# British Standard

**BRITISH STANDARD**

**BS 4447:1973**

*Incorporating Amendment No. 1*

CONFIRMED
DECEMBER 1990

## Specification for

# The performance of prestressing anchorages for post-tensioned construction

UDC 624.012.46:693.564:4:693.565.8:620.172.2

# Co-operating organizations

The Cement, Lime and Gypsum Products Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations.

Association of Consulting Engineers
British Precast Concrete Federation*
British Quarrying and Slag Federation
British Railways Board
British Ready Mixed Concrete Association
British Steel Corporation*
Cement and Concrete Association*
Cement Makers' Federation
Chemical Industries Association
Concrete Society Ltd*
Department of the Environment*
Department of the Environment — Building Research Establishment
Federation of Civil Engineering Contractors*
Greater London Council
Gypsum Products Development Association
Institution of Civil Engineers*
Institution of Municipal Engineers
Institution of Structural Engineers*
Institution of Water Engineers
National Federation of Building Trades Employers
The Royal Institution of Chartered Surveyors
Sand and Gravel Association
Society of Chemical Industry
Welwyn Hall Research Association

The Government department and scientific and industrial organizations marked with an asterisk in the above list, together with the following were directly represented on the committee entrusted with the preparation of this British Standard.

Electricity Council, The Central Electricity Generating Board and the Area Boards in England and Wales

This British Standard, having been approved by the Cement, Lime and Gypsum Products Industry Standards Committee, was published under the authority of the Executive Board on 12 October, 1973



First published March 1969
First revision October 1973

The following BSI references relate to the work on this standard:
Committee reference CEB/22
Draft for comment 71/11660

**ISBN 0 580 07865 5**

**Amendments issued since publication**

| Amd. No. | Date of issue | Comments |
|---|---|---|
| 6194 | November 1990 | Indicated by a sideline in the margin |
| | | |
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# Contents

# Foreword

This British Standard was first published in March 1969. As a result of international experience it has been found that some revision to the methods covered were necessary and the standard has therefore been revised.

This standard describes three complementary methods of testing prestressing anchorages for post-tensioned concrete construction using wire, strand or bar tendons. These three methods of test are:

1) the test of static efficiency and of elongation of the anchored tendon;

2) the test of dynamic behaviour of the anchored tendon;

3) the test of force transfer to the end block.

The standard methods are intended to supply basic information on the performance of an anchorage under specified conditions, but it remains the responsibility of the structural engineer to ensure that the anchorage system is detailed and used correctly in each application and according to the appropriate Codes of Practice. It is the responsibility of the manufacturer to maintain such quality controls as are necessary.

It is not however practical for the anchorage manufacturer to carry out tests for all anchorage types and for all varieties of tendon material available in sufficient numbers to allow the characteristic efficiency and the characteristic elongation to be calculated for all the alternatives, since a minimum of twenty tests would be required in each case. However, where the client nominates a tendon material for which the manufacturer has no test evidence, the manufacturer shall be entitled to request that he carry out up to three tests of the type described in Clause **4** using the nominated tendon before any performance figures are given. The apportionment of the cost of these tests, including all labour, materials, transport and fees, shall be agreed between the client and the anchorage manufacturer.

To comply with this standard, the anchorage when tested with a specific tendon must comply with the requirements of Clause **4**.

Anchorages which do not comply with the figure in Clause **4** may be used at proportionately reduced stressing forces by agreement between the manufacturer and the client.

There are a number of practical considerations that can affect the efficiency of an anchorage which should be taken into account at the design stage of the structure. Some of these are:

1) the ease of ensuring full compaction of the concrete around the anchorage;

2) the degree of misalignment of the anchorage relative to the tendon axis;

3) the surface condition of the anchorage and tendon;

4) the possibility of extreme environmental conditions;

5) the correct reinforcement of the end block in accordance with good engineering practice. The design of end blocks is outside the scope of this standard.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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**Summary of pages**

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, 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.

## 1 Scope

This British Standard specifies standard test procedures to be used in establishing the satisfactory performance of prestressing anchorages of various types. Such fundamental data, being presented in certified form, may then be used in design with the knowledge that all the information has been derived from approved test procedures. These methods are not intended to be adopted as routine acceptance tests.

