British Standard

BRITISH STANDARD

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Incorporating amendments issued January, 1971 (AMD 679), December, 1972 (AMD 1039) and September, 1982 (AMD 4052)

Specification for

The use of high strength friction grip bolts in structural steelwork metric series —

Part 1: General grade

UDC 621.882:624.014.2:693.814

Co-operating organizations

The committee responsible for the preparation of this British Standard consists of representatives from the following Government departments and scientific and industrial organizations:

Association of Crane Makers
Black Bolt and Nut Association of Great Britain
British Bolt, Nut, Screw and Rivet Federation
British Constructional Steelwork Association
British Steel Industry
Greater London Council
Ministry of Defence, Army Department
Ministry of Transport, Road Research Laboratory
Individual consultants

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Foreword

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 9,000, fully indexed and with a note of the contents of each, will be found in the BSI Catalogue which may be purchased from BSI Sales Department. The Catalogue may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

BS 449, *The use of structural steel in building — Part 2: Metric units*.

BS 4395, *High strength friction grip bolts and associated nuts and washers for structural engineering. Metric series — Part 1: General grade*.

BS....., *Podger spanners. Metric series*[1)].

BS 3294-1[2)] gives rules for the use in structural steelwork of high strength friction grip bolts of the general grade specified in BS 3139-1[3)]. Both those standards are in imperial units.

The present standard is now issued, in metric terms, to cover the use of general grade bolts as specified in BS 4395-1[4)]. The technical content is substantially that of BS 3294-1[2)].

The tightening methods specified in the standard both aim at a shank tension of at least the proof load. Tests and experience show that the excess over proof load obtained in practice is not detrimental. The design factors also are based on extensive experimental work. Variations in them are permissible, under the engineer's authority, where the structure, the materials or other considerations demand them.

The use of higher grade bolts will be covered by Part 2 (Parallel shank bolts) and Part 3 (Waisted shank bolts), which are in course of preparation.

The metric values are given in SI units, details of which are to be found in BS 3763[5)] and PD 5686[6)].

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Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 8, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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1) In course of preparation.

2) BS 3294, "The use of high strength friction grip bolts in structural steelwork", Part 1, "General grade bolts".

3) BS 3139, "High strength friction grip bolts", Part 1, "General grade bolts".

4) BS 4395, "High strength friction grip bolts", Metric series, Part 1, "General grade".

5) BS 3763, "International system (SI) units".

6) PD 5686, "The use of SI units".

1 General

1.1 Scope

This Part of this British Standard specifies requirements for the use of high strength friction grip bolts of the general grade, as specified in BS 4395-1[7], in friction grip connections in structural steelwork which complies with the requirements of BS 449-2[8]. The standard also specifies requirements for the use of high strength bolts as ordinary bolts (see **1.3**).

1.2 Definitions

For the purposes of this Part of this British Standard the following definitions apply:

1.2.1
high strength friction grip bolts

bolts of high tensile steel, used in conjunction with high strength nuts and hardened steel washers, which are tightened to a specified minimum shank tension so that transverse or axial loads or both can be transferred between the connected parts otherwise than by shear in, or bearing on, the bolts

1.2.2
grip

the total thickness of steel parts, excluding washers, to be held together

1.2.3
ply

a single thickness of steel forming part of a structural joint

1.2.4
length of bolt

the overall dimension from the underside of the bolt head to the extreme end of the shank, including any chamfer or radius

1.2.5
effective interface

a common contact surface between two load-transmitting plies, excluding any packing pieces, through which the bolt passes

1.2.6
slip factor

the ratio of the load, per effective interface, required to produce slip in a pure shear joint to the nominal shank tension (i.e. proof load) induced in the bolt or bolts

1.2.7
load factor

the numerical value by which the load which would cause slip in a joint is divided to give the permissible working load on the joint

1.2.8
the engineer

the person responsible for the design and satisfactory completion of the structure, as covered by this specification

1.3 Conditions of use

General grade bolts which are intended for use, within the definition of high strength friction grip bolts, in a particular application with a tightening procedure shall be used in accordance with the requirements of clauses **2** to **5**.

