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Steels for the reinforcement of concrete – Reinforcement couplers – Requirements and test methods

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to ii, pages 1 to 16, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 August 2015. It was prepared by Technical Committee ISE/104, *Concrete reinforcing and pre-stressing steels*. A list of organizations represented on this committee can be obtained on request to its secretary.

Information about this document

Product certification. Users of this British Standard are advised to consider the desirability of third-party certification of product conformity with this British Standard. Users seeking assistance in identifying appropriate conformity assessment bodies or schemes may ask BSI to forward their enquiries to the relevant association.

Test laboratory accreditation. Users of this British Standard are advised to consider the desirability of selecting test laboratories that are accredited to BS EN ISO/IEC 17025 by a national or international accreditation body.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This British Standard specifies requirements and test methods for steel reinforcement couplers (hereafter called couplers) to be used for the mechanical splicing of steel reinforcing bars. It specifies requirements for couplers to be used for mechanical splices in reinforced concrete structures under predominantly static loads and additional requirements for couplers to be used in elements of structures subject to high cycle elastic fatigue loading. It also specifies requirements for the evaluation of conformity of couplers.

This British Standard does not specify requirements for couplers which are to be used for mechanical splices in reinforced concrete structures subject to low cycle loading in the elastic-plastic range.

This British Standard specifies performance requirements for couplers. The couplers are tested as part of a mechanical splice between two lengths of reinforcing steel, manufactured in accordance with BS 4449 or BS 6744. The performance tests specified are therefore for mechanical splices incorporating the coupler being assessed. The requirements of this standard apply to the manufacture of couplers and not the assembly or installation of mechanical splices on site.

NOTE Instructions for assembly or installation of couplers can be obtained from the manufacturer.

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.

BS 4449, *Steel for the reinforcement of concrete – Weldable reinforcing steel – Bar, coil and decoiled product – Specification*

BS EN ISO 7500-1, *Metallic materials – Verification of static uniaxial testing machines – Part 1: Tension/compression testing machines – Verification and calibration of the force-measuring system*

BS EN ISO 9513:2012, *Metallic materials – Calibration of extensometer systems used in uniaxial testing*

BS EN ISO 15630-1:2010, *Steel for the reinforcement and prestressing of concrete – Test methods – Part 1: Reinforcing bars, wire rod and wire*

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

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1 characteristic value

value of a material or product property having a prescribed probability of not being attained in a hypothetical unlimited test series

NOTE This value generally corresponds to a specific fractile of the assumed statistical distribution of the particular property of the material or product.

3.1.2 coupler
device for the mechanical connection of two lengths of reinforcing bar providing a transfer of tension and/or compression loads from one bar to the other

NOTE Also known as a reinforcement coupler.

3.1.3 coupler length (L_1)
actual length of the coupler, including all load-transferring parts, and including lock nuts, if any

3.1.4 extension measurement device
assembly consisting of a device or devices for the measurement of extension and any system used to fix it/them to a mechanical splice

3.1.5 length of mechanical splice (L)
coupler length plus two times the nominal bar diameter at each end of the coupler

NOTE This is a conventionally agreed definition taking into account the affected zone in an approximate way.

3.1.6 mechanical splice
complete assembly of a coupler including any additional intervening material or other components providing a connection between two reinforcing bars (and including the length of reinforcing steel, L_2, affected by the connection at either end)

3.1.7 qualification test
initial type tests performed on a mechanical splice system

3.1.8 reference bar
length of reinforcing bar from the same bar as used for the mechanical splice, tested for comparison with the performance of the splice

3.1.9 slip
permanent change in the length of a mechanical splice after being loaded to a defined load level and unloaded to zero

3.1.10 stress ratio
ratio of the minimum stress to the maximum stress in one cycle of loading in a fatigue test

3.1.11 sub-assembly
pair of load-transmitting components where a coupler consists of more than two load-transmitting components