The Committee considers this approach to be practical, non-restrictive and well suited to the conditions existing in the industry without restricting future anchorage development.

NOTE The titles of the British Standards referred to in this standard are listed on the inside back cover.

## 2 Definitions

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

**2.1**
**anchorage**

a mechanical device designed to retain the force in a stressed tendon

**2.2**
**anchorage system**

a combination of the anchorages, the tendons and the reinforcement acting together within the end block to transmit the force in an ungrouted tendon to the prestressed concrete member

**2.3**
**anchorage type**

anchorages of varying capacity but of the same design form

**2.4**
**end block**

the end section of a prestressed concrete member which is specially reinforced to resist the secondary stresses created by the anchorages

**2.5**
**tendon**

an extensible steel element or group of elements used to impart prestress to a concrete member

## 3 General

The maximum load on the anchorage generally occurs during the tensioning operation when a prestressing force is applied. During and after lock-off, the prestressing force reduces for various reasons. This reduction can be caused by relaxation, concrete shrinkage and creep, anchorage pull-in and elastic shortening of the member where the prestressing force is applied successively through several separate stressing operations. In the case of a fully bonded tendon, after the grout has hardened, any relaxation or creep within the anchorage zone will not affect the prestressing force beyond the end block since any change in force will be maintained by the bond between the tendon and the concrete. Similarly, any change in the force in fully bonded tendons due to an externally applied load will likewise be distributed by bond and will not increase the anchorage force.

In the case of an unbonded tendon, any reduction in the anchorage force due to creep or relaxation will result in a lower prestressing force throughout the member. Any change in the force in the tendon due to an externally applied load could be transmitted directly to the anchorage. Therefore, in the case of unbonded tendons, it is essential to ensure that the anchorage and the end block are capable of retaining the final prestressing force for an indefinite period and that they will withstand a specified cyclic loading depending on the type of application.

## 4 Minimum performance

In order to comply with this standard, single anchorages when tested with a tendon of a quality not lower than the lowest characteristic strength specified in BS 4486 or BS 5896 shall have the following minimum performances in at least three consecutive tests.

1) The actual efficiency of the anchored tendon shall not be lower than 92 %. The actual efficiency of the anchored tendon shall be taken as the ratio of the failure force as measured in Clause **5** to the average ultimate tensile strength of the tendon. The average ultimate tensile strength shall be determined from three specimens taken at random from the total length of the tendon used in the tests and tested in accordance with the methods specified in BS 18 or BS 4545 as appropriate.

2) The percentage elongation at maximum load as measured in Clause **5** shall not be less than 1.8 %.

3) For an unbonded tendon, when tested in accordance with the method given in Clause **6**, not more than 5 % of the initial cross sectional area of the tendon shall fail.

4) The anchorage system tested in accordance with the test given in Clause **7** shall be capable of supporting a load of 1.1 $f_{pu}$ (where $f_{pu}$ is the characteristic strength of the tendon for which the anchorage is designed).

In the case of a range of anchorages of various capacities but of similar design form using the same size and type of tendon material, the intermediate sizes shall be deemed to comply with the requirements of the whole standard provided at least three consecutive test results in each of two sizes comply.

## 5 Test of load efficiency and of elongation of the anchored tendon

**5.1 Description of test.** This is a short term static tensile test carried out on an anchorage attached to a tendon (see Figure 1).

