

Category B1: Together with the bond force of a specified portion of the bar (F_b) the head shall be capable of anchoring the minimum specified tensile strength of the reinforcing bar, $R_{eH,spec} \cdot (R_m/R_{eH})_{spec} \cdot A_{B,nom}$. For this category, only ribbed bars are acceptable.

In cases where only an $R_{m,spec}$ value is specified in the reinforcing bar standard, the force to be anchored shall at least be $R_{m,spec} \cdot A_{B,nom}$.

The minimum A_{gt} measured in the reinforcing bar outside the bond length of the bar shall be at least 0,7 times the specified characteristic A_{gt} value of the reinforcing bar. Where A_{gt} is not specified for the reinforcing bars, a minimum value of 3 % shall be reached in the bar outside bond length before failure of the test piece.

The value of F_b shall be determined by the producer, and the associated development length to be used in the tests shall be calculated for the relevant reinforcement steel and concrete strength according to an appropriate concrete design standard. The qualification test is valid for all rib areas larger than or equal to the rib area of the test specimen.

Category B2: Without any bond force, the head shall be capable of anchoring the minimum specified tensile strength of the reinforcing bar, $R_{eH,spec} \cdot (R_m/R_{eH})_{spec} \cdot A_{B,nom}$.

In cases where only an $R_{m,spec}$ value is specified in the reinforcing bar standard, the force to be anchored shall be at least $R_{m,spec} \cdot A_{B,nom}$.

The minimum A_{gt} measured in the reinforcing bar outside the bar-to-head connection shall be at least 0,7 times the specified characteristic A_{gt} value of the reinforcing bar. Where A_{gt} is not specified for the reinforcing bars, a minimum value of 3 % shall be reached in the bar outside bar-to-head connection before failure of the test piece.

Category B3: Without any bond force, the head shall be capable of anchoring a force corresponding to the actual tensile strength of the headed reinforcing bar that is tested, $R_{m,act} \cdot A_{B,nom}$. The requirement is considered to be fulfilled if at least one of the following occurs:

a) the failure occurs outside the affected zone;

b) the minimum specified elongation required for the bar is reached;

c) at least 0,95 $R_{m,act}$ is reached by comparing with the actual tensile strength of an adjacent non-headed specimen from the same batch or with the retested bar of the broken test specimen, if possible.

Test specimens for this category shall be made of specially selected reinforcing steel from the upper 50 % of the tensile strength range. The selection may be based on mill certificates.

NOTE 1 The lower head anchorage capacity in Category B1 may be due to reduced head dimensions or lower strength in the head-to-bar connection.

NOTE 2 The A_{gt} value specified for the reinforcing bars is normally a characteristic value. Since it is not practical to specify a characteristic A_{gt} value for qualification testing, the value should be considered as a minimum value.

NOTE 3 The demonstration of a bar break for Category B3 implies that a load that is significantly larger than the minimum tensile force is transferred by the head, and that a strain larger than minimum A_{gt} (or A_5 or A_{10}) is attained and thus that maximum ductility of the reinforcing bar is ensured.

The test requirement for load transfer in concrete shall be considered fulfilled for B1, B2 and B3 if the movement δ of the anchor head (see ISO 15698-2) is less than 0,20 mm, or if the specimen is cut through and no indication of concrete crushing is observed.

7.2.3 Anchorage capacity under high-cycle elastic fatigue loading — Category F

Two categories for headed bars subject to high-cycle elastic fatigue loading are defined. The requirements to each category are as follows.

Category F1: One or more of the specimens may fail in the affected zone. The number of cycles to failure shall be recorded.

Category F2: All specimens shall fail in the parent bar outside the affected zone. The test may be terminated when the requirement for the parent bar is fulfilled.

The test requirement for load transfer in concrete shall be considered fulfilled for both F1 and F2 if the movement δ of the anchor head (see ISO 15698-2) is less than 0,20 mm, or if the specimen is cut through and no indication of concrete crushing is observed.

The test report shall include plots showing the number of stress cycles to failure at, at least, two different stress ranges together with the S-N-diagram of the parent reinforcing bar, if available.

The specified number(s) of stress cycles, stress range(s) $2\sigma_a$ and maximum stress(es) σ_{max} shall be in accordance with relevant standards for the reinforcing bar used or as agreed between the purchaser and manufacturer at the time of enquiry or order. For each series of headed bars, a minimum of three specimens shall be tested for each stress range.

7.2.4 Anchorage capacity under low-cycle elastic-plastic loading — Category S

There is one category for headed bars subject to low-cycle elastic-plastic loading. The requirement is:

Category S: The head-to-bar connection sustains stages 1 through 3 of the specified loading programme without failure.

Loading programme:

— Stage 1: 20 load cycles between 0,05 $R_{eH,spec}$ and 0,95 $R_{eH,spec}$

— Stage 2: 4 load cycles between 0,05 $R_{eH,spec}$ and $2\varepsilon_{y,act}$

— Stage 3: 4 load cycles between 0,05 $Re_{H,spec}$ and $5\varepsilon_{y,act}$

— Stage 4: Loading to failure

For each test, three specimens shall be tested. The tests shall be carried out in accordance with ISO 15698-2.

The position of the failure, the failure mode and failure load shall be recorded and included in the test report.

NOTE Testing with reverse elastic-plastic loading is not considered relevant as the failure mode in compression will be related to the concrete and is a concrete design issue.

If the requirement for Category B is fulfilled during the Category S tests, the Category B tests may be omitted, and the headed bar may be classified according to the requirements of B1, B2 or B3, respectively.

7.3 Robustness tests of head-to-bar connection

7.3.1 General

The robustness of the head-to-bar connection shall be verified by the wedge tensile test or the bend test.

NOTE For connections other than welded or forged, the bend test is not applicable. Therefore the wedge tensile test is used for these products.

Robustness tests of head-to-bar connection shall be carried out for all bar diameters of each series.

For each test, three specimens shall be tested. The tests shall be carried out in accordance with ISO 15698-2. Reference is made to ISO 6892-1.

7.3.2 Wedge tensile tests

The wedge tensile test for headed bars shall be performed with at least a 3° wedge angle. However, for welded and forged connections, the test shall be performed with at least a 10° wedge angle. The wedge angle used in the test shall be stated in the test report.

NOTE 1 The bend test is the most appropriate for forged and welded headed bars to check the risk of local brittleness (forged heads) and local weld fusion line defects (welded heads). In order to reveal possible flaws, the larger wedge angle has to be applied if the wedge test is used.

The headed bar shall be subjected to the following tensile force:

Category B1: The head shall be capable of anchoring $(R_m/R_{eH})_{spec} \cdot R_{eH,\,spec} \cdot A_{B,nom} - F_b$.

Category B2: The head shall be capable of anchoring $(R_m/R_{eH})_{spec} \cdot R_{eH,\,spec} \cdot A_{B,nom}$. In cases where only an $R_{m,spec}$ value is specified in the reinforcing bar standard, the force to be anchored shall at least be $R_{m,spec} \cdot A_{B,nom}$.

Category B3: The head shall be capable of anchoring a force corresponding to the actual tensile strength of the headed reinforcing bar that is tested, $R_{m,act} \cdot A_{B,nom}$. The requirement is considered to be fulfilled if at least one of the following occurs:

— the failure occurs outside the affected zone;

— the minimum specified elongation required for the bar is reached;

— at least 0.95 $R_{m,act}$ is reached by comparing with the actual tensile strength of an adjacent non-headed specimen from the same batch or with the retested bar of the broken test specimen, if possible.

For threaded heads of Categories B1 and B2, the wedge tensile test shall be executed with the yield strength of the reinforcing bars within the lower 50 % of the yield strength range of the steel grade for which the heads are intended.

For threaded heads of Category B3, the wedge tensile test shall be executed with the yield strength of the reinforcing bars within both the lower and the upper 50 % of the yield strength range of the steel grade for which the heads are intended. The upper yield strength for which the head-to-bar connection is tested will represent the maximum allowable actual bar yield strength ($R_{eH,act}$) for the achievement of a bar break. A corresponding statement shall be included in the test report.

NOTE 2 The yield strength range is either specified in the reinforcing steel standard as the difference between maximum and minimum yield strength or obtained from the reinforcing steel manufacturer.

NOTE 3 For Category B3, the threads of the bar will normally be the weaker link and, thus, a low yield strength of the bar will provide the lowest anchorage capacity. However, if the bar yield strength is high compared to the yield strength of the head material, the threads of the head may be the weakest link. As the strength of the bar material may vary quite considerably for one and the same nominal strength, both limits have to be verified.

For shear-bolted sleeve-headed bars, each wedge tensile test shall be executed with reinforcement within both the upper and lower region of the actual ultimate tensile strength range for which the heads are intended. The

upper tensile strength for which the head-to-bar connection is tested will represent the maximum allowable actual bar tensile strength ($R_{m,act}$). A corresponding statement shall be included in the test report.

NOTE 4 The penetration of the shear bolts into the bar depends on the hardness of the bars, which is related to its tensile strength.

7.3.3 Bend tests

The test specimen shall be bent around the mandrel to an angle of at least 60° with no observed partial or total fracture of the head, the bar, or the head-to-bar connection. The mandrel diameters shall be less than or equal to the diameters specified for the bend test in ISO 17660-1.

For welded headed bars, the carbon equivalent for the material used in the test qualifies materials with an equal or lower carbon equivalent, but not those with higher carbon equivalents.

NOTE Weldability and forge-ability are both dependant on the composition of the steel, which varies significantly from one mill to another.

For each test, three specimens shall be tested. The tests shall be carried out in accordance with ISO 15698-2. In the head, the bar, or the head-to-bar connection, there shall be no cracks visible to a person with normal or corrected vision.

8 Manufacture

8.1 General

The following requirements, depending on the method for head attachment, are given in order to ensure a consistent production and to ensure product traceability.

8.2 Welded headed bars

A welding procedure conforming to ISO 17660-1 shall be used for all required production welding of the head to the bar, including friction welding. Other relevant standards at the option of the manufacturer may be used, subject to the approval of the purchaser.

8.3 Forged headed bars

The heads on integrally-forged headed bars shall be produced by deforming the bar ends in a hot-forging process.

Appropriate temperatures set by the manufacturer shall be verified and maintained throughout the heating and forging process to eliminate the risk of a brittle failure at the head-to-bar connection.

8.4 Threaded headed bars

Any specified thread form may be used, provided that the test requirements of this part of ISO 15698 and ISO 15698-2 are satisfied. The specified thread form shall include tolerances. Go-NoGo gauges shall be used to control the threads.

Care shall be exercised to account for out-of-roundness in the as-rolled reinforcing bar in the production of the threads, so that the minimum thread dimensions around the full circumference of the bar, as required by the manufacturer for the product, are maintained.

Hot-rolled or cold-rolled, or machine-cut threads into the surface of the bar and/or heads may be used at the option of the manufacturer, provided that test requirements of this part of ISO 15698 are satisfied.

The head shall be fixed to the bar in such a way that the head does not loosen from the vibration of a concrete vibrator, either by appropriate threads, by locking nuts or by other means.

8.5 Swaged and extruded headed bars

Swaged and extruded headed bars shall be made only with ribbed bars. The sleeves may be pressed either radially or axially. The assembly instructions shall clearly define, for each bar size:

— the model of the pressing tool and, if adjustable, its power;

— the number, location and orientation of the pressing operations.

Hydraulic press and suitable dies may be used to attach coupling sleeves with heads to the reinforcing bar by a cold-swaging procedure. A separate internally taper-threaded head that is secured to a mating cold-swaged threaded coupler may be used.

When the sleeve is connected to the head by threads, the provisions of threaded headed bars shall apply. When the sleeve is connected to the head by welding, the provisions of welded headed bars shall apply.

8.6 Shear-bolted sleeve-headed bars

The assembly instruction shall clearly define:

— the type of tool to be used to tighten the bolts (impact wrench or continuous drive);

— the sequence by which the bolts must be tightened;

— the recommendations to ensure that the bolt does not fail by flexure or fatigue.

When the sleeve is connected to the head by threads, the provisions of threaded headed bars shall apply. When the sleeve is connected to the head by welding, the provisions of welded headed bars shall apply.

8.7 Labelling

Labelling shall be sufficient to provide product traceability.

For loose heads, the manufacturer shall label each package of heads with an appropriate identification to provide traceability.

All headed bars, manufactured under this part of ISO 15698, shall be identified by a distinguishing set of symbols legibly stamped onto the head, away from the bar, to denote:

— the point of origin: a letter or symbol established as the manufacturer's designation;

— product designation and head categories; for loose heads, in addition, maximum applicable bar grade;

— lot number for individual heads to be referenced in inspection documents.

At least the following information shall be marked on each bundle of headed bars:

— manufacturer's factory;

— product identification (head categories, minimum applicable concrete strength, bar grade, bar size, bar length);

— number of pieces in a bundle;

— batch number or equivalent information for cross-reference to inspection documents.

8.8 Information to be provided by the purchaser

The purchaser shall provide the following information at the time of the enquiry and order:

— product designation;