3.2 Symbols

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

Table 1 **Symbols**

Symbol	Unit	Designation
A_{gt}	%	Percentage total elongation at maximum tensile force, F_{max}
d	mm	Nominal diameter of the reinforcing bar
F_{max}	N	Maximum tensile force
N	–	Specified number of load cycles in axial load fatigue test
R_e	MPa [A)]	Characteristic yield strength of the reinforcing bar
$R_{p0.2}$	MPa	Characteristic 0.2% proof strength, non-proportional extension, of the reinforcing bar
R_m	MPa	Tensile strength of the reinforcing bar
(R_m/R_e)	–	Characteristic tensile/yield strength ratio of the reinforcing bar
$(R_m/R_{p0.2})$	–	Characteristic tensile/proof strength ratio of the reinforcing bar
$2\sigma_a = \triangle\sigma_{rsk}$	MPa	Stress range of a high cycle fatigue test
σ_{max}	MPa	Maximum stress in a high cycle fatigue test
σ_{min}	MPa	Minimum stress in a high cycle fatigue test

[A)] 1 MPa = 1 N/mm^2

4 Requirements

4.1 General

The requirements shall apply to the coupler, although the assessment of conformity of the coupler is carried out on a mechanical splice that has been assembled in accordance with the manufacturer's written instructions, using reinforcing bar of the grade for which the coupler is qualified (see Table 2).

When tested in accordance with Clause **5**, the specified requirements shall be met for the following:

a) slip under static forces; and

b) strength under static forces.

Optionally, when tested in accordance with **5.5**, the specified requirements shall be met for performance under high cycle fatigue loading in the elastic range.

In addition, the following shall be recorded:

1) ductility under static forces; and

2) identification and marking.

NOTE If stainless steel couplers are specified then these should be used in accordance with the recommendations set out in Annex A.

4.2 Slip under static forces

4.2.1 General

The slip across the mechanical splice shall be taken to be the residual extension (in tension) or contraction (in compression) of the mechanical splice after loading the splice to a load equivalent to 0.65 R_e and unloading to zero.

NOTE Slip is usually measured after loading and then unloading in tension. The measurement of slip in compression is only required where this is specified by the designer.

4.2.2 Slip requirement in tension or compression

When tested in accordance with **5.3**, the slip value measured for a simple coupler, consisting of no more than two load-transmitting components, shall not exceed 0.10 mm.

For couplers consisting of more than two load-transmitting components, when tested in accordance with **5.3**, either:

a) the slip value shall not exceed 0.10 mm; or

b) the strain measured across the splice at a load equivalent to 0.65 R_e shall not exceed 0.16% or the actual value measured on the reference bar, whichever is the greater. In addition for qualification testing the slip measured across each sub-assembly after unloading shall not exceed 0.10 mm.

4.3 Strength and ductility under static forces

4.3.1 Strength

When tested in accordance with **5.4**, the tensile strength of the mechanical splice shall meet the requirements in Table 2.

Table 2 **Tensile strength requirements for mechanical splices**

Reinforcing bar standard	Grade	Minimum tensile strength, R_m (MPa)
BS 4449	B500A	525
BS 4449	B500B	540
BS 4449	B500C	575

If couplers are used to connect bars of different diameters, the tensile strength shall be calculated using the nominal cross-sectional area of the smaller reinforcing bar.

4.3.2 Ductility

When tested in accordance with **5.4**, the A_{gt} developed in the bar shall be measured and recorded. The A_{gt} shall not be a cause for rejection.

NOTE Ductility of the coupler itself is not subject to testing; only the ductility of the splice.

4.4 Failure location and mode

The location of the failure and its mode shall be reported according to the requirements of **5.4.4**.

4.5 Properties under high cycle fatigue loading in the elastic range

When tested in accordance with **5.5**, the high cycle elastic fatigue performance shall meet the specified requirement(s).

Where the specification of the requirement(s) for performance under high cycle fatigue is by means of a specified minimum number of cycles to be sustained under specified fatigue loading conditions, testing shall be carried out in accordance with **5.5**.

When tested in this way, the following acceptance criteria shall be applied.

- If all test samples resist the fatigue loading, the test is passed.
- If one test sample fails the test, five additional samples of the same type and diameter as those that have failed shall be tested. If all five additional test samples pass, the test is passed.
- If two or more test samples fail the fatigue test, the test is failed.