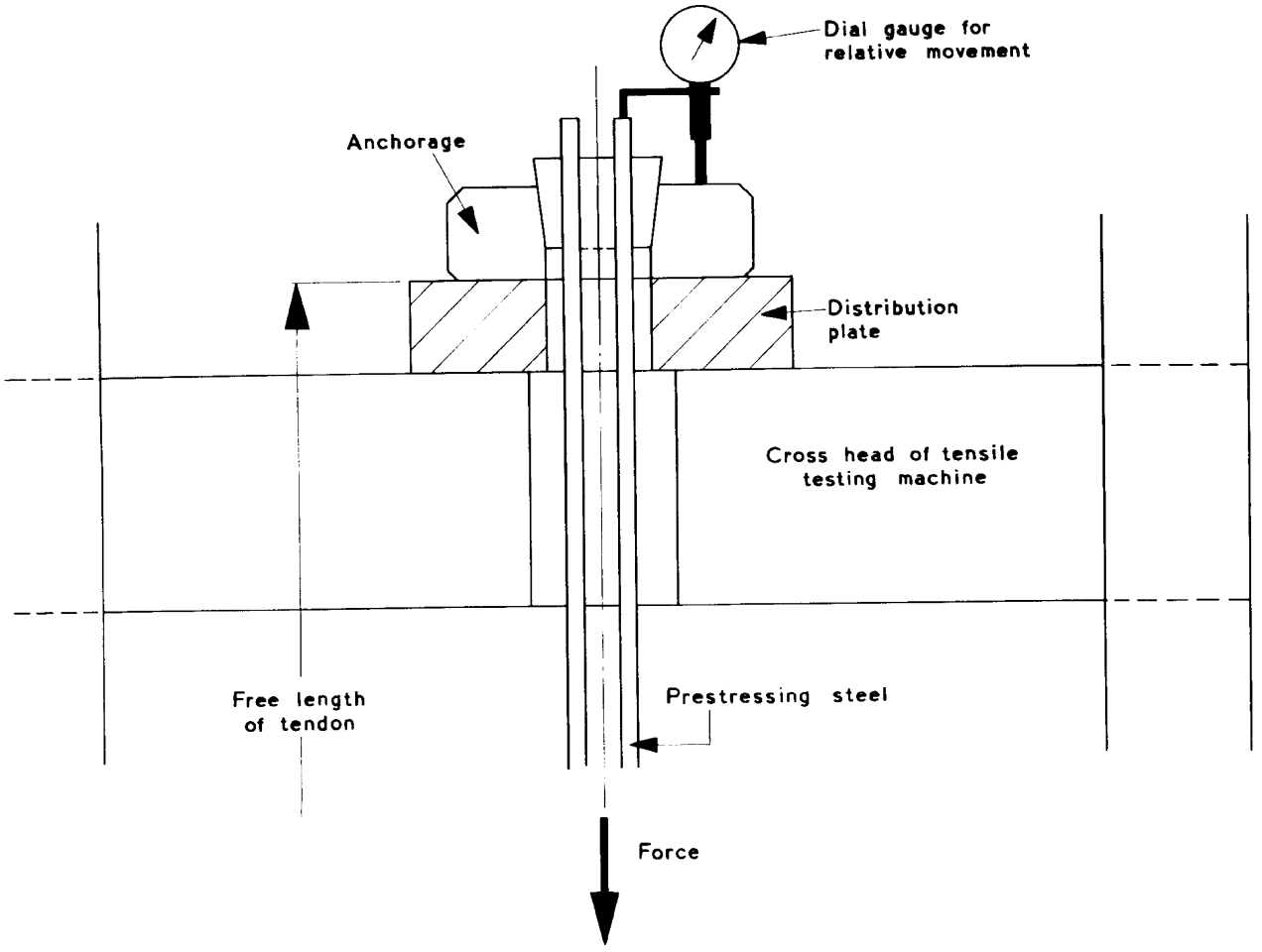


**Figure 1 — Short term static tensile test**

**5.2 Test specimen.** The test specimen shall consist of suitable lengths of wire, strand or bar held at each end by the anchorage under test, or at one end by the anchorage and at the other by a special device which ensures that the failure occurs at a point remote from that end. The test shall be carried out using, at least at one end, all parts of the anchorage which contribute to the actual gripping or supporting of the tendon but not necessarily those parts normally cast into the concrete. The method of supporting the anchorage parts shall be chosen by the anchorage manufacturer but shall simulate the effect of any geometric deviation of any individual wires, strand or bars within the anchorage. The number of wires, strands or bars forming the tendon shall be the maximum for which the anchorage is designed.

**5.3 Test procedure.** The test load shall be applied uniformly on tendons which have been previously prestressed by a representative prestressing operation to not less than 0.70 of the characteristic strength of the tendon, either by calibrated jacks or by a suitable tensile testing machine. Alternatively, where it can be demonstrated that the prestressing operation has no effect on the load transfer, the whole of the test load may be applied by calibrated jacks or by a suitable testing machine. The failure force shall be the force at which the test specimen no longer supports any increase in the loading at which point the total elongation of the tendon shall be recorded, or deduced from elongation readings at lower loadings.

The test load shall be applied at a rate of not more than 200 $N/mm^2$ per minute and the tests shall be carried out at ambient temperature unless otherwise stated.

The percentage elongation shall be taken as the ratio of the net elongation to the original length of the tendon: the anchored length shall not be less than 3 m. Due allowance for draw in, slip and other extraneous causes shall be taken into account in determining the net elongation, which shall be measured over the outside face of the anchorages or special device.

The characteristic strength of an anchored tendon is the product of the characteristic strength of the tendon times the actual efficiency.

## 6 Test of dynamic behaviour of the anchored tendon

**6.1 Description of test.** The test is a fluctuating load test carried out in a tensile testing machine or a fatigue testing machine applying a fluctuating tensile force. It is applicable to unbonded tendons only.

**6.2 Test specimen.** The test specimen shall be similar to that for the test given in Clause **5**, but with the tendon length appropriate to the testing machine used. In the case of a very large tendon for which the test loads exceed the capacity of equipment available, the number of elements in the tendon may be reduced provided that they are distributed uniformly in the anchorage and their geometric arrangement is not more favourable than in the complete tendon.

In preparing the test specimen, such measures as would be taken in practice to avoid fretting of any part of the tendon shall be taken.

**6.3 Test procedure.** The test specimen shall be subjected to a fluctuating force between 0.60 $f_{pu}$ and 0.65 $f_{pu}$ at a frequency not exceeding 10 Hz for a minimum of $2 \times 10^6$ cycles. Loss of not more than 5 % of the initial cross-sectional area of the tendon due to fatigue failures of individual elements shall not invalidate the test.

## 7 Test of force transfer to the end block

**7.1 Description of test.** The test is a short-term static test normally in a compression testing machine without a tendon (see Figure 2).

**7.2 Test specimen.** The test specimen shall include all the parts of the anchorage which are in contact with and transmit forces to the concrete, either cast into or thrusting against a rectangular concrete prism simulating a typical end block condition. The dimensions of the prism shall be such that the ratio of width of the loaded area ($2a_{1)}$ to the width of the prism ($2a$) shall be 0.6 and the length of the prism shall not be less than $2a$.

Bursting steel reinforcement in the specimen shall be determined in accordance with Appendix A. Additional reinforcement as is necessary for good engineering practice shall be provided in non-critical zones of the test specimen.

The specimen shall be tested when the concrete attains a cube strength of 0.75 $f_{cu}$ to 0.90 $f_{cu}$ (where $f_{cu}$ is the 28 day characteristic cube strength of the particular grade of concrete for which the anchorage has been designed).

**7.3 Test procedure.** The test specimen shall be installed in a compression test machine and supported on the full area of its base. A compression force shall then be applied to the test specimen by means of calibrated jacks or other suitable means acting on an area which simulates the loading condition in a complete anchorage system. The load shall be gradually applied until it is demonstrated that the test specimen can continuously support a minimum force of 1.1 $f_{pu}$. The extent of cracking in the concrete during the test shall be noted.

When an anchorage system is subjected to forces of a temporary nature acting through a loaded area differing from the anchorage (e.g. the bearing of a jack during a tensioning operation), a supplementary preliminary test shall be carried out in which a load of 0.85 $f_{pu}$ is applied to this modified area.

## 8 Test reports

Reports of tests carried out in accordance with this standard shall include the following information:

1) a statement that tests have been carried out in accordance with this standard;

2) details of the anchorage parts tested;

3) details of the type and quality of the tendon material used; the British Standard or other standard with which it complies; the source of manufacture and its specified characteristic strength ($f_{pu}$);

4) details of the end block reinforcement used and a statement that it conforms with the requirements of Clause **7** of this standard (force transfer tests only);

5) the strength of the concrete in the end block;

6) a statement describing the ultimate mode of failure including details of wire or strand failures or any failures or any distress in the component parts of the anchorage;

7) the results of every consecutive test in the appropriate series;

8) a statement confirming that the required load efficiency and percentage elongation of the anchored tendon and force transfer to the end block have been achieved.

Records of all tests shall be kept by the manufacturer and made available for inspection by the client or his representative.

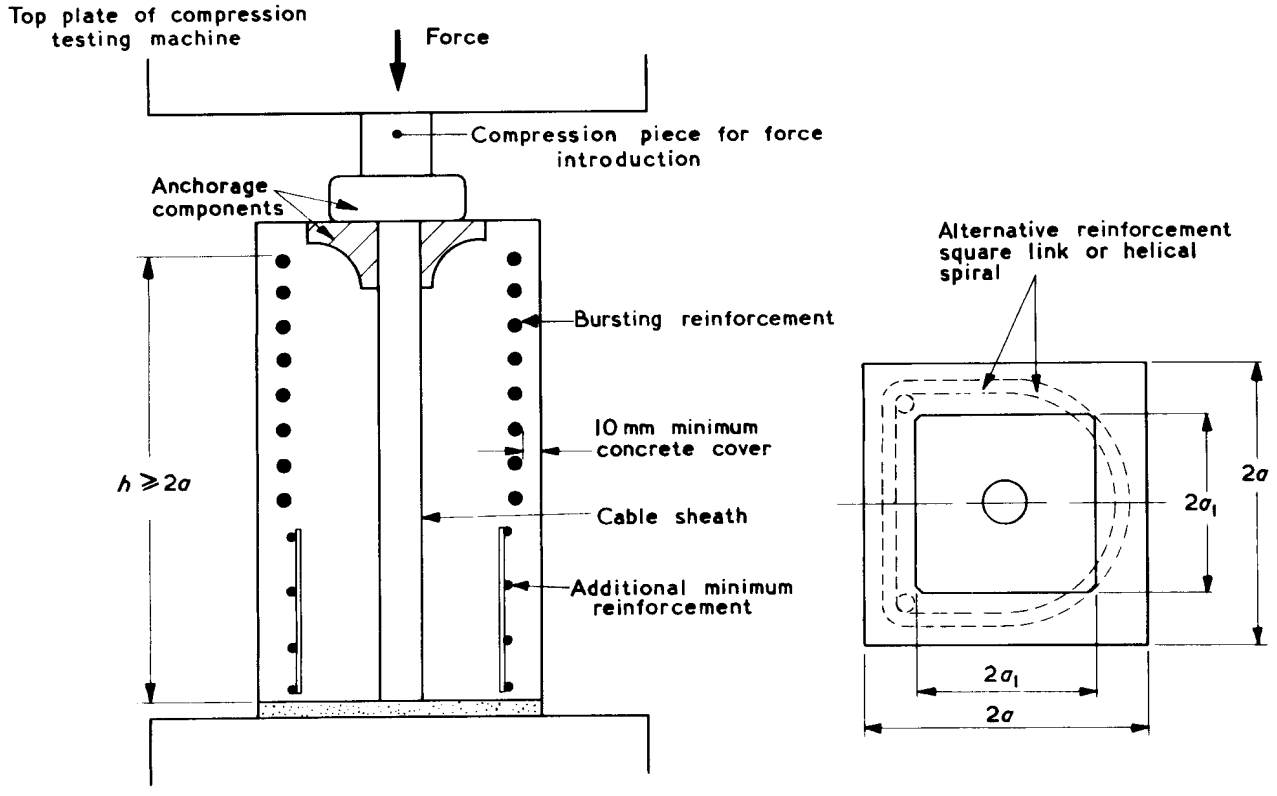


**Figure 2 — Short term static compressive test**

## Appendix A Bursting reinforcement requirements for the test specimen (see Clause 7)

**Notation**

$2a_1$ the side of the loaded area, which for non-rectangular systems shall be taken as $\sqrt{\text{area of anchor face}}$

$2a$ the side of the end block

$A_c$ cross-sectional area of the test specimen minus the area of the duct

$A_s$ total required area of bursting reinforcement

$\alpha,\beta,\xi$ coefficients dependent on $a_1/a$

$f_{max}$ maximum tensile stress in concrete = $\alpha P/A_c$

$f_{ct}$ permissible concrete tensile stress = $0.83\,\xi f_{cyt}$

$f_s$ permissible working stress in the bursting reinforcement

$f_y$ the characteristic strength of the bursting reinforcement

$P$ design applied loading taken as the maximum permissible tendon force applied during stressing, normally not exceeding $0.8\,f_{pu}\,A_{ps}$

$f_{pu}$ the characteristic strength of the tendon for which the anchorage is designed

$P_u$ ultimate applied loading = $1.1\,f_{pu}\,A_{ps}$ by definition

$f_{cyt}$ the tensile splitting strength of the concrete which shall be taken as $4.0 \pm 0.8$ N/mm$^2$ for a cube strength in the range $50 \pm 10$ N/mm$^2$

Bursting steel reinforcement required in the test specimen shall be provided to satisfy either the normal working condition or the ultimate condition, whichever demands the greater amount of reinforcement calculated from the following working formulae:

*Normal working condition*

$$A_s = \frac{P}{f_s}\beta\left[1 - \left(0.8\,\xi f_{cyt}\frac{A_c}{\alpha P}\right)^2\right]$$

where for $\frac{a_1}{a} = 0.6$

$\alpha = 0.48$

$\beta = 0.22$

$\xi = 1.42$

*Ultimate condition*

$$A_s = \frac{P_u}{f_y}\beta$$

The bursting reinforcement shall be located in the test specimen within the length given in Figure 3.

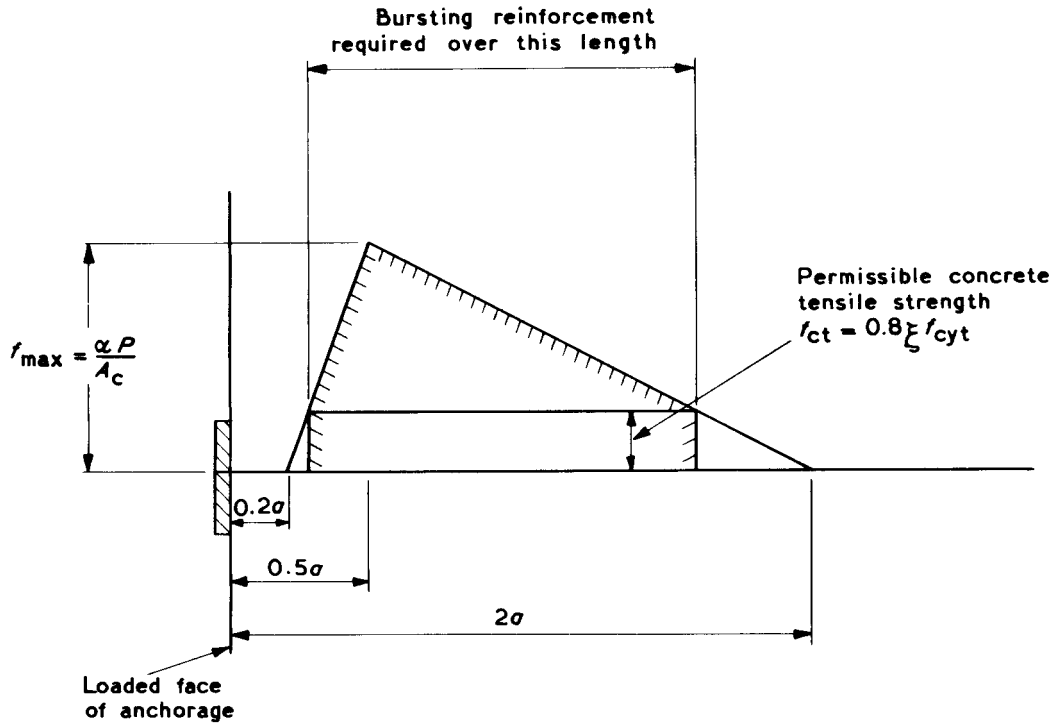


**Figure 3 — Position of bursting reinforcement**

# Publications referred to

This standard makes reference to the following British Standards:

BS 18, *Methods for tensile testing of metals (including aerospace materials).*

BS 4486, *Specification for hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete.*

BS 4545, *Methods for mechanical testing of steel wire.*

BS 5896, *Specification for high tensile steel wire and strand for the prestressing of concrete.*



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