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Indian Standard

IS 16172 : 2023

कंक्रीट में प्रयुक्त इस्पात सरियों के यांत्रिक संबंधन हेतु प्रबलन युग्मक — विशिष्टि

(पहला पुनरीक्षण)

Reinforcement Couplers for Mechanical Splices of Steel Bars in Concrete — Specification

(First Revision)

ICS 77.140.15

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Concrete Reinforcement Sectional Committee, CED 54

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Concrete Reinforcement Sectional Committee had been approved by the Civil Engineering Division Council.

Various method of reinforcement splicing that are in use include lapping, welding and by mechanical means. Lapping of reinforcement bars using binding wires has been the conventional method and is still widely used in construction projects.

Mechanical means of splicing of reinforcement bars involve joining of two reinforcement bars end to end using a reinforcement coupler and is a relatively new method being adopted in various projects. Mechanical splices may be reliable under conditions of cyclic loading into the inelastic range and may also be advantageous at locations where inelastic yielding may occur. Mechanical splicing of large diameter bars are often advantageous as this results in less congestion during concreting and faster construction. However, the condition and quality of the concrete and minimum clear cover requirements are to be ensured even in case of mechanical splicing of bars. Further, the material of the reinforcement coupler should be compatible with the material of the reinforcement bar to be spliced and as well as with the concrete.

With increased use of mechanical splicing systems and reinforcement couplers in construction, this standard was first formulated in 2014 so as to cover the requirements for reinforcement couplers for use with reinforcing bars conforming to IS 1786 : 2008 'High strength deformed steel bars and wires for concrete reinforcement (*second revision*)'. In this version of the standard, the requirements for couplers were based on the properties of reinforcing bars of grade Fe 550D of IS 1786. It was so done because the product was new, and the need was felt to rationalize varieties so as to avoid difficulty in storing/stacking; for ease of identification by users (including construction workers); and to avoid inadvertent wrong use of couplers at construction sites. It was therefore decided by the committee to restrict the standard to cover couplers corresponding to the highest commonly used grade, that is Fe 550D. It was, however, also provided then, that for specific projects which may require use of reinforcement bars of grades lower than Fe 550D only, the requirements for such couplers may be as agreed between the purchaser and the manufacturer or as specified by the engineer-in-charge of the project, subject to meeting the minimum requirements specified in the standard. Similarly, in view of limited production and use of reinforcement bars of Fe 600 grade at that time, requirements of couplers to be used with such bars were also not covered, and their specifications were also to be mutually agreed.

With the further increased use of couplers in various projects and experience gained over the years, the committee now decided that the standard should cover reinforcement couplers corresponding to each of the grades covered in IS 1786, for appropriate use by the concerned stakeholders.

Accordingly, in this revision of the standard the following major changes have been incorporated:

a) The title of the standard has been modified from 'Reinforcement couplers for mechanical splices of bars in concrete — Specification' to 'Reinforcement couplers for mechanical splices of steel bars in concrete — Specification'.
b) The scope of the standard has been extended to cover reinforcement couplers corresponding to all the grades covered in IS 1786.
c) Definitions of some terms have been modified for more clarity and new terms and their definitions have also been added.
d) Hybrid couplers have been included.
e) Provisions on reducer/transition couplers have been added.
f) Disengagement test for threaded couplers has been incorporated.
g) The provisions on tensile strength, cyclic test, high cycle fatigue test have been modified to cover requirements for various grades of couplers.
h) Slip test requirements have been modified to address swaged coupling sleeves, grout/steel filled coupling sleeve, etc, having length more than 100 mm.

j) Provisions on information to be provided in the test report of static tensile test have been modified, for clarity.

k) Provisions on packing of couplers have been added.

m) The frequency of sampling and criteria for conformity for acceptance test has been modified considering the requests received from the industry as well as keeping in view the provisions for the same in the international standard. The sampling plan has been based on consignment sizes normally encountered and in accordance with IS 2500 (Part 1) : 2000/ISO 2589-1 : 1999 'Sampling procedure for inspection by attributes: Part 1 Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection (*third revision*)'.

n) The validity period of various type tests has also been modified in view of practical considerations.

p) Quality control checks to be practiced during mechanical splicing of reinforcing bars using couplers have been included for guidance.

This standard covers requirements that apply to reinforcement couplers only. This standard does not cover the performance requirements of mechanically spliced joints in the field. Information on commonly used reinforcement couplers are given in Annex A. Users may ascertain the limitations associated with use of different types of reinforcement couplers and are encouraged to follow minimum precautionary installation measures, as applicable. Quality control checks to be practiced at construction site during mechanical splicing of reinforcing bars using couplers covered by this standard have been covered in Annex G for guidance.

Users are also encouraged to carry out corrosion test in the coupler-bar connections exposed to marine or severe environmental conditions to rule out any risk of galvanic corrosion. Specialist literature may be referred to in such cases.

The provisions on splicing of reinforcement bars are covered in IS 456 : 2000 'Plain and reinforced concrete — Code of practice (*fourth revision*)'.

Assistance has been derived from the following International Standards in the formulation of this standard:

International Standard	*Title*
ISO 15835-1 : 2018	Steels for the reinforcement of concrete — Reinforcement couplers for mechanical splices of bars — Part 1: Requirements
ISO 15835-2 : 2018	Steels for the reinforcement of concrete — Reinforcement couplers for mechanical splices of bars — Part 2: Test methods
ISO 15835-3 : 2018	Steels for the reinforcement of concrete — Reinforcement couplers for mechanical splices of bars — Part 3: Conformity assessment scheme

Keeping in consideration the design principles applicable for reinforced concrete, construction practices followed, installation techniques and equipment used in field and the skill level of construction workers, deviations have been made in this standard from the International Standards. The major deviations are:

a) Requirements have been aligned for use of couplers with reinforcement bars conforming to IS 1786;

b) Varieties as covered in the previous version of IS 16172, that is, Class L and Class H have been retained, unlike the ISO standard which now covers three varieties, namely, basic, fatigue and seismic. As most parts of the country is earthquake prone, low cycle fatigue test requirement has been specified for all classes of couplers;

c) Changes have been made in the requirement of low cycle fatigue test, considering the earthquake vulnerability of India and relevant testing facilities available in the country;

d) A cyclic test of 100 cycles in tension has been specified which simulate to loading experienced in tall and stack like structures; and

e) Standard temperature conditions prevailing in the country have been adopted in the test methods.

The technical committee responsible for the formulation of this standard has opined that use of reinforcement couplers conforming to the requirements given in this standard is very important for ensuring structural safety of structures wherein they are adopted.

The composition of the Committee and the Working Group responsible for formulation of this standard is given in Annex H.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Indian Standard

REINFORCEMENT COUPLERS FOR MECHANICAL SPLICES OF STEEL BARS IN CONCRETE — SPECIFICATION

(First Revision)

1 SCOPE

1.1 This standard covers the requirements and tests applicable to reinforcement couplers to be used in reinforced concrete constructions for mechanical splicing of reinforcement bars conforming to IS 1786.

1.2 The provisions of this standard applies to tension and tension-compression couplers subject to satisfying the performance criteria of this standard.

1.3 This standard does not cover compression-only couplers such as end bearing sleeves and coupling sleeve and wedge.

2 REFERENCES

The standards given below contain provisions which, through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of these standards:

IS No.	*Title*
IS 1608 (Part 1) : 2022 /ISO 6892-1 : 2019	Metallic materials — Tensile testing: Part 1 Method of test at room temperature (*fifth revision*)
IS 1786 : 2008	High strength deformed steel bars and wires for concrete reinforcement — Specification (*fourth revision*)
IS 1828 (Part 1) : 2022 /ISO 7500-1: 2018	Metallic materials — Calibration and verification of static uniaxial testing machines: Part 1 Tension/ Compression testing machines — Calibration and verification of the force-measuring system (*fifth revision*)
IS 4905 : 2015 /ISO 24153 : 2009	Random sampling and randomization procedures (*first revision*)
IS 12872 : 2021 /ISO 9513 : 2012	Metallic materials — Calibration of extensometer systems used in uniaxial testing (*second revision*)

3 TERMINOLOGY

For the purpose of this standard, the terms and definitions given in IS 1786 and the following shall apply.

3.1 Mechanical Splice — Complete assembly of a coupler including any additional intervening material or other components providing a splice of two reinforcing bars.

3.2 Reinforcement Coupler — Coupling sleeve or threaded coupler or hybrid coupler for mechanical splices of reinforcement bars (*see* Annex A) for the purpose of providing transfer of axial tensile force and compressive force from one bar to the other.

3.3 Coupler Length — Actual length of the reinforcement coupler including all load transferring parts, if more than one, and including lock nuts, if any.

3.4 Length of Mechanical Splice — Length of reinforcement coupler plus two times the nominal bar diameter at both ends of the coupler (*see* Fig. 1).

NOTE — This is a conventionally accepted definition to take into account the affected zone in an approximate way.

3.5 Slip — The permanent extension of a mechanical splice after being loaded to a defined load level.

3.6 Slip Measurement Device — The assembly constituted by the extensometer and any system used to fix it to the mechanical splice.

3.7 Tests

3.7.1 *Type Tests* — Tests carried out to prove conformity with the standard. These are intended for product/type approval and are carried out whenever a change is made in the type of the reinforcement coupler or manufacturing process/conditions or crimping method or forging or threading machine.

3.7.2 *Acceptance Tests* — Tests carried out on samples taken from a lot passing type tests for the purpose of acceptance of the lot.

4 TYPES OF REINFORCEMENT COUPLERS

There are various types of reinforcement couplers used in mechanical splicing of bars in reinforced concrete constructions. Some of the commonly used mechanical splicing systems based on the type of reinforcement coupler used in them have been described in Annex A.

5 CLASSIFICATION

5.1 Reinforcement couplers supplied in accordance with this standard shall be classified into the following classes:

a) Class H; and
b) Class L.

5.1.1 Couplers which meet both low cycle fatigue test and high cycle fatigue test requirements of **9.5.1** and **9.5.2** respectively shall be classified and designated as class H coupler.

5.1.2 All other couplers which meet only low cycle fatigue test requirement of **9.5.1** shall be classified and designated as class L coupler.

NOTE — Class H couplers are recommended for use in concrete structures which are subjected to high cycle of fatigue like road bridges, railway bridges, machine foundations, tall buildings, slender structures like stack, etc.

6 MANUFACTURE

Reinforcement couplers shall have adequate strength, length and internal threads (in case of threaded couplers) as per manufacturer's design to be able to meet the performance requirements of this standard.

7 WORKMANSHIP AND FINISH

7.1 All reinforcement couplers shall be finished smooth and shall be free from burrs, cracks and other manufacturing defects. The threads of threaded couplers and hybrid coupler (wherever applicable) shall be cleanly formed and shall be free from imperfections.

7.2 The thread quality of the coupler, wherever applicable shall be verified after manufacturing, with the help of suitable 'GO' and 'NO GO' gauge duly calibrated. The test frequency shall be 1 piece at production start-up and 5 pieces per hour of manufacturing per diameter of the same cast of the raw material. Whenever desired by the purchaser, the records of these tests shall be made available to them by the manufacturer.

8 NOMINAL SIZES

The nominal sizes of reinforcement couplers based on their internal diameter shall correspond to the nominal sizes of bars covered under IS 1786.

9 PERFORMANCE REQUIREMENTS

9.1 All reinforcement couplers shall meet the performance requirements of **9.2**, **9.3**, **9.4** and **9.5.1**. Class H couplers in addition to above, shall also meet the requirements of **9.5.2**.

9.1.1 The requirements apply to the reinforcement coupler even though the above tests on the coupler are carried out on a mechanical splice that has been installed in accordance with the manufacturer's written instructions.

9.2 Static Tensile Test

9.2.1 *Tensile Strength*

The tensile strength of the mechanical splice when tested in accordance with the details given in Annex B shall meet either of the following requirements:

a) It shall not be less than 130 percent of f_y (where, f_y = specified minimum yield stress or 0.2 percent proof stress given in IS 1786 for the grade of reinforcement bar to be spliced) irrespective of the location of failure; or
b) If it is less than 130 percent of f_y (where, f_y = specified minimum yield stress or 0.2 percent proof stress given in IS 1786 for the grade of reinforcement bar to be spliced), the failure shall occur in the bar outside the length of the mechanical splice (*see* **3.4**).

In case of reducer/transition coupler which are used for splicing reinforcement bars of two different sizes, the above criteria as in Sl No. (a) or (b) shall be measured with respect to lower size bar.

9.2.1.1 *Disengagement test for threaded couplers*

The safety margin in threading of reinforcing bar and coupler design shall be such that required performance for static tensile test as per Annex B is ensured even if 15 percent of the total thread's length, equally distributed on both sides (7.5 percent on both sides), are out of coupler.

9.2.2 *Percentage Elongation*

The minimum percentage elongation at maximum force (also termed as uniform elongation) when measured in accordance with the method given in Annex B in the reinforcing bar outside the length of the mechanical splice shall be minimum 3 percent before the failure of the test piece.

9.3 Slip Test

The total slip value, ΔL_s, when measured in accordance with the test procedure described in Annex C shall be as given below:

a) $\Delta L_s \leq 0.10$ mm for coupler length $\leq$ 100 mm;

b) $\Delta L_s \leq 0.20$ mm for coupler length $\geq$ 300 mm; and

c) Slip value shall be interpolated for coupler lengths between 100 mm and 300 mm (*see* Note below).

NOTE — This standard applies to tension and tension-compression couplers such as threaded couplers, swaged coupling sleeves, grout/steel filled coupling sleeve, etc. Length of threaded coupler used for splicing of reinforcement bars in civil construction is less than 100 mm. Swaged coupling sleeves, grout/steel filled coupling sleeves are more than 100 mm in length, where higher slip value can be permitted. Longer the coupler length, larger the volume of concrete through which the coupler slip will dissipate.

9.4 Cyclic Tensile Test

The mechanical splice shall withstand 100 cycles of the stress variation from 5 percent to 90 percent of f_y (where, f_y = specified minimum yield stress or 0.2 percent proof stress given in IS 1786 for the grade of reinforcement bar to be spliced) when tested in accordance with the details given in Annex D without loss of static tensile strength capacity when compared with like specimen. The static tensile strength capacity of the test piece shall be determined by testing it statically to failure in accordance with the procedure given in Annex B after subjecting it to stress cycles.

9.5 Fatigue Test

There are two types of fatigue tests namely low cycle fatigue test and high cycle fatigue test. All reinforcement couplers shall satisfy the requirement for low cycle fatigue test as specified in **9.5.1**. Couplers of class H in addition to above shall also meet the high cycle fatigue test requirement as specified in **9.5.2**.

9.5.1 *Low Cycle Fatigue Test*

The mechanical splice shall withstand 10 000 cycles of alternating tension and compression load when tested in accordance with the method given in Annex E.

9.5.2 *High Cycle Fatigue Test for Class H Reinforcement Coupler Only*

The mechanical splice, when tested in accordance with the method given in Annex E**,** shall withstand 2 000 000 cycles of varying axial tensile load with a stress range, $2\sigma_a$, of 60 MPa without failure. The upper stress, σ_{Max}, in the test shall be 0.6f_y, where f_y = specified minimum yield stress or 0.2 percent proof stress given in IS 1786 for the grade of reinforcement bar to be spliced.

10 TESTS

10.1 Classification of Tests

10.1.1 The static tensile test shall constitute acceptance test.

10.1.2 The following shall constitute type tests:

a) Static tensile test;
b) Slip test;
c) Cyclic tensile test;
d) Low cycle fatigue test; and
e) High cycle fatigue test for class H couplers only.

10.2 Selection and Preparation of Test Sample for Performance Tests

10.2.1 All tests specified under **10.1.1** and **10.1.2** and described in Annex B to Annex E shall be carried out on mechanical splices assembled in the manner as they are prepared for normal use, with a reinforcement bar conforming to minimum yield stress or 0.2 proof stress in IS 1786 for the grade of reinforcement bar to be spliced. The above tests shall be conducted on selected sample to ensure conformity with the performance requirements laid down in **9.2** to **9.5**.

NOTE — Assembled and prepared for normal use implies to carry out the assembling according to the manufacturer's installation instructions.

10.2.2 A reference bar from the same heat and conforming to the grade of IS 1786 for which the coupler is intended, shall be tested to determine its actual mechanical properties. The performance of some types of mechanical splices is dependent on the rib geometry of the steel reinforcing bar. The specified rib geometry shall be provided by the supplier and recorded with the test results, however, this requirement shall not apply to threaded couplers.

10.2.3 The test pieces shall be prepared according to the installation instructions provided by the manufacturer. The coupler shall be positioned in the middle of the test piece.

11 SAMPLING AND CRITERIA FOR CONFORMITY

11.1 The sampling procedure and the criteria for conformity shall be as given in Annex F.

11.2 Where at a project site, reinforcement coupler is used for splicing of two different sizes of reinforcing bars (referred as reducer or transition coupler), as the weaker section will be the lower diameter, type test reports of higher diameter bar coupler shall be acceptable.

12 PACKING

All couplers shall be protected against rust by application of rust prevention methods/measures or by packing in volatile corrosion inhibitor (VCI) bags. The couplers shall be packed in stackable wooden boxes for delivery to site as per manufacturer's delivery lot size.

13 INSTALLATION INSTRUCTIONS

The manufacturer/supplier shall provide written installation instructions. The installation instructions shall be clear and understandable. The described installation procedure of the reinforcement coupler shall be repeatable and able to achieve its performance under different job site circumstances.

14 QUALITY CONTROL AT SITE

The quality control checks to be practiced at project site during mechanical splicing of reinforcing bars using couplers covered by this standard, are given in Annex G for guidance.

15 IDENTIFICATION AND MARKING

15.1 Each reinforcement coupler container shall be indelibly and clearly marked indicating the class designation of the coupler and the nominal size and the highest grade of reinforcing bar for which it is intended.

15.2 Each reinforcement coupler shall be indelibly and clearly marked by the manufacturer or supplier with its nominal size and batch number from which the original cast of the raw material and the date of manufacturing can be traced. Every facility shall be given to the purchaser or his authorized representative for tracing the reinforcement couplers to the cast from which they were made. Each coupler shall be identifiable by marks/brands which indicate the name of the manufacturer or their brand name.

15.3 BIS Certification Marking

The reinforcement coupler conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the reinforcement coupler may be marked with the Standard Mark.

ANNEX A

(*Foreword and Clause* 4)

DIFFERENT MECHANICAL SPLICING SYSTEMS BASED ON TYPE OF REINFORCEMENT COUPLER USED

A-1 MECHANICAL SPLICING SYSTEMS BASED ON THREADED COUPLER

A-1.1 In these types of mechanical splicing systems, the threaded ends of the reinforcing bar are joined together using internally threaded coupler and with appropriate tightening (*see* **A-1.1.1**, **A-1.1.2** and **A-1.1.3**).

A-1.1.1 *Mechanical Splicing Systems with Parallel Threaded Couplers*

A mechanical splice system with parallel threaded couplers is one in which the ends of the reinforcement bars are sawn square and a parallel thread is formed on the ends, which are then connected by a coupler having matching internal parallel threads.

NOTE — The occurrence and impact of play between the reinforcement bars and the coupler should be kept in consideration when using such splicing systems. The effect of reduction in bar diameter at the ends due to threading, on strength capacity of the reinforcement bars should also be considered.

A-1.1.2 *Mechanical Splicing Systems with Upset Parallel Threaded Couplers*

A mechanical splice system with upset parallel threaded coupler is one in which the ends of the reinforcement bars are sawn square and then hydraulically enlarged by cold forging, such that the core diameter of the bar is increased to a pre-determined diameter. A parallel thread is cut or formed onto the upsized/enlarged end of the reinforcing bars, which are then connected by a coupler having matching internal parallel threads.

NOTE — The occurrence and impact of play between the reinforcement bars and the coupler should be kept in consideration when using such splicing systems.

A-1.1.3 *Mechanical Splicing Systems with Tapered Threaded Couplers*

A mechanical splice system with tapered threaded coupler is one in which the ends of reinforcement bars are sawn square and a tapered thread is formed onto the bar to suit the taper threads inside the coupler. The reinforcement bars are then connected by the coupler having matching internal threads. The thread length is not through and through and the middle portion of the coupler is solid.

NOTE — The effect of reduction in bar diameter at the ends due to threading, on strength capacity of the reinforcement bars should be kept in consideration when using such splicing systems.

A-2 MECHANICAL SPLICING SYSTEMS BASED ON COUPLING SLEEVE

A-2.1 Mechanical Splicing Systems with a Crimped Sleeve

Use of mechanical splicing systems with a crimped sleeve is applicable to all deformed reinforcing bars. It consists of the introduction of the bars to be spliced into a sleeve which is crimped by means of a hydraulic crimping tool onto the deformed bars in order to fill the voids between them and the inner surface of the sleeve. The deformations on the bar penetrate into the relatively softer steel of the sleeve and the deformations work in shear.

NOTE — The impact of lengthening of the sleeve during crimping should be kept in consideration while using such splicing systems.

A-2.2 Mechanical Splicing Systems with Injected Sleeves

In these mechanical splicing systems, the space between the reinforcing bars and the sleeve is filled/injected with special molten metal or grout or epoxy resin, which forms a rigid interlocking layer between the bar deformations surface and the preformed frictional surface inside the sleeve.

A-3 MECHANICAL SPLICING SYSTEMS BASED ON SHEAR BOLTING

In these mechanical splicing systems, the sleeve contains high-strength radially-arranged shear bolts of appropriate sizes which are tightened by using appropriate torque to provide an interlocking mechanism between the reinforcing bar deformations and the interior surface of the sleeve.

A-4 MECHANICAL SPLICING SYSTEMS BASED ON HYBRID CONNECTIONS

A-4.1 In this mechanical splicing systems, the rebars are connected with combination of any of the systems specified in **A-1**, **A-2** and **A-3**.

ANNEX B

(*Clauses* 9.2.1, 9.2.1.1, 9.2.2, 9.4, 10.2.1, D-3.2 *and* E-3.1)

METHOD OF STATIC TENSILE TEST

B-1 PREPARATION OF TEST PIECE

The test piece for the tensile test shall be prepared in accordance with **10.2**. It shall be sufficiently long to ensure a free length between the grips of the testing machine to allow determination of percentage elongation at maximum force. The minimum sufficient free length of the test piece for the tensile test (L_3) in millimeters shall be 400 + L, where L is the length of the mechanical splice (*see* **3.4** and Fig. 1).

B-2 TESTING EQUIPMENT

The testing equipment shall conform to IS 1608 (Part 1).

B-3 TEST PROCEDURE

B-3.1 Tensile Strength

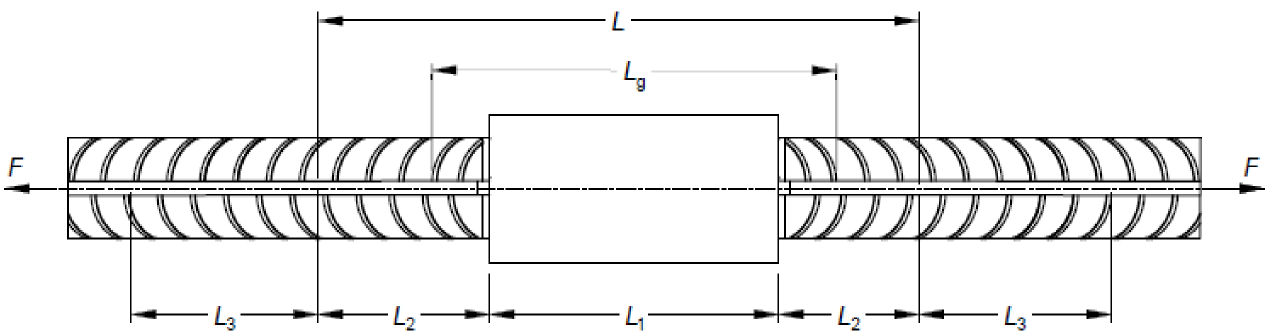
The tensile strength shall be determined by means of test carried out in accordance with IS 1608 (Part 1). A tensile test on an un-spliced specimen from the same bar used for the preparation of spliced specimen shall be performed to establish actual tensile strength of the reinforcing bar.

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

B-3.2 Percentage Elongation at Maximum Force

The gauge length for determining percentage elongation at maximum force for both spliced and un-spliced specimens shall be the same. In spliced specimens, it shall be located outside the length of the mechanical splice in both the bars (*see* Fig. 1).

The percentage elongation at maximum force shall be tested and measured according to IS 1608 (Part 1) outside the length of the mechanical splice on both sides of the connection. Both values shall be recorded and the largest shall be used to assess conformity.



Key

F Applied force

L Length of the mechanical splice (as defined in **3.4**)

L_1 Coupler length

L_2 2d where d is the nominal diameter of the reinforcing bar

L_3 Minimum free length for the measurment of percentage elongation at maximum force/slip

L_g Gauge length for the measurement of slip

FIG. 1 DEFINITION OF LENGTHS FOR MEASURING ELONGATION AND SLIP OF THE MECHANICAL SPLICE

B-4 Test Report

B-4.1 Each individual test report on both the spliced and un-spliced specimens shall include at least the following information:

a) Tensile strength;
b) Total percentage elongation at maximum force;
c) Load-extension curve to the smaller of 2 percent strain or the strain at specified tensile strength of the reinforcing bar; and
d) Location of failure for spliced specimen.

ANNEX C

(*Clause* 9.3)

METHOD OF SLIP TEST

C-1 PRINCIPLE

The slip (ΔL_s) across the mechanical splice shall be found as the difference between the measured gauge length after unloading the mechanical splice from a load level of at least 0.6 f_y (where f_y = specified minimum yield stress or 0.2 percent proof stress in IS 1786 for the grade of reinforcement bar to be spliced) and the gauge length prior to loading:

$$\Delta L_s = L_{g2} - L_{g1}$$

where

L_{g2} = gauge length measured after releasing the load; and

L_{g1} = gauge length measured after gripping the sample in the tensile testing machine and prior to loading.

C-2 PREPARATION OF TEST PIECE

The test piece shall be prepared in accordance with **10.2**. The gauge length of the extensometers shall be between ($L_1 + 2d$) and ($L_1 + 6d$), as close to ($L_1 + 2d$) as possible. The minimum sufficient free length of the test piece for the slip test (L_3) in millimeters shall be 250 + L, where L is the length of mechanical splice (*see* **3.4** and Fig. 1).

NOTE — Some types of extensometers have a fixed gauge length, which may not be equal to the length of the mechanical splice (*see* **3.4**). In case of choice, a shorter gauge length is preferable.

C-3 TESTING EQUIPMENT

C-3.1 The tensile testing machine to be used shall conform to IS 1608 (Part 1).

C-3.2 The extensometer used shall be of Class 1 or better and shall be in accordance with IS 12872. The extensometer used to determine the slip shall be at least a two-point (averaging) type, but preferably a three-point (averaging) type (*see* Fig. 2).

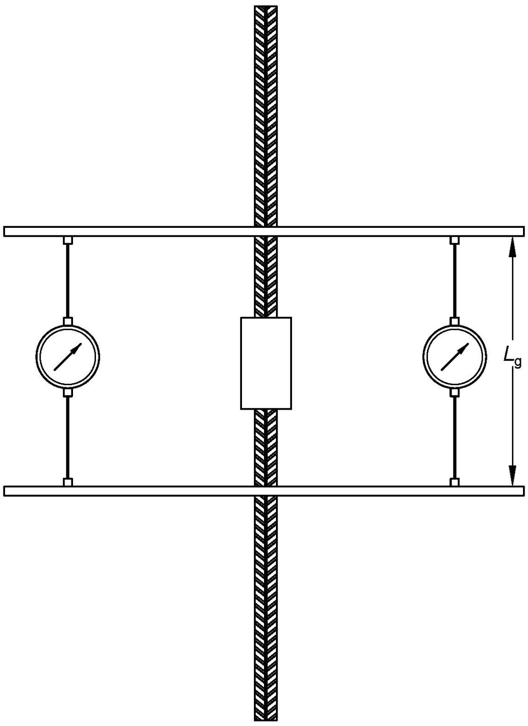


FIG. 2 PRINCIPLE OF SLIP MEASUREMENT

C-3.3 The slip measurement device shall be rigid enough, and fixed securely, so that the slip can be measured with an accuracy of not less than 0.01 mm.

C-3.3.1 The accuracy of slip measurement device should be checked periodically (for example, annually and always, if there is a change in the testing conditions) by performing the test on a control bar with the same gauge length. The measurement accuracy is computed as the sum of the accuracy of the extensometer (as stated by its manufacturer) plus the error that could be generated by the fixing devices. The measurement accuracy is the reading after the load is returned to zero.

C-4 TEST PROCEDURE

a) The test piece shall be gripped in the tensile 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 piece.

b) The slip measurement device shall then be attached such that the dial indicators are 180º apart in case of two-point extensometers and 120º apart in case of three-point extensometers. Zero them out.

c) The slip measurement shall be conducted with the minimum possible pre-load applied to the test piece. Any load applied to the sample during gripping shall not exceed 10 MPa.

NOTE — Preloading of the test piece will normally take most of the slip out. A preloading does not normally occur for spliced bars in a structure.

d) The gauges shall be set to zero after closure of the jaws of the tensile testing machine.

e) An axial tensile load shall be applied such that the tensile stress in the reinforcing bar equals 0.6 f_y (where f_y = specified minimum yield stress or 0.2 percent proof stress in IS 1786 for the grade of reinforcement bar to be spliced). The force to be applied shall be determined using the nominal cross-sectional area of the reinforcing bar. The load shall be maintained until a steady reading is obtained on both dial indicators, and shall not deviate from the theoretical load by more than ± 3 percent. The recommended maximum speed of loading is 500 MPa/min.

f) The load shall then be reduced to 10 MPa and the readings of the two/three extensometers, as applicable shall be taken.

g) Sum the value of the readings and divide the resultant sum by two or three as the case may be. The result shall be reported as total slip.

h) The slip measurement device shall then be removed and an axial tensile load sufficient to cause failure of the test piece shall be applied to it.

j) The load shall be recorded and the type and location of failure and any necking of the bar shall be noted. The maximum load attained shall be recorded as maximum test load.

ANNEX D

(*Clause* 9.4)

METHOD OF CYCLIC TENSILE TEST

D-1 PREPARATION OF TEST PIECE

The test piece shall be prepared in accordance with **B-1**.

D-2 TESTING EQUIPMENT

The testing equipment shall conform to IS 1608 (Part 1).

D-3 TEST PROCEDURE

D-3.1 The test specimen shall be subjected to 100 cycles of stress variation specified in **9.4**. One cycle is defined as an increase from the lower load to higher load and return. The load shall vary cyclically according to a wave-form of constant frequency. The frequency shall be 0.5 Hz for bar sizes ≥ 36 mm and 0.7 Hz for bars of smaller size.

D-3.2 If the specimen does not fail at the end of 100 cycles, the axial tensile load shall be increased statically to cause failure in the specimen and its static tensile strength capacity shall be determined in accordance with Annex B.

ANNEX E

(*Clauses* 9.5.1 *and* 9.5.2)

METHOD OF FATIGUE TEST

E-1 The purpose of fatigue testing of mechanical splices for steel reinforcing bars is to determine the fatigue strength of the mechanical splice. The fatigue performance of a mechanically spliced bar will normally be lower than that of the un-spliced bar.

E-2 PREPARATION OF TEST PIECE

The test piece for the fatigue test shall be prepared in accordance with **10.2** and shall be sufficiently long to ensure a free length between the grips of the testing machine, which is larger than the length of the mechanical splice.

E-3 LOW CYCLE FATIGUE TEST

E-3.1 Test Procedure

The fatigue test shall be conducted on the sample by loading it to + 173 MPa to - 173 MPa for 10 000 cycles. The load shall vary cyclically according to a waveform of constant frequency. The frequency shall be 0.5 Hz for bars of size ≥ 36 mm and 0.35 Hz for bars size < 36 mm. If the specimen does not fail at the end of 10 000 cycles, the axial tensile load shall be increased statically to cause failure in the specimen and its static tensile strength capacity shall be determined in accordance with Annex B.

E-4 HIGH CYCLE FATIGUE TEST

E-4.1 Principle

In the high cycle fatigue test, the test piece is subjected to an axial tensile load which varies cyclically according to a sinusoidal waveform of constant frequency in the elastic range.

E-4.2 Testing Equipment

The fatigue test shall be carried out by means of a hydraulic ram under load control. The fatigue testing machine shall be calibrated as per IS 1828 (Part 1) and the accuracy shall be ± 1 percent or better and the machine shall be capable of maintaining the upper stress level, σ_{Max} , within ± 2 percent of the specified value and the lower stress level, σ_{Min}, within ± 2 percent of the specified value.

E-4.3 Test Procedure

a) The test piece 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 test piece.

b) The temperature in the testing laboratory should be 27 °C ± 2 °C.

c) The test piece shall be subjected to sinusoidally varying axial tensile load with a stress range, $2\sigma_a$, of 60 MPa. The upper stress, σ_{Max}, in thatest shall be asspecified in **9.5.2** (*see* Fig. 3).

d) The frequency of load cycles shall be constant during the test and shall be between 1 Hz and 200 Hz.

NOTE — A frequency of less than 60 Hz normally gives an acceptable temperature of the samples throughout the test.

e) The test is terminated upon fracture of the test piece or upon reaching the specified number of cycles (2 000 000 cycles) without fracture.

f) If the test piece fails in the gripping zone, and the mechanical splice is still intact, the test may be continued after re-gripping the test piece.

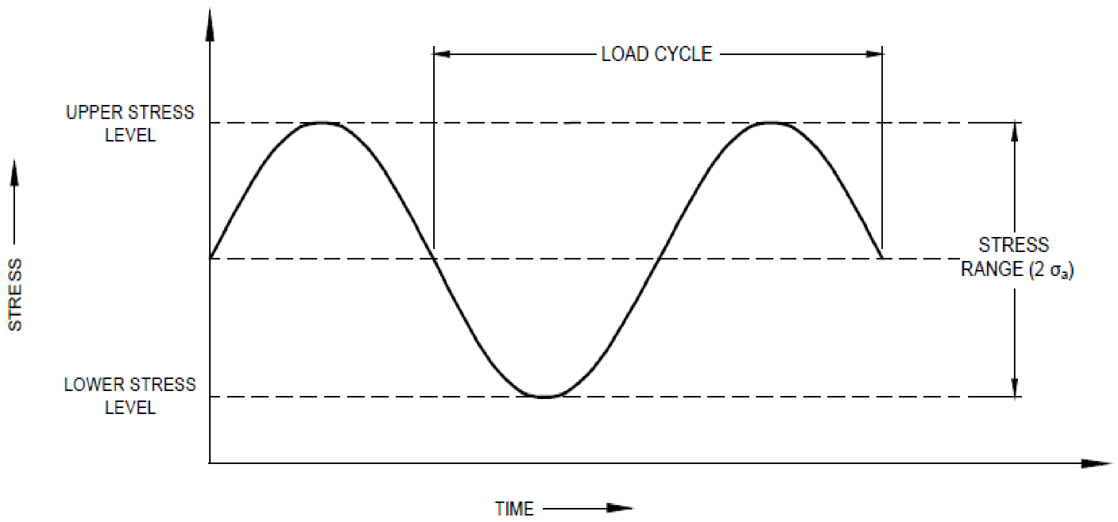


FIG. 3 LOAD CYCLE DIAGRAM FOR HIGH CYCLE FATIGUE TEST

ANNEX F

(*Clause* 11)

SAMPLING AND CRITERIA FOR CONFORMITY

F-1 ACCEPTANCE TESTS

F-1.1 Acceptance tests are carried out on samples selected from a lot for the purpose of acceptance of the lot.

F-1.2 Lot

In any consignment, all the reinforcement couplers of the same size, type, grade, class, material traceable to the same cast and manufactured under similar conditions of production shall be grouped together to constitute a lot. A lot shall represent a maximum number of 10 000 couplers.

F-1.3 For ascertaining the conformity of the lot to the requirements of the standard, samples shall be tested from each lot separately. The number of couplers to be selected from the lot shall depend on the size of the lot and shall be according to Table 1.

F-1.4 The couplers shall be selected at random from the lot and in order to ensure the randomness of selection, random number table shall be used. For guidance and use of random number tables, IS 4905 may be referred to.

F-1.4.1 *Static Tensile Test*

For the purpose of static tensile test, the number of samples given for the first sample in col (4) of Table 1 shall be taken from the lot and subjected to this test. A coupler failing to satisfy the requirements given in **9.2.1**, **9.2.1.1** (wherever applicable) or **9.2.2** shall be considered as defective. The lot shall be deemed to have satisfied the requirement if the number of defectives found in the first sample is less than or equal to the corresponding acceptance number given in col (6). The lot shall be deemed not to have met these requirements, if the number of defectives found in the first sample is greater than or equal to the corresponding rejection number given in col (7). If, however, the number of defectives found in the first sample lies between the corresponding acceptance and rejection numbers given in col (6) and (7), a second sample of the size given in col (4) shall be taken and examined for these requirements. The lot shall be considered to have satisfied these requirements if the number of defectives found in the cumulative sample is less than or equal to the corresponding acceptance number given in col (6), otherwise not.

F-2 TYPE TESTS

F-2.1 Type tests are intended to prove the suitability and performance of a new type of coupler or a new manufacturing process. Such tests therefore need to be applied only when a change is made in the type of the coupler or in manufacturing process conditions or crimping method or forging or threading machine.

F-2.1.1 *Slip Test*

For this type test, the manufacturer or the supplier shall furnish to the testing authority a minimum of three samples of coupler of all sizes, grades, types and classes (selected preferably from a regular production lot).

F-2.1.1.1 The samples so selected shall be tested for compliance with requirements of slip test as given in **9.3**.

F-2.1.1.2 If all the samples pass the requirements of slip test, the type of coupler or the change under consideration shall be considered to be eligible for type approval which shall be normally valid for a period of one year.

F-2.1.1.3 At the end of the validity period (normally one year) or earlier, if necessary, the testing authority may call for fresh samples for type test for the purpose of type approval.

Table 1 Scale of Sampling and Criteria for Conformity

(*Clauses* F-1.3 *and* F-1.4.1)

Sl No.	No. of Couplers in the Lot	Sample Number	Sample Size	Cumulative Sample Size	Acceptance Number	Rejection Number
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Up to 500	First	5	5	0	2
		Second	5	10	1	2
ii)	501 to 3 200	First	8	8	0	2
		Second	8	16	1	2
iii)	3 201 to 10 000	First	13	13	0	2
		Second	13	26	1	2

F-2.1.2 *100 Cycle Test*

For this type test, the manufacturer or the supplier shall furnish to the testing authority a minimum of three samples of coupler of the largest size, three samples of the medium size and three samples of the smallest size of each grade (selected preferably from a regular production lot).

F-2.1.2.1 The samples so selected shall be tested for compliance with requirements of 100 cycle test as given in **9.4**.

F-2.1.2.2 If all the samples pass the requirements of 100 cycle test, the type of coupler or the change under consideration shall be considered to be eligible for type approval which shall be normally valid for a period of five years.

F-2.1.2.3 At the end of the validity period (normally five years) or earlier, if necessary, the testing authority may call for fresh samples for type test for the purpose of type approval.

F-2.1.3 *Low Cycle Fatigue Test*

For this type test, the manufacturer or the supplier shall furnish to the testing authority a minimum of three samples of coupler of the largest size, three samples of the medium size and three samples of the smallest size of each grade (selected preferably from a regular production lot).

F-2.1.3.1 The samples so selected shall be tested for compliance with requirements of low cycle fatigue test as given in **9.5.1**.

F-2.1.3.2 If all the samples pass the requirements of low cycle fatigue test, the type of coupler or the change under consideration shall be considered to be eligible for type approval which shall be normally valid for a period of five years.

F-2.1.3.3 At the end of the validity period (normally five years) or earlier, if necessary, the testing authority may call for fresh samples for type test for the purpose of type approval.

F-2.1.4 *High Cycle Fatigue Test (for Class H Coupler only)*

For this type test, the manufacturer or the supplier shall furnish to the testing authority a minimum of three samples of coupler of the largest size, three samples of the medium size and three samples of the smallest size of each grade (selected preferably from a regular production lot).

F-2.1.4.1 The samples so selected shall be tested for compliance with requirements of high cycle fatigue test as given in **9.5.2**.

F-2.1.4.2 If all the samples pass the requirements of high cycle fatigue test, the type of coupler or the change under consideration shall be considered to be eligible for type approval which shall be normally valid for a period of five years.

F-2.1.4.3 At the end of the validity period (normally five years) or earlier, if necessary, the testing authority may call for fresh samples for type test for the purpose of type approval.

ANNEX G

(*Clause* 13)

QUALITY CONTROL CHECKS AT SITE

G-1 The quality control checks as given in **G-2** to **G-6** shall be followed for mechanical splicing systems with different types of couplers.

G-2 QUALITY CHECKS FOR THREADING OF REINFORCING BARS AT SITE

The following shall be the minimum process requirement for threading of reinforcing bars at site. Each manufacturer may stipulate additional processes that should also be followed.

a) *Cutting* — The ends of reinforcement bars shall be sawn cut or square cut by suitable cutting machine to get a perfect plain end surface, perpendicular to the axis of the bar. The tolerance to perpendicular axis cutting to be as per manufacturer's design and recommendation. Disc-cutting or gas cutting is not permitted as these raise quality risks due to over-heating of rebars and non-perpendicular cut.

   NOTE — The tolerance to perpendicularity is generally maintained within ± 3 degrees.

b) *Cold forging (wherever applicable)* — After cutting, the ends of the bar shall be hydraulically enlarged by cold forging so that the area of cross-section after threading shall not be less than the area of cross-section of the parent bar. The length of cold forging shall be adequate for proposed thread length as per manufacturer's design. In case ribs of reinforcing bar are too big, these can be smoothened before the cold-forging activity so as to ensure uniform geometry throughout the required length, as per manufacturer's recommendation.

   Double cold forging of bars is not permitted. In case of improper cold forging, the end of the bar shall be square or sawn cut and fresh cold forging shall be undertaken. A visual inspection shall be carried out after cold forging to ensure that there is no obvious cracking of the rebar.

c) *Threading process to create the required profile on the end of the reinforcing bar* — The threads in bars shall be parallel type in case of parallel threaded couplers and tapered in case of taper threaded couplers as per manufacturer's design and recommendations. The thread length and depth shall also be as per manufacturer's design.

   The major diameter of threads on parallel threaded reinforcing bars shall be checked by 'GO' and 'NO GO' gauges. Threads that failed the control shall be cut-off and the rebars shall be reprocessed.

d) *Proof load check of threaded reinforcing bars* — Every threaded reinforcing bar end shall undergo a load test prior to actual use. The minimum test loading shall be equivalent to 80 percent of the minimum specified yield strength/proof strength of reinforcing bar. The proof load test equipment shall have digital display for automatic setting and control of pressure and proof load imparted to each reinforcing bar. The equipment shall be managed in automatic mode with display of setting pressure and actual pressure applied, and shall be accepted if applied pressure is equal to or higher than setting pressure. A positive indication shall be punched on the reinforcing bar by the load testing machine to indicate that this operation has been carried out and the bar end has qualified for specified strength. No manual punching of the bars shall be permitted.

e) *Disengagement test* — Disengagement test as given in **9.2** shall be carried out as per the frequency given in Annex F.

f) After threading is completed, the threaded length of the bars shall be protected by providing plastic caps before taking the bars out of the fabrication shop. This cap shall be removed only when next bar is to be attached and then cleaned before joining the next bar.

G-3 SWAGING OF THE REINFORCING BARS WITH SWAGED COUPLER

G-3.1 Swaging of reinforcing bars shall be done at site. The various stages involved in swaging shall be as given below:

a) Straighten and clean the rebars to be swaged.
b) Each rebar end to be marked at a distance equal to half the length of swaging coupler.
c) Swaging to be done from centre towards the end of the coupler. The hydraulic jack used for swaging operation should have adequate dies and preparation as per

manufacturer’s design and recommendation. The pressure to be applied for swaging shall be as per manufacturer’s design and recommendation.

G-4 SPLICING OF THE REINFORCING BARS WITH BOLTED COUPLER

The bolted coupler’s dimensions, number of bolts, etc, shall be as per manufacturer’s design. The coupler shall be provided with suitable arrangement inside the coupler to ensure that the connecting reinforcing bars are at centre. This is particularly important to ensure proper tightening and connection. The first rebar to be inserted in the bolted coupler shall be pushed inside the coupler until the centre of the coupler. The tightening of the bolts shall then to be carried out in accordance with the manufacturer’s installation instruction.

In case the reinforcing bars inside the fixed coupler are not straight or the bolts do not shear-off, it is recommended to gas cut the reinforcing bar and replace the coupler. In case some bolt heads do not shear-off, but the recommended torque specified by manufacturer’s design is achieved, it is acceptable to install the coupler.

G-5 SPLICING OF REINFORCING BARS WITH GROUTED COUPLERS

The manufacturer’s installation instructions shall be followed including the specification and preparation of the non-shrink grout to be used. Alternative grouts, even with the same compressive strength, may not provide equivalent performance, and therefore shall not be permitted. The location of the starter bars and the couplers shall be carefully controlled using templates to ensure the position and alignment. Prior to installation of the grouted coupler, the grout material’s quality checks including compressive strength shall be carried out. Also, the length of the starter bar should be verified to ensure sufficient engagement. A visual check on the inside of the grout coupler shall also be carried out to ensure absence of foreign materials. Formwork and seals may be necessary to ensure that the grout is confined in the areas where it is intended to be used. Temporary supports for the elements shall be left in place until the minimum grout strength is achieved, as per manufacturer’s recommendations.

G-6 SPLICING OF REINFORCING BARS WITH HYBRID COUPLERS

The installation instructions shall be in accordance with the combination of two respective splice methods, given in **G-2** to **G-5**.

ANNEX H

(*Foreword*)

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