NOTE Annex B gives the specified fatigue test requirements for highway structures on UK motorways and trunk roads, and for use of couplers in designs in accordance with BS EN 1992-1-1. Other fatigue performance requirements can be agreed between the client and the manufacturer.

Alternatively, the performance of a mechanical splice under high cycle stresses of different amplitudes can be characterized by an S-N diagram; if an S-N diagram is determined, the provisions in **5.5.4** shall be applied. Where this option is selected, the decision on the suitability of the splice under high cycle elastic fatigue loading shall be agreed between the client and the manufacturer for each contract.

4.6 Identification and marking

Each coupler shall be legibly and durably marked (e.g. hard stamped) with the manufacturer's identification, the coupler type, the nominal bar size for which it is intended and a batch mark for traceability purposes. Each coupler shall be traceable back to its production data.

4.7 Installation instructions

The manufacturer shall provide clear, written installation instructions. The described processing of the couplers shall be achievable under construction site conditions.

5 Testing of mechanical splices

5.1 General

All tests shall be carried out on mechanical splices assembled in accordance with the manufacturer's written instructions. In cases of dispute, test specimens shall be tested in an artificially aged condition. Where required, a reference sample from the same bar used for the splice shall be tested to determine its actual mechanical properties. A reference bar shall always be tested in the case of qualification testing and continuous independent testing. The test methods to be carried out shall be:

a) slip test;

b) tensile test; and

c) high cycle fatigue test (optional).

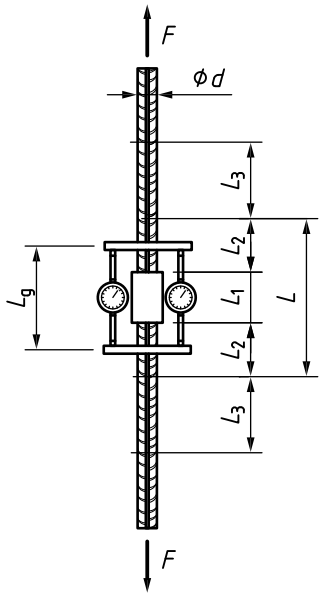
NOTE 1 The principle of measurement of tensile properties is shown in Figure 1.

NOTE 2 Artificially aged means heating the splice to 100 °C, maintaining at this temperature ±10 °C for a period of 1 h ±15 min and then cooling in still air to ambient temperature.

NOTE 3 It is advisable to retain a reference bar for all tests for investigation purposes.

*NOTE 4 It is not normal practice to conduct a compression strength test of mechanical splices. It is reasonable to assume that for couplers tested in tension in accordance with **5.4**, the mechanical splice would perform in an equivalent manner in compression.*

Figure 1 **Principle of measurement of tensile properties**



Key

F	Applied force	L_2	Distance, taken as 2d, used to characterize the mode of tensile failure
L	Length of the mechanical splice		
L_1	Length of the coupler	L_3	Length for the measurement of A_{gt}
		L_g	Gauge length for the measurement of slip

5.2 Preparation of test specimens

The test specimens shall be assembled and prepared in accordance with the written instructions from the manufacturer of the coupler. The coupler shall be positioned approximately in the middle of the test piece.

The two pieces of steel reinforcement that make up the test specimen used for mechanical testing shall be taken from the same length of reinforcement bar, unless different bar diameters are used in the splice. The gauge length for the measurement of slip shall be the length of the coupler (L_1) plus between 1d and 3d at each end.

For couplers with adjustable length, splices shall be tested at their maximum extension in accordance with the manufacturer's instructions.

Where a reference bar is required, this shall also be taken from the same length of reinforcing bar as used for the test splice. Where different diameter bars are used in a splice, the reference bar shall be taken from the same length of reinforcing bar as the smaller bar diameter of the splice.

5.3 Slip test

5.3.1 General

The slip shall be measured in accordance with Figure 1. The slip measurement shall be taken as the residual extension indicated by the extension measuring device after loading to 0.65 R_e in either tension or compression and unloading to zero.

NOTE The extension measuring devices should be positioned as close as possible to the axis of the splice and approximately evenly spaced around the circumference of the coupler.

5.3.2 Testing equipment

The testing equipment shall conform to BS EN ISO 15630-1.

The extension measurement device used shall conform to BS EN ISO 9513:2012, Class 1 or better, and shall be at least a two-point (averaging) type.

The extension measurement device shall be rigid enough, and fixed securely, so that the slip can be measured with an accuracy of at least 0.01 mm.

5.3.3 Test procedure

The test specimen shall be gripped in the testing equipment in such a way that the load is transmitted axially and as much as possible free of any bending moment on the whole length of the test specimen. Any preloading stress in the bar due to gripping shall be less than 10 MPa. The load shall be reduced to zero prior to the commencement of testing.

NOTE Significant preloading of the test piece normally takes most of the slip out. A preloading is not usually carried out for spliced bars in a structure.

The extension measuring device(s) shall be set to zero after closure of the jaws of the tensile testing machine.

The slip shall be measured after loading to a stress equivalent to 0.65 R_e and unloading to zero. The force to be applied shall be calculated using the nominal cross-sectional area of the reinforcing bar. The actual force applied shall not deviate by more than ±3% from the calculated value.

The maximum rate of loading shall be 500 MPa/min.

5.4 Tensile test

5.4.1 General

The strength and ductility of the splice shall be determined by means of a tensile test specified in **5.4.3**.

*NOTE The test specimen from the slip test (see **5.3**) may be used for this test.*

5.4.2 Testing equipment

The testing equipment shall conform to BS EN ISO 15630-1.

5.4.3 Test procedure

The test shall be carried out in accordance with BS EN ISO 15630-1:2010, Clause **5**.

For the calculation of stresses, the nominal cross-sectional area of the reinforcing bar shall be used.

The percentage total elongation at maximum tensile force, A_{gt}, in the two spliced bars outside the length of the splice shall be measured in accordance with BS EN ISO 15630-1. Both values shall be measured and recorded.

5.4.4 Failure mode and location

The location of the failure shall be measured from the face of the coupler to the nearest fracture face.

When this distance exceeds 2*d*, then the failure shall be described as a bar failure. When the failure occurs within the length of the coupler, then the failure shall be described as "within coupler". When the failure is within 2*d* of the coupler, the failure location shall be described as "within splice length", and the distance measured from the coupler to the fracture shall be recorded.

Where failures occur either within the coupler or within the splice length, a description of the mode of failure shall be recorded.

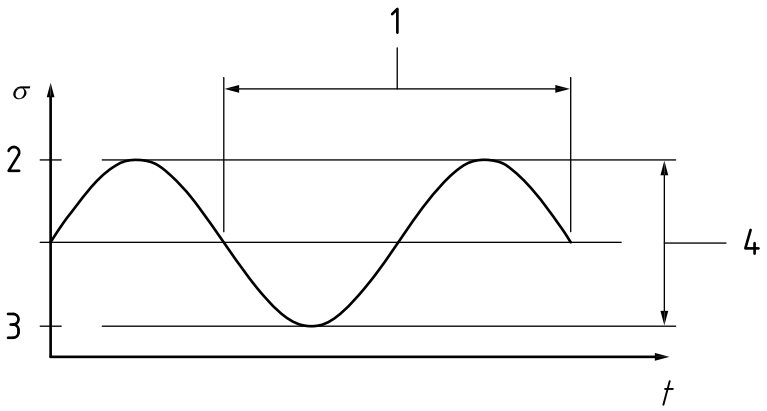
NOTE Examples of mode of failure are threads stripped, broken at the threads, coupler deformed, etc.

5.5 High cycle fatigue test

5.5.1 Principle of the test

In the axial load fatigue test, the test piece shall be subjected to an axial tensile force which varies cyclically according to a sinusoidal wave-form of constant frequency and amplitude in the elastic range (see Figure 2).

Figure 2 **Load cycle diagram for the high cycle fatigue test**



Key

t	Time	2	Upper stress level (σ_{max})
σ	Stress	3	Lower stress level (σ_{min})
1	Load cycle	4	Stress range ($2\sigma_a$)

5.5.2 Testing equipment

The fatigue test shall be carried out under load control.

The fatigue testing machine shall be calibrated to conform to BS EN ISO 7500-1, the accuracy shall be ±1% or better, and the machine shall be capable of maintaining the upper stress level, σ_{max}, within ±2% of the specified value and the stress range, $2\sigma_a$, within ±4% of the specified value.

5.5.3 Test procedure

5.5.3.1 Placement of the test piece

For the calculation of stresses, the nominal cross-sectional area of the reinforcing bar shall be used.

The test piece shall be gripped in the fatigue testing machine in such a way that the force is transmitted axially and as much as possible free of any bending moment.

5.5.3.2 Frequency and temperature

The frequency of load cycles shall be between 1 Hz and 200 Hz.

NOTE The frequency of load cycles should be approximately constant during the test and during the test series on a particular coupler type and size.

The temperature of the test piece throughout the test shall not exceed 40 °C. The temperature in the testing laboratory shall be between 18 °C and 30 °C.

5.5.3.3 Termination of the test

The test shall be terminated upon fracture of the test piece or upon reaching a specified number of cycles without fracture.

NOTE If the test piece fails outside the length of the mechanical splice, the mechanical splice is still intact and there is enough bar length left for gripping, the test may be continued after re-gripping the test piece.

5.5.4 S-N diagram

Where required, the S-N diagram of a mechanical splice shall be determined by performing a minimum of 12 fatigue tests. If a range of the same type of mechanical splice is to be tested, the smallest size, the largest size and an intermediate size shall be tested.

The tests shall be conducted at a minimum of four different stress ranges, with at least three specimens tested at each stress range. The tests shall be based on a fixed maximum stress, or a fixed stress ratio, or be as agreed between the client and the manufacturer.

5.6 Identification and marking

The identification and marking on the couplers shall be visually checked for their readability. The markings on the test pieces shall be stated in the test report.

6 Test report

The test report shall contain at least the following information:

a) reference to this British Standard;

b) name of the laboratory;

c) name of the organization ordering the test (including the date);

d) name of the individual who prepared the test piece;

e) standard for, and grade of, reinforcement with which the test piece was prepared;

f) nominal size of the bar;

g) name of the supplier of the coupler and markings on the coupler (size, type and batch number, legibility of batch number);

h) details of assembly of the test piece(s) (where applicable);

i) diameter and length of the coupler (including adjustment length for positional couplers);

j) force used for slip testing;

k) slip values obtained;

l) tensile strength achieved (where applicable);

m) location of failure (i.e. in the bar, within the splice length or in the coupler) and description of the failure mode;

n) the A_{gt} results (where applicable);

o) the tensile results on the reference bar (where applicable);

p) results of fatigue tests, where carried out;

q) name of the laboratory operator;

r) name and signature of the person responsible for preparation of the test report; and

s) statement of compliance (where applicable).

7 Evaluation of conformity

7.1 General

The conformity of the couplers to the requirements of this standard shall be evaluated according to the method specified in **7.2** to **7.4**.

7.2 Qualification tests

Random samples shall be taken from the products to be tested, which reflect the properties of the products to be delivered. Tests shall be performed for all characteristics of the products for which the manufacturer intends to declare conformity.

The qualification tests shall be as follows:

a) slip under static forces;

b) strength and ductility under static forces (where applicable);

c) performance under high cycle fatigue loading in the elastic range (where required); and

d) identification and marking.

For each type of coupler, and each manufacturing location, qualification testing shall be performed in accordance with Table 3, by an external independent laboratory.

NOTE If different types of couplers are similar and use identical components, the manufacturer may decide not to test all types, subject to agreement with the client.

Qualification tests shall be required after a significant change in material properties, geometry or production technology.

7.3 Continuous independent testing

At least once per year, a series of external independent tests shall be conducted on the product from each manufacturing location according to the requirements of Table 3.

If fatigue properties are declared, the frequency of testing of the properties (with the exception of fatigue S-N curves) shall be such that all sizes are tested within a period of 5 years, and always if there is a change in material properties, geometry or production technology for which a change in the product properties is registered.

7.4 Factory production control

The manufacturer shall demonstrate that the factory production control system is sufficient to ensure that the level of confidence in the conformity of the finished product is achieved. The factory production control system shall cover all characteristics of the products for which the manufacturer intends to declare conformity, with the exception of high cycle elastic fatigue loading. Testing shall be conducted in accordance with the requirements of Table 3.

Table 3 **Testing frequency**

Stage	**Size**	**Scope of testing**		
		Strength and ductility (99% characteristic value)[A]	**Slip and effective strain**	**High cycle elastic fatigue loading**[B] **(where required)**
Qualification testing[C]	All sizes for each type	Three samples of each selected size and type[D]	Three samples of each selected size and type	Five samples of each selected size and type
Continuous independent[E]	One size of each type	Three samples[D]	Three samples	Five samples[F]
Factory production control[G]	One sample for each delivery of 5 000	One sample for each delivery of 5 000	One sample for each delivery of 5 000	Not required

[A] 95% characteristic value for factory production control. See Annex C.
[B] See **4.5**.
[C] If one of the samples fails, the whole test series is repeated for that size, except for high cycle fatigue (see **4.5**).
[D] When the batch fails to meet the 99% characteristic value of tensile strength, additional samples from the same batch may be tested and included in the data.
[E] If one of the samples fails, the test series is repeated with six samples and no failure should occur. If two or more samples fail during testing, then a cause should be found by the manufacturer and appropriate corrective actions taken, after which six samples should be tested without failure.
[F] All approved product types to be tested within a five-year cycle.
[G] To be undertaken by the organization manufacturing the splice and/or the splicing company. If the sample fails, then a cause should be found by the manufacturer and appropriate corrective actions taken, after which three samples should be tested without failure.

Annex A (informative) Stainless steel couplers

A.1 General

This annex relates to stainless steel couplers only. It lists the differences in terminology, as well as the differences (where applicable) in requirements and test methods of stainless steel couplers. This annex should be read in conjunction with the rest of this document. Unless otherwise stated in this annex, the rest of this document also applies to stainless steel couplers.

A.2 Limitations of use

Stainless steel couplers described in this annex are for the following use:

- Mechanically connecting BS 6744 Grade 500 stainless steel rebar;
- Mechanically connecting BS 6744 Grade 500 stainless steel rebar to BS 4449 Grade B500 carbon steel rebar;
- Mechanically connecting BS 4449 Grade B500 rebar.

NOTE Particular care should be exercised when specifying stainless steel couplers for use with carbon steel rebars due to the potential for galvanic corrosion effects.

A.3 Materials

Coupler material should conform to a material designation as listed in BS 6744:2001+A2:2009, Table 5. Care should be taken to ensure that the stainless steel designation used for the coupler material has the appropriate corrosion resistance performance for the intended use.

A.4 Symbols

Throughout this British Standard, the symbol R_e should be replaced by $R_{p0.2}$ when related to stainless reinforcing steel.

A.5 Strength

For the connection of stainless steel rebar conforming to BS 6744, the tensile strength of the mechanical splice should meet the requirements set out in Table A.1.

Table A.1 **Tensile strength requirements for mechanical splices in stainless steel**

Reinforcing bar standard	Grade	Minimum tensile strength, R_m (MPa)
BS 6744	500	550

For stainless steel couplers required to connect two lengths of carbon steel rebar conforming to BS 4449, the tensile strength of the mechanical splice should meet the requirements of Table 2.

For stainless steel couplers required to connect a length of stainless steel rebar conforming to BS 6744 to a length of carbon steel rebar conforming to BS 4449, the minimum requirements should be the lesser of the requirements in Table 2 and Table A.1.

Annex B (informative) High cycle elastic fatigue testing

B.1 General

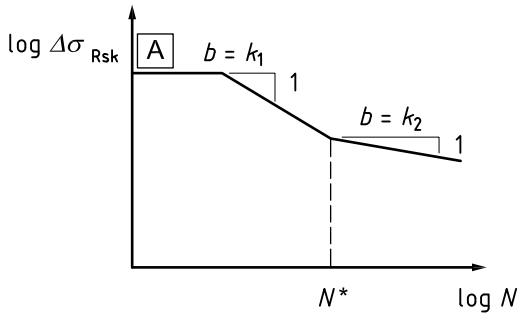
Unless specified otherwise, couplers used in structures where verification of fatigue is necessary, in accordance with BS EN 1992-1-1, should sustain a fatigue loading of at least 2 million cycles with a stress range, $2\sigma_a$, of 60 MPa without failure. The upper stress, σ_{max}, in the test should be 0.6 R_e. Such couplers should be designated Type F.

If an S-N approach is to be used for couplers used in structures designed for fatigue in accordance with BS EN 1992-1-1, the design S-N parameters are given by Table B.1 and are illustrated in Figure B.1.

Table B.1 **Design parameters for S-N curves for reinforcing steel in accordance with BS EN 1992-1-1**

Type of reinforcement	N*	Stress exponent		σ_{Rsk} at N* cycles (MPa)
		k_1	k_2	
Splicing devices (including couplers)	1.0×10^7	3	5	35

Figure B.1 **Shape of the design S-N fatigue strength curve for mechanical couplers in accordance with BS EN 1992-1-1**



Key

A Reinforcement at yield

NOTE Taken from BS EN 1992-1-1:2004, Figure 6.30.

B.2 Requirements for highway structures on UK motorways and trunk roads

The specification for highway structures on UK motorways and trunk roads requires proof of coupler fatigue strength when they are intended for use in highway structures. The fatigue requirements are defined by the following classes with the stress conditions and specified minimum endurances given in Table B.2.

NOTE 1 See Manual of contract documents for highway works (MCHW) *[1].*

Table B.2 **Basis of fatigue testing specification for highway schemes in the UK**

Test environment	Required minimum endurance (cycles)	Stress range σ_r (Nmm^{-2}) for each fatigue class			Stress ratio[A)]
		R_1 (≤16 mm)	R_2 (>16 mm)	D	
air	0.5×10^6	262	201	170	0.2
air	1.0×10^6	242	186	135	0.2
air	3.5×10^6	211	162	89	0.2

[A)] Where stress ratio is $\sigma_{min}/\sigma_{max}$.

NOTE Information based on UK CARES TA1-A testing schedule [2].

There are two classes of fatigue, Class D and Class R.

a) Class D for reinforced concrete applications which might be subject to limited fatigue loading where the coupler has been included in the original design for a new structure and additional reinforcement has been used to reduce the dynamic stresses as necessary.

b) Class R1 (≤16 mm) and Class R2 (>16 mm) for reinforced concrete applications which are subject to fatigue loading, where the coupler has not been included in the original design. The coupled bar can be treated as a continuous bar for design purposes.

NOTE 2 When designing a scheme for maintenance or refurbishment of an existing highway structure, using the existing reinforcement, Class D is acceptable provided a fatigue verification shows that the coupler (certified to Class D) has a better fatigue capacity than the assessed fatigue loading at the coupler location for the design life of the structure.

Annex C (informative) Example of calculation of 99% and 95% characteristic strength based on test results

C.1 Example of calculation of 99% characteristic strength based on test results

The characteristic strength, C_v, can be calculated using Equation C.1, which is based on the premise that at the 90% probability level, 99% of the results in a limited series of tests are at or above the stated characteristic value.

$$C_v = \bar{x} - k_1 s \quad \text{(C.1)}$$

where:

$\bar{x}$ is the average value;

k_1 is a coefficient, listed in Table C.1; and

s is the estimate of the standard deviation of the population.

Table C.1 **Coefficient, k_1, as a function of number of tested samples**

Number of samples	Coefficient k_1
3	7.34
4	5.44
5	4.67
6	4.24
7	3.97
8	3.78
9	3.64
10	3.53
25	2.95
50	2.74

C.2 Example of calculation of 95% characteristic strength based on test results

The characteristic strength, C_v, can be calculated using Equation C.2, which is based on the premise that at the 90% probability level, 95% of the results in a limited series of tests are at or above the stated characteristic value.

$$C_v = \bar{x} - k_2 s \quad \text{(C.2)}$$

where:

$\bar{x}$ is the average value;

k_2 is a coefficient, listed in Table C.2; and

s is the estimate of the standard deviation of the population.

Table C.2 **Coefficient, k_2, in Equation C.2 as a function of number of tested samples**

Number of samples	Coefficient k_2
3	5.31
4	3.96
5	3.40
6	3.09
7	2.89
8	2.75
9	2.65
10	2.57
25	2.13
50	1.97

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