VOLUME 3 HIGHWAYS STRUCTURES: INSPECTION AND MAINTENANCE

SECTION 4 ASSESSMENT

PART 9

BA 55/00

THE ASSESSMENT OF BRIDGE SUBSTRUCTURES AND FOUNDATIONS, RETAINING WALLS AND BURIED STRUCTURES

SUMMARY

The Advice Note deals with the assessment of structures and structured elements where their behaviour is directly influenced by soil-structure interaction.

INSTRUCTIONS FOR USE

1. Remove BA 55/94, which is superseded by BA 55/00 and archive as appropriate.

2. Insert BA 55/00 in Volume 3, Section 4, Part 9.

3. Archive this sheet as appropriate.

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THE HIGHWAYS AGENCY

THE SCOTTISH EXECUTIVE DEVELOPMENT DEPARTMENT

THE NATIONAL ASSEMBLY FOR WALES
CYNULLIAD CENEDLAETHOL CYMRU

THE DEPARTMENT FOR REGIONAL DEVELOPMENT*

The Assessment of Bridge Substructures and Foundations, Retaining Walls and Buried Structures

*A Government Department in Northern Ireland

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REGISTRATION OF AMENDMENTS

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Contents

Chapter

1. INTRODUCTION

1.1 The current Bridge Assessment and Strengthening Programme, in addition to superstructures involves the assessment of bridge substructures (abutments and wing walls including cantilevered wing walls and skeletal abutments), foundations, retaining walls and buried structures. The basic requirements for substructures etc (the term will be used henceforth to include all such structural elements and structures) are given in BD 21 (DMRB 3.4.3), the Assessment Standard and BD 34 (DMRB 3.4), the Implementation Standard for Stage 1 of the Assessment and Strengthening Programme. Advice is also contained in BA 34 (DMRB 3.4).

1.2 The structural behaviour of substructures etc is more complex than that of superstructures in that the loading applied to superstructures is largely unaffected by their deformations and movements. On the other hand, the principal loads applied to substructures etc, ie earth pressures and foundation reactions, are sensitive to their movements. Another source of complexity is the distinction between the internal adequacy of the structural components, for example regarding rupture of the stem of a retaining wall, and the overall adequacy of the structure in terms of soil-structure stability, for example with respect to sliding and rotation.

1.3 Where assessment by calculation is required for substructures etc, certain difficulties may be encountered in applying the requirements. Firstly, the general rules for assessment contained in BD 21 (DMRB 3.4.3) and other assessment-related documents are primarily intended for bridge superstructures (decks). Most of these rules are less directly applicable to substructures or structures associated with soil interaction. Secondly, in the absence of relevant assessment standards, assessment calculations for substructures etc are being carried out using design standards such as BD 30 (DMRB 2.1) for backfilled retaining walls, BD 31 (DMRB 2.2) for buried concrete box type structures and BD 74 (DMRB 2.1.8) for foundations (including piled foundations). These documents, as is to be expected from design standards, contain conservative requirements. Application of unmodified design rules to assessments is likely to produce unduly pessimistic estimates of load carrying capacity.

1.4 The purpose of this Advice Note is to clarify the present requirements concerning the assessment of substructures etc and to provide guidance on the use of the above-mentioned design standards for assessment purposes.

1.5 It is recognised that adaptation of the design rules for substructures etc for their assessment can be carried out, at present, only by ad-hoc reasoning. Reliability based methodologies for determining the factors of safety for such structures and structural elements are being developed. Such techniques may be used in individual assessments with the agreement of the Overseeing Organisation.

Scope

1.6 This Advice Note is intended to cover the assessment of structures and structural elements the behaviour of which is directly influenced by soil-structure interaction. It does not deal with the stems of free-standing piers and columns but covers the assessment of their foundations.

Implementation

1.7 This Advice Note should be used forthwith for the assessment of bridge substructures and foundations, retaining walls and buried structures. The advice should be applied to assessments already in progress provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay. Its application to particular assessments should be confirmed with the Overseeing Organisation.

Clause References

1.8 It is necessary that this Advice Note should refer to specific clauses of relevant Standards and Advice Notes. The particular versions of the documents, which are referred to by clause numbers in the text, are indicated by including the year of document publication with the document reference.

2. PRESENT REQUIREMENTS

Basic Principles

2.1 The purpose of the current Bridge Assessment and Strengthening Programme is to ensure that structures on the highway network are adequate for present day traffic needs, which are considerably more onerous compared to those prevailing when many of the present structures were designed and built. The Programme, therefore, essentially involves structures likely to suffer from increased traffic loading (primary normal live loading) although Stage 2 of the Programme additionally includes those likely to contain gross inadequacies as a result of deficiencies in the original design rules. When assessing substructures etc, therefore, the primary concern should be whether traffic loading has any significant effect on it or not.

2.2 The basic purpose of any assessment is to determine whether the structure will have adequate strength for the worst credible combinations of loading and strength conditions at the ultimate limit state (ULS). For bridge decks, it is essential to check this explicitly since any failure is likely to have catastrophic consequences. For substructures etc any failure, in general, is likely to be progressive and there will usually be some warning signs (such as movement, settlement, rotation, cracking, evidence of reinforcement corrosion, locked bearings etc) well before the final collapse takes place. For that reason, a bridge deck may be considered to be inadequate even without any sign of distress; however, substructures etc, in general, need not be assessed by calculations unless there are evident signs of distress determined from an inspection for assessment or any other inspection of the substructure.

2.3 When assessment by calculation is deemed necessary for substructures etc, realistic parameters (such as earth pressure coefficients) should be used as far as possible. If any substructures etc are found to be inadequate as a result of initial assessment, before taking any precipitate action, detailed soil surveys should be carried out, if such information is likely to improve the assessment. Furthermore, when a range of values of a particular factor of safety is recommended in a code, only the least conservative one should be used, unless otherwise stipulated by the Overseeing Organisationm.

2.4 Substructures etc should be considered inadequate only if they both fail theoretical assessment and exhibit signs of distress. Inadequate substructures etc should be strengthened or replaced as necessary.

Summary of Relevant Requirements

[Refer to 1.8 for the need to cross refer to specific versions of Departmental Standards and Advice Notes]

2.5 BD 21 (DMRB 3.4.3) states that if a foundation, retaining wall or a substructure shows no sign of distress, such items may be assumed to be adequate and no further assessment is necessary.

2.6 BA 16 (DMRB 3.4.4) deals with spandrel and dry-stone walls, substructures and foundations. It says that the adequacy of such items is to be determined from qualitative assessments of their general condition including the significance of any defects.

2.7 BD 34 (DMRB 3.4) states that retaining walls providing structural support to a road and not designed for Type HA surcharge or equivalent are to be assessed. Furthermore it says that structures which are thought to have a reduced load capacity as a result of serious deterioration, foundation deficiency, inadequacy of back-filling materials or damage are to be assessed. It also states that bridges, culverts, buried structures etc of spans less than 1.8m (or 5m total when multispan) and retaining walls of height 1.5m or less need not be assessed. Additionally, culverts and buried structures of 3m or less span with cover of 1m or more, or buried to an extent that highway loading is only of marginal significance when compared to earth pressures, need not be assessed.

2.8 BA 34 (DMRB 3.4) contains advice on substructures and foundations. Factors of safety stipulated for design purposes may be relaxed for assessments with the agreement of the Overseeing Organisation. When a superstructure is to be strengthened or replaced, the adequacy of the substructure and foundations should be checked as for any new design.

3. ASSESSMENT BY CALCULATION

3.1 When assessment by calculation is considered to be necessary, in the absence of assessment standards, design standards may be used. Advice on the use of design provisions for assessment purposes for certain types of structures and structural elements is given in the following sections.

Backfilled retaining walls and bridge abutments

[Refer to 1.8 for the need to cross refer to specific versions of Departmental Standards and Advice Notes]

3.2 BD 30 (DMRB 2.1) may be used for assessing by calculation all backfilled retaining walls and bridge abutments including the older types such as mass concrete, mass brick or cellular brick walls and abutments. Clause 5 of BD30/87 (DMRB 2.1) is applicable, using the following qualifications:-

(1) Clause 5.1. See (3.4) below for embedded retaining walls.

(2) Clause 5.2.2. Instead of BD 24 (DMRB 3.4), BD 44 (DMRB 3.4) should be used. The structure should be considered inadequate if calculations confirm any specific deficiency indicated by cracking etc.

(3) Clause 5.2.3. Not appropriate; however, if cracks etc have been noticed, close monitoring may be advisable.

(4) Clause 5.2.4. Applicable, but with the minimum factors of safety specified in CP 2. Nominal values of dead and highway live loads should be as given in BD 21 (DMRB 3.4). The structure is to be considered inadequate if calculations confirm any deficiency indicated by movements etc.

(5) Clause 5.2.5. Not applicable in general; however, if movements are noticed, and the structure passes the ULS checks, close monitoring may be advisable.

(6) Clause 5.3.2. 'Active' earth pressure should be used instead of the 'at rest' earth pressure.

(7) Clause 5.4. Wherever possible, soil parameters should be confirmed by tests.

Buried Concrete Box-Type Structures

[Refer to 1.7 for the need to cross refer to specific versions of Departmental Standards and Advice Notes]

3.3 For the assessment of buried concrete box-type structures used as culverts, subways etc or portal frame bridges, BD 31/87 (DMRB 2.2) may be used, based on the following guidelines:

(1) Clause 2.3. BD 21 (DMRB 3.4) should be used instead of BS 5400 : Part 2.

(2) Clause 3.1. The assessment of structural elements may be carried out using the provisions of this clause except that assessed inadequacy for serviceability does not by itself mean that any remedial action has to be undertaken (see BD 34 (DMRB 3.4) for further guidance). Furthermore, only Load Combination 1 should be considered, unless there are signs of tilting, possibly as a result of braking forces.

(3) Clause 3.2. Only the ultimate limit states of soil - structure behaviour should be checked.

(4) Clause 3.2.1. Assessment for braking forces or unequal earth pressures should only be carried out if there are signs of movement or tilting of the structure. Equal minimum earth pressure coefficients should be used on both side walls of the structure in all other cases. When checking for braking forces, the minimum coefficient should be used in the direction of the braking force and the maximum in the opposite direction. When CP 2 factors of safety are used for checks against tilting or sliding, the minimum recommended values should be used.

Embedded Retaining Walls

3.4 BD 42 (DMRB 2.1.2) should be used for the assessment of embedded retaining walls, embedded cut and cover tunnel walls and bridge abutments. This Standard is applicable to retaining structures whose main stability is provided by having a significant length of wall stem embedded in the ground. The wall may be unpropped, propped at either the top or at excavation level, or doubly-propped or anchored.

Guidance is given for retaining walls embedded in over-consolidated stiff or firm clay and also granular materials. Walls in soft clay are not covered by this Standard.

Assessment of embedded retaining walls should be carried out using the limit state design principles described in BD 42 (DMRB 2.1.2). Assessment should additionally consider the serviceability limit state for walls embedded in over-consolidated soils as this is often more onerous than the ultimate limit state. The following adaptations to BD 42 (DMRB 2.1.2) apply to its use for assessment purposes:

(1) Clause 2.6. Only necessary to consider global and local movements which are due to post construction changes and in the long term. Adjacent and supported structures should be examined for signs of distress.

(2) Clause 2.11. Not appropriate.

(3) Clause 3.3. Applicable. First assessment of ground movements should be based upon relevant field data and from experience of similar structures in similar ground conditions. Adjacent structures and buried services should be inspected for signs of distress and monitored closely where appropriate.

(4) Clause 3.4. Not applicable for construction stage. Deformation analysis may be required for consideration of the long term condition.

(5) confirm any specific deficiency.

(6) Clause 3.5. Instead of BD 13 (DMRB 1.3), BD 24 (DMRB 1.3.1) and BD 16 (DMRB 1.3), BD 56 (DMRB 3.4.12), BD 44 (DMRB 3.4) and BD 61 (DMRB 3.4.16) shall be used. Instead of BD 37 (DMRB 1.3), BD 21 (DMRB 3.4.3) shall be used.

(7) Clause 3.7. Instead of BD 37 (DMRB 1.3), BD 21 (DMRB 3.4.3) shall be used.

(8) Clause 3.9. Wherever possible, soil parameters and pