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

AM-STR-06036
June 2014
About TII

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Each document within TII Publications has a range of attributes associated with it, which allows for efficient access and retrieval of the document from the website. These attributes are also contained on the inside cover of each current document, for reference. For migration of documents from the NRA and RPA to the new system, each current document was assigned with new outer front and rear covers. Apart from the covers, and inside cover pages, the documents contain the same information as previously within the NRA or RPA systems, including historical references such as those contained within NRA DMRB and NRA MCDRW.

Document Attributes

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<td>Historical Reference</td>
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NRA DMRB and MCDRW References

For all documents that existed within the NRA DMRB or the NRA MCDRW prior to the launch of TII Publications, the NRA document reference used previously is listed above under ‘historical reference’. The TII Publication Number also shown above now supersedes this historical reference. All historical references within this document are deemed to be replaced by the TII Publication Number. For the equivalent TII Publication Number for all other historical references contained within this document, please refer to the TII Publications website.
The Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing

June 2014
Summary:

This standard which covers the Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing has been superseded by the Eurocodes but may be used for Assessment purposes.
PART 13

NRA BD 58/14

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

Contents

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1. Implementation

2. Enquiries

Annex A NRA Addendum to BD 58/94

Annex B BD 58/94 The Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing
1. IMPLEMENTATION

General

1.1 The Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing has been superseded by the Eurocodes (for Design), but may still be required in the Assessment of an existing structure. Refer to ‘NRA TB 4 The Structural Eurocodes’ for further information in this regard.

1.2 This NRA BD 58 shall only be used as referenced from an Assessment Standard contained within Section 4 of Volume 3 of the NRA DMRB.

Annex A - NRA Addendum to BD 58/94

1.3 Annex A contains NRA Addendum to BD 58/94

Annex B – BD 58/94 The Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing

1.4 Annex B contains BD 58/94 The Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing.
2. **ENQUIRIES**

2.1 All technical enquiries or comments on this document, or any of the documents listed as forming part of the NRA DMRB, should be sent by e-mail to infoDMRB@nra.ie, addressed to the following:

Head of Network Management, Engineering Standards & Research  
National Roads Authority  
St Martin’s House  
Waterloo Road  
Dublin 4

........................................
Pat Maher  
Head of Network Management,  
Engineering Standards & Research
ANNEX A: NRA ADDENDUM TO BD 58/94

A.1. This annex contains NRA Addendum to BD 58/94.
NRA ADDENDUM TO

BD 58/94

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

Standard BD 58/94 - The Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing - is applicable in Ireland with the following amendments:

GENERAL

1. Where the Standard is applied for the design of structural components which are procured through a contract incorporating the NRA Specification for Road Works, products conforming to equivalent standards and specifications of other member states of the European Union will be acceptable in accordance with the terms of Clauses 104 and 105 of that Specification. Any contract for the procurement of structural components which does not include these Clauses must contain a suitable clause of mutual recognition having the same effect, regarding which advice should be sought.

2. The Standard provides specification requirements for use in public purchasing contracts. It does not lay down legislation requirements for products and materials used in road construction in Ireland.

3. At several locations:

   For: “Overseeing Organisation”
   Read: “National Roads Authority”;

   For: “highway”
   Read: “road”.

For: “Overseeing Organisation”
Read: “National Roads Authority”;

For: “highway”
Read: “road”.

December 2000
SPECIFIC

4. Page 1/1, Paragraph 1.4:
Delete Paragraph 1.4 and replace with:
“1.4 This Standard should be used forthwith for all schemes for the construction and/or improvement of national roads. The Standard should be applied to the design of schemes already being prepared unless, in the opinion of the National Roads Authority, application would result in significant additional expense or delay progress. In such cases, Design Organisations should confirm the application of this Standard to particular schemes with the National Roads Authority.”

5. Page 4/1, Section 4:
Delete text and replace with:
“4.1 All technical enquiries or comments on this Standard should be sent in writing to:

Head of Project Management and Engineering
National Roads Authority
St Martin’s House
Waterloo Road
Dublin 4”

E O’CONNOR
Head of Project Management and Engineering
ANNEX B: BD 58/94 THE DESIGN OF CONCRETE HIGHWAY BRIDGES AND STRUCTURES WITH EXTERNAL AND UNBONDED PRESTRESSING

B.1 This annex contains BD 58/94 The Design of Concrete Highway Bridges and Structures with External and Unbonded Prestressing.
This Standard gives the requirements for the design of bridges with external and unbonded prestressing.
<table>
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November 1994
### REGISTRATION OF AMENDMENTS

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November 1994
PART 9

BD 58/94

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

Contents

Chapter

1. Introduction
2. Design Requirements
3. References
4. Enquiries
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.

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.

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.
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 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) Delete last line "The ... Table 24".

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"


Clause 6.3.3.1(d) Add at the end "multiplied by the appropriate value of \( \gamma_f \)"

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 \( \gamma_f \) 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.

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".

(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 γL."

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".

<table>
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<tr>
<th>COEFFICIENT OF FRICTION µ</th>
<th>STEEL TUBE</th>
<th>HDPE TUBE</th>
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<tr>
<td>Lubricated strand</td>
<td>0.18</td>
<td>0.12</td>
</tr>
<tr>
<td>Lubricated wire</td>
<td>0.20</td>
<td>0.14</td>
</tr>
<tr>
<td>Non-lubricated strand</td>
<td>0.25</td>
<td>0.15</td>
</tr>
<tr>
<td>Non-lubricated wire</td>
<td>0.27</td>
<td>0.17</td>
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</table>
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.

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

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."

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°.

Add new Clause.


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.

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<th>TENDON (STRAND NUMBER-SIZE)</th>
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<tr>
<td>19-13mm and 12-15mm</td>
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</tr>
<tr>
<td>31-13mm and 19-15mm</td>
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<tr>
<td>53-13mm and 37-15mm</td>
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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

4. **ENQUIRIES**

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

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<th>The Chief Highway Engineer</th>
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<tr>
<td>The Highways Agency</td>
</tr>
<tr>
<td>St Christopher House</td>
</tr>
<tr>
<td>Southwark Street</td>
</tr>
<tr>
<td>London SE1 0TE</td>
</tr>
<tr>
<td>T A ROCHESTER Chief Highway Engineer</td>
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<table>
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<tr>
<th>The Deputy Chief Engineer</th>
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<tbody>
<tr>
<td>The Scottish Office Industry Department</td>
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<tr>
<td>Roads Directorate</td>
</tr>
<tr>
<td>New St Andrew's House</td>
</tr>
<tr>
<td>Edinburgh EH1 3TG</td>
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<tr>
<td>J INNES Deputy Chief Engineer</td>
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<tr>
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<td>K J THOMAS Director of Highways</td>
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<table>
<thead>
<tr>
<th>Chief Engineer - Roads Service</th>
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<tr>
<td>Department of the Environment for Northern Ireland</td>
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<td>Roads Service Headquarters</td>
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<tr>
<td>Clarence Court</td>
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<tr>
<td>10-18 Adelaide Street</td>
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<tr>
<td>Belfast BT2 8GB</td>
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<tr>
<td>W J McCOUBREY Chief Engineer - Roads Service</td>
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