[7] BS 4395, "High strength friction grip bolts", Metric series, Part 1, "General grade".

[8] BS 449, "The use of structural steel in building. Part 2, Metric units".

General grade bolts which are intended for use as ordinary high strength bolts, i.e not pre-loaded to any specific load, shall only comply with the following requirements.

1) The design of connections using high strength bolts as ordinary bolts shall be in accordance with BS 449-2[9], as they are not being used with the definition of high strength friction grip bolts.

2) The nuts to be used shall be in accordance with BS 4395-1[10].

3) For subsequent identification purposes the hardened steel washers specified in BS 4395-1[10] shall not be used.

2 Materials and dimensions

2.1 Bolts, nuts and washers

2.1.1 Dimensions and properties. The bolts, nuts and washers shall comply with the requirements of BS 4395-1[10].

2.1.2 Storage. Care shall be taken that bolts, nuts and washers are stored in dry weatherproof conditions in such a way that they will not deteriorate. They are normally supplied by the manufacturers with a light coating of oil which is not detrimental and should not be removed. In this condition they are ready for normal use, and any further treatment at works or site is not recommended.

2.2 Length of bolt

The minimum length of the bolt shall be calculated by adding to the grip the allowance given in Table 1.

The figures given in Table 1 allow for the thickness of one nut and one flat washer and for sufficient protrusion of the bolt end.

When other washer arrangements are used (including taper washers as in **4.1**) an additional allowance will be required when calculating the length of a bolt.

Table 1 — Bolt length allowances

Nominal size and thread diameter	Allowance to be added to the grip
	mm
M 12	22
M 16	26
M 20	30
M 22	34
M 24	36
M 27	39
M 30	42
M 36	48

3 Design

3.1 Design procedure

The following design procedures are consequent upon the tightening of every bolt to at least its minimum shank tension as given in Table 2.

3.1.1 Shear connections. In connections subject only to shear in the plane of the friction faces, the number of friction grip bolts and their disposition shall be such that the resulting load at any bolt position does not exceed the value:

$$\frac{\text{slip factor}}{\text{load factor}} \times \text{number of effective interfaces} \times \text{proof load of one bolt.}$$

[9] BS 449, "The use of structural steel in building". Part 2, "Metric units".

[10] BS 4395, "High strength friction grip bolts and associated nuts and washers for structural engineering. Metric series", Part 1, "General grade".

In this expression, the load factor shall be taken as **1.4** for structures and materials covered by BS 449-2[11]. Where the effect of wind forces on the structure has to be taken into consideration, this load factor may be reduced to **1.2** provided the connections are adequate when wind forces are neglected. For structures covered by other specifications, the load factor may be increased at the discretion of the engineer.

Where surfaces in contact comply with the conditions set out in **3.2.1**, the slip factor shall be taken as 0·45. Where the surfaces are treated, the requirements of **3.2.2** shall apply.

No additional factor is required to take account of fatigue conditions.

No additional factor is required to take account of packings within a joint. Proof loads of bolts are given in Table 2.

3.1.2 Connections subject only to external tension in the direction of the bolt axes. In these cases, the maximum, permissible external tension on any bolt shall not exceed 0·6 of the proof load of the bolts used, as given in Table 2. However, where fatigue conditions are involved, the maximum permissible external tension on any bolt shall be limited to 0·5 of the proof load.

3.1.3 Connections subject to external tension in addition to shear. An externally applied tension in the direction of the bolt axes reduces the effective clamping action of a bolt which has been tightened to induce shank tension. To allow for this effect, the permissible resulting load at any bolt position, as calculated from the expression in **3.1.1**, shall be reduced by substituting for the proof load of the bolt an effective clamping force obtained by subtracting 1.7 times the applied external tensile load from the proof load.

Under this rule, the effective clamping action of a bolt is considered to cease when the externally applied tension reaches 0·6 of its proof load, which is the maximum permissible value (see **3.1.2** above).

Table 2 — Proof loads of bolts (minimum shank tensions)

Nominal size and thread diameter	Proof load (minimum shank tension)
	kN
M 12	49.4
M 16	92.1
M 20	144
M 22	177
M 24	207
M 27	234
M 30	286
M 36	418

NOTE 1 The proof loads in this table are those specified in Table 4 of BS 4395, "High strength friction grip bolts and associated nuts and washers for structural engineering. Metric series", Part 1, "General grade".
NOTE 2 The torque necessary to induce a specified tension is determined by actual site conditions and equipment.
NOTE 3 For calibration purposes, the minimum shank tensions are to be increased by 10 % (see **4.3**).

3.2 Surfaces in contact

3.2.1 Untreated surfaces. At the time of assembly, the surfaces in contact shall be free of paint or any other applied finish, oil, dirt, loose rust, loose scale, burrs and other defects which would prevent solid seating of the parts or would interfere with the development of friction between them. Tight mill scale is not detrimental.

3.2.2 Treated surfaces. If the surfaces in contact are coated or otherwise treated, including the use of a machined surface, it shall be the responsibility of the engineer to determine the slip factor for use in **3.1.1** by a series of tests such as that recommended in Appendix A. The slip factor used shall be obtained as follows:

$$\text{Slip factor} = \frac{\text{Slip load}}{2 \times \text{specified proof load of one bolt} \times \text{number of bolts}}$$

[11] BS 449. "The use of structural steel in building. Part 2, Metric units".

where the slip load is as defined in Appendix A. The figure of 2 in the denominator takes account of the existence of two interfaces. The method of tightening the bolts in the test joints shall be the same as that in the assembly of the structure.

3.3 Holes in members

All holes shall be drilled and burrs shall be removed. Where the number of plies in the grip does not exceed three, the nominal diameters of the holes shall be 2 mm larger than those of the bolts for bolt diameters up to 24 mm, and 3 mm larger than those of the bolts for diameters larger than 24 mm. Where the number of plies in the grip exceeds three, the nominal diameters of the holes in the two outer plies shall be as above and the nominal diameters of the holes in the inner plies shall be not more than 3 mm larger than those of the bolts.

Where high strength friction grip bolts are used, the deduction in cross-sectional area of connected tension members shall be in accordance with the appropriate British Standard except that, in calculating the area to be deducted, the diameter of the hole shall be used. No deduction shall be made in the case of compression members.

The distance from the centre of any hole to the edge of a member and the distance between the centres of the holes shall be in accordance with the requirements of the appropriate British Standard.

3.4 Minimum ply thickness

In any joint using high strength friction grip bolts no outer ply, and wherever possible no inner ply, shall be less in thickness than half the bolt diameter or 10 mm whichever is smaller, unless it can be demonstrated to the satisfaction of the engineer that any consequent limitations to the performance of the joint owing, for example, to crumpling, tearing, buckling or bending of plies, to corrosion between plies or to limited extensibility of short bolts are adequately catered for.

NOTE The problem of limited extensibility is not peculiar to the presence of thin plies but may arise with any bolt where the grip is small and where there is only a short length of thread between the bolt head and the face of the nut.

In connections using high strength friction grip bolts, no outer ply shall be smaller in thickness than half the bolt diameter or 10 mm whichever is less.

Wherever possible, this condition for minimum thickness shall be observed for inner plies.

4 Assembly

4.1 General

Where plane parallel surfaces are involved, each bolt-and-nut assembly shall include one washer, placed under the bolt head or the nut, whichever is to be rotated during tightening.

The rotated bolt head or nut shall always be tightened against a surface normal to the bolt axis; this will require the use of an appropriate tapered washer where the surfaces are not parallel. Such a washer shall also be used under the non-rotated component except where the angle between bolt axis and contact surface is within the limits of 87° and 93°. Tapered washers shall be correctly positioned.

No gasket or other flexible material shall be placed between the plies. Holes in parts to be joined shall be sufficiently well aligned to permit bolts to be freely inserted. Driving of bolts is not permitted. Nuts shall be so placed that their identification marks are clearly visible after tightening.

Bolts and nuts shall always be tightened in a staggered pattern and, where there are more than four bolts in a joint, from the middle of the joint outwards. High strength friction grip bolts, nuts and washers may be used temporarily to facilitate assembly during erection of a structure; if they are so used, care shall be taken that there is no deterioration of the thread surfaces which will affect the torque-tension relation, and final tightening shall be in the correct pattern for the complete joint.

If after final tightening a bolt or nut is slackened off for any reason, the bolt, nut and washer or washers shall be discarded and not re-used.

The method of tightening to be employed for all bolts shall be that described in **4.2** wherever possible.

The method described in **4.3** may be used when adequate calibration facilities are available.

Control by any other means is not precluded by this specification provided the shank tension attained is at least equal to that given in Table 2.

4.2 The part-turn method of tightening

When bolts and nuts are tightened by the part-turn method, the following procedure shall be adopted:

On assembly of the joint, all bolts and nuts are subjected to preliminary tightening to bring the joint surfaces into close contact. Such a tightening is not intended as a corrective for faulty workmanship in the assembled plies. For bolts up to and including 24 mm in diameter, this can usually be achieved by tightening with spanners complying with BS....[12)].

Power-operated wrenches may be used and will probably be required for larger bolts.

After completion of the preliminary tightening of all nuts in a joint, permanent marks are made on each nut and the protruding threads of its bolt to record their relative positions. Each nut is then finally tightened, preferably with a power-operated wrench, so that it turns relative to its bolt by the amount given in Table 3.

Table 3 — Final tightening of nuts

Nominal size and thread diameter of bolt	Grip of bolt for rotation of the nut (relative to the bolt shank)	
	Not less than ½ turn	Not less than ¾ turn
	mm	mm
M 16	Up to 115	—
M 20	Up to 115	Over 115 to 225
M 22	Up to 115	Over 115 to 275
M 24	Up to 160	Over 160 to 350
M 27	Up to 160	Over 160 to 350
M 30	Up to 160	Over 160 to 350
M 36	Up to 160	Over 160 to 350

NOTE 1 With the amount of nut rotation specified in the above table, a bolt tension at least equal to the proof load will be attained.
NOTE 2 This method of tightening is not recommended for M 12 bolts.

4.3 The torque-control method of tightening

When bolts and nuts are tightened by the torque-control method, the following procedure shall be adopted.

This method requires the use of a calibrated tightening device, either a power-operated or a hand-operated torque wrench. The bolt and nut are tightened to a minimum bolt tension equal to the proof load. The torque necessary to induce this tension is determined by the actual site conditions.

Where there are several bolts in a single joint, the wrench is re-applied to tighten up bolts previously tightened which may have lost tension through tightening of subsequent bolts, until all are finally tightened to the prescribed torque.

The recommendations of the wrench manufacturer should be followed. It is essential to ensure that the wrench is maintained in proper working condition and calibration. The calibration is as follows.

The tightening equipment, whatever its type or pattern, shall be calibrated regularly at least once per shift, and more frequently if in the engineer's opinion conditions of site and usage so demand. The calibration shall consist of tightening a sample bolt (which thereafter shall not be used either for calibration or structural purposes) against a load cell or similar device capable of measuring the shank tension induced. The equipment shall be adjusted to give a shank tension 10 % higher than the minimum given in the second column of Table 2, by the means provided either in the wrench or by ancillary equipment supplied or recommended by the wrench manufacturer.

The equipment shall be recalibrated if there is a change in the diameter of bolt being used, or if there is a change in grip length exceeding one fifth of that used for calibration.

With air-operated wrenches, where stall or cut-off is controlled by air pressure, it is recommended that a working time of 10 s to 15 s be used to attain the required shank tension. The nut shall in any case be kept in motion throughout the calibration period. The length of hose between wrench and compressor shall be the same when calibrating as when in actual use; the length between wrench and reducing valve shall be as short as possible, and not more than 3 m.

[12)] BS ...., "Podger spanners. Metric series" (in course of preparation).

The load cell or similar device shall be checked for register and accuracy at intervals as recommended by the manufacturer.

5 Inspection

5.1 Inspection procedure

It shall be ascertained that an appropriate hardened washer has been fitted under every bolt head and nut where one is required (see **4.1**). Where a tapered washer is required, it shall be of the correct taper and properly positioned.

Where the part-turn method of tightening has been used it shall be ascertained that the procedure of **4.2** has been correctly followed and that each bolt, or nut, has been finally tightened by the correct amount.

Where the torque-control method of tightening has been used, it shall be ascertained that the wrench has been correctly calibrated and that the correct minimum tension has been induced in every bolt.

With tightening by torque control, a routine sampling procedure is required for inspection purposes; the details must be agreed with the engineer. It is suggested that a suitable sample will consist of at least 32 bolts, selected at random from a batch such as that comprised in the daily work of one gang. The torque required to tighten these bolts further may be measured by means of a calibrated hand wrench or impact tool. If the torque for any bolt is less than that found in the calibration to be required to induce the correct shank tension, every bolt in the batch shall be examined, and tightened further if necessary. Alternatively, the sample bolts may be checked by a calibrated wrench set to produce a torque 5 % in excess of that required. Such a wrench should not move the nut; if it does, every bolt shall be examined and tightened if necessary.

Where any other means of control has been used it shall be ascertained that the minimum shank tension has been attained.

Bolts and nuts found to be in any way defective shall be discarded and replaced by new ones.

Appendix A Test for slip factor

A.1 Form of test specimen. The form of test specimen recommended on the ground of reliability of results consists of two inner or tongue plates bolted between two cover plates (see Figure 1). Care should be taken to ensure that the inner plates used are the same in thickness; this can be ensured by cutting them consecutively from the same piece of material and assembling them in the original relative positions. The longitudinal axis of the specimens should be in the direction of rolling of the material. Care should be taken in setting up the specimen to ensure that the bolts are not already in bearing.

The tests should be done with not less than two bolts on each side of the joint for each thickness of plate. Not less than three tests should be made for each type of joint. The dimensions of the plate should be such that the stress does not reach the yield point of the material. The size of the plates used in a test to determine slip factor is governed principally by the capacity of the testing machine available. Attention is drawn to the limits of outer ply thickness in **3.4**.

A.2 Time of testing. At least 18 h should preferably elapse after the completion of the tightening of the bolts in the test specimen, before it is tested. In exceptional circumstances the specimen may be tested after 2 h and the slip load to be assumed in determining the slip factor shall be taken as 95 % of the test result.

A.3 Rate of loading. The load should be applied at a uniform rate of approximately 50 kN/min provided that slip does not occur in less than 3 min.

A.4 Slip load. The slip load shall be taken as the load required to produce a displacement between adjacent points in an inner plate and a cover plate, in the direction of the applied load, in the plane of the effective interfaces of the joint of at least 0·1 min. The slip load used for determining the slip factor should be taken as the least of the three or more test results obtained, except that if in the opinion of the engineer one result is unrepresentative, a further series of tests may be carried out.

NOTE The characteristics of some finishes may cause a slip of more than 0·025 mm at the working load (which is 0·7 of the slip load). The engineer should take note of this and make such adjustment to the slip factor as he considers necessary for the application concerned.

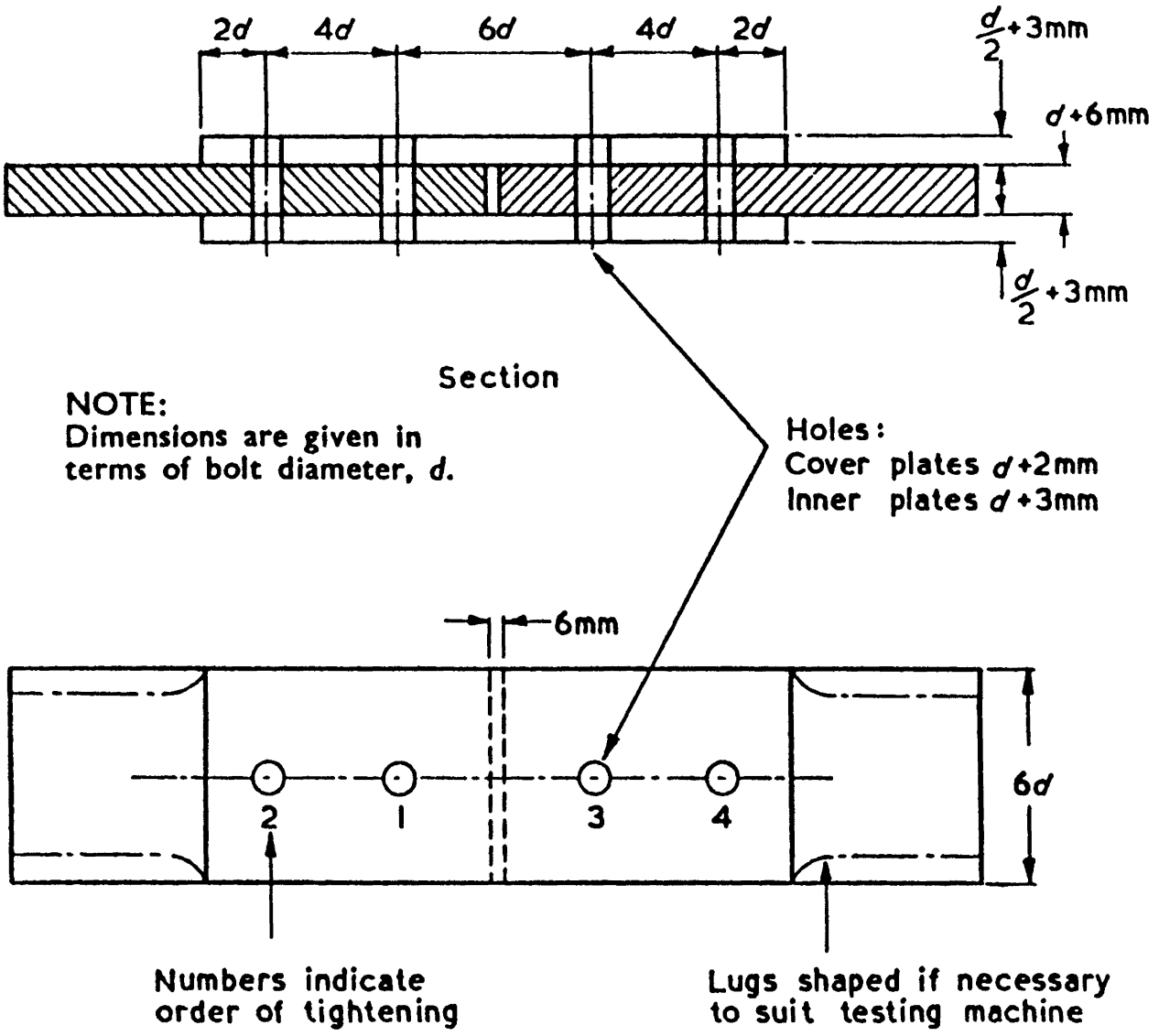

Figure 1 — Typical test specimen

British Standards

The following are available on application:
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