THE HIGHWAYS AGENCY BD 58/94

THE SCOTTISH OFFICE INDUSTRY DEPARTMENT

THE WELSH OFFICE
Y SWYDDFA GYMREIG

THE DEPARTMENT OF
THE ENVIRONMENT FOR NORTHERN IRELAND

The Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing

Summary: This Standard gives the requirements for the design of bridges with external and unbonded prestressing.

REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

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VOLUME 1	HIGHWAYS STRUCTURES: APPROVAL PROCEDURES AND GENERAL DESIGN
SECTION 3	GENERAL DESIGN

PART 9

BD 58/94

THE DESIGN OF CONCRETE HIGHWAY BRIDGES AND STRUCTURES WITH EXTERNAL AND UNBONDED PRESTRESSING

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1. INTRODUCTION

General

1.1 The design of prestressed concrete with unbonded prestressing is not covered in the Code of Practice for the Design of Concrete Bridges, BS 5400: Part 4: 1990. The purpose of this Standard is to provide design requirements for the use of prestressed concrete with unbonded prestressing in highway structures.

1.2 Further advice on the use of unbonded prestressing together with some background information on the design requirements given in this document are provided in BA 58 (DMRB 1.3.10).

1.3 Any reference in this document to a British Standard is to that Standard as implemented by the appropriate DMRB Standard.

Implementation

1.4 This Standard should be used forthwith for all schemes currently being prepared provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay progress. Design Organisations should confirm its application to particular schemes with the Overseeing Organisation.

Scope

1.5 The scope of this Standard is limited to the use of post-tensioned concrete with external prestressing in bridges and other highway structures, although some guidance is given on the use of ungrouted ducted post-tensioning. It supplements the requirements of BS 5400 Part 4 by introducing additional clauses and modifications to the existing clauses for the design of bonded post-tensioned concrete.

1.6 This document shall not be used for cable stays or other tendons which are above or below the concrete cross-section; nor shall it be used for structures with tendons temporarily ungrouted during construction.

Definition

1.7 Unbonded prestressing is prestressing where, in the finished structure, no continuous bond is provided between the prestressing elements and the concrete section, either by the provision of grout or by any other means. The term, external prestressing is applied to that class of unbonded prestressed structures where some or all of the prestressing is unbonded and outside the concrete section, and where the load is transferred to the concrete through end anchorages and deviators. It is, in theory, possible to use unbonded prestressing elements in ducts which lie within the concrete section. This is unbonded internal prestressing.

2. DESIGN

General

2.1 All external and unbonded tendons shall be replaceable without having to restrict traffic on the highway. Where the detailing does not enable tendons to be removed and replaced without damage to either the tendons or the structure, a method statement defining how the tendons can be replaced shall be provided. A method statement defining how the structure can be demolished shall also be provided.

2.2 Adequate provision shall be made for the inspection and maintenance of external tendons.

2.3 Bridges shall be checked to ensure that failure of either any two tendons or of 25% of those at one section, whichever has the more onerous effect, will not lead to collapse at the ultimate limit state under the design ultimate permanent loads.

Modifications to BS 5400: Part 4: 1990

2.4 All Clauses of BS 5400: Part 4 are applicable to the design of unbonded prestressing except where stated otherwise in this document.

2.5 Where **all** tendons in a particular section are external, the following modifications to BS5400: Part 4 shall be made:

Clause 4.2.2(a)	Delete "for lightly trafficked highway bridges and railway bridges where the live loading is controlled;"
Clause 4.2.2(b)	Insert "either" before "Class 2"

2.6 The following modifications are designed to enable rules for external and unbonded prestressing to be applied to mixed tendon layouts (which could include sections with some pretensioned tendons in conjunction with unbonded prestressing), as well as all unbonded or external layouts.

Clause 4.2.3	Between "In calculating the resistance of members to" and "vertical shear and torsion" add "flexure,".
Clause 6.1.1	In para 2, delete "any of the following"; insert "lightweight aggregate". Delete (a), (b) and (c).
Clause 6.2.2(a)	Delete "In the absence of .....depth to tension reinforcement (in mm)".
Clause 6.3.2.1(b)	Delete everything after first sentence and insert. "Class 3 members shall be treated as reinforced sections in which the axial force and moment due to prestress is considered as an applied load. The prestress force considered shall be that before or after losses, whichever is the worst case".
Clause 6.3.2.4(a) (2)	Delete last line "The ... Table 24".
Clause 6.3.2.4(a) (3)	**Class 3 members.** Delete the existing text "For Class 3 members ..... additional reinforcement", and substitute as follows: "For Class 3 members the maximum crack width calculated as for columns should be less than the design crack widths given in Table 1. See Clause 6.3.2.1".
Tables 24, 25 & 26	Delete.
Clause 6.3.3.1(d)	Add at the end "multiplied by the appropriate value of γ_{fL}".
Clause 6.3.3.1(e)	Delete "An empirical approach ... " to end of Clause, "can be satisfied", and insert Clauses 6.3.3.1 (f) and (g) as follows:

New Clause 6.3.3.1 (f). The strain in unbonded tendons shall be assumed not to increase above the initial value due to prestress after all losses including γ_{fL} except that either;

(i) In slabs and beams, the strain in the mid span region of cables which are within 0.1d of the soffit at mid-span and which do not extend beyond the supports may be taken to increase by 0.0005, with no additional calculation.

(ii) The strain in the tendons at failure may be calculated from a non-linear analysis of the structure. If this is done checks shall be made to ensure that conventional "conservative" assumptions, such as ignoring the tensile strength of concrete, do not have the effect of increasing the tendon strain and hence the ultimate strength.

New Clause 6.3.3.1 (g). Tendons and reinforcing bars which are anchored within a distance equal to h/2 of the section being considered shall be ignored. However, within h/2 of a simply supported end, all prestress which is anchored beyond the centre line of the support and all reinforcement which complies with the requirements of 5.8.7 (1) or (2) may be considered effective.

Clause 6.3.3.2 Delete.

Clause 6.3.3.3 Delete.

Table 27 Delete.

Clause 6.3.4.1 Delete everything after first paragraph and insert:

"Sections with unbonded or external tendons shall be checked for shear by considering them as reinforced concrete columns subjected to an externally applied load. The external load shall be the tendon force after all losses multiplied by the appropriate value of γ_{fL}".

"4.75 N/mm^2" in Clause 5.3.3.1 may be replaced by "5.8 N/mm^2"

Clause 6.3.4.2 Delete.

Clause 6.3.4.3 Delete.

Clause 6.3.4.4 Delete everything from "Where links are used" to "460 N/mm^2".

Clause 6.7.2.5 In the first sentence beginning "The loss of prestress in the tendons ...", add "bonded " before "tendons".

After the first sentence add "The loss of prestress in unbonded tendons should be calculated from the creep movement between anchors or other fixed points in the tendons".

Clause 6.7.3.3 Add at end of Clause, "The effect may be ignored in sections of unbonded tendon which are free to move laterally at the time they are stressed".

Clause 6.7.3.4 After "values for μ", add "for internal tendons."

After "moving on lead", add "0.05 for greased coated monostrands moving on plastic sheaths".

For external tendons, in the absence of more exact data, the values of μ may be taken from the following table:

COEFFICIENT OF FRICTION μ	STEEL TUBE	HDPE TUBE
Lubricated strand	0.18	0.12
Lubricated wire	0.20	0.14
Non-lubricated strand	0.25	0.15
Non-lubricated wire	0.27	0.17

Clause 6.7.5 After first paragraph add the following new paragraph:

"End blocks and anchors for unbonded tendons shall be checked at the ultimate limit state for a load equal to the characteristic strength of the tendon".

Clause 6.7.6 Add new Clause:

Clause 6.7.6 Deviators. Deviators for external tendons shall be checked at the ultimate limit state for a load equal to the characteristic strength of the tendon. Where serviceability checks are required, as for flexural cracking in deviator beams, the design service load in the tendons shall be taken as the tendon load before long term losses.

Clause 6.8.3.3 Delete last sentence and substitute "For deviators restrained in reinforced concrete, consideration shall be taken of the tensile and splitting forces generated".

Clause 6.8.4 Add at end of the paragraph "The minimum amount of bonded reinforcement in members containing external or unbonded prestressing shall be 0.2% of the concrete cross-sectional area. This requirement does not apply to segmental construction."

Clause 6.8.7 Delete existing clause and substitute new Clause.

Clause 6.8.7 Deflected pre-tensioned tendons. For single tendons the deflector in contact with the tendon shall produce a radius of not less than 5 times the tendon diameter for wire, or 10 times the diameter for strand. The total angle of deflection should not exceed 15^0.

Clause 6.8.8 Add new Clause.

Clause 6.8.8. External tendons.
6.8.8.1 *Tendon Restraint.* To avoid second order effects due to beam deflections between points where tendons are fixed, external tendons shall be restrained transversely relative to the concrete section at centres not exceeding 12 times the minimum depth of the beam between the fixing points. If the spacing between points where the tendons are held in position laterally exceeds 12m, checks shall be made to ensure that the first natural frequency of the tendons vibrating between fixing points is not in the range 0.8 to 1.2 times that of the bridge.

6.8.8.2 *Tendon profile*. In the absence of test results or other investigation justifying smaller values, the radius of curvature of tendons in the deviators should not be less than the following values.

TENDON (STRAND NUMBER-SIZE)	MINIMUM RADIUS (m)
19-13mm and 12-15mm	2.5
31-13mm and 19-15mm	3.0
53-13mm and 37-15mm	5.0

3. REFERENCES

1 Design Manual for Roads and Bridges

Volume 1: Section 3 General Design

BA 58/94	The Design of Concrete Highway Bridges and structures with External and Unbonded Prestressing (DMRB 1.3.10)
BD 57/94	Design for Durability (DMRB 1.3.7)
BA 57/94	Design for Durability (DMRB 1.3.8)

2 British Standards

BS 5400: Part 4: 1990: Code of Practice for the Design of Concrete Bridges.

4. ENQUIRIES

All technical enquiries or comments on this Standard should be sent in writing as appropriate to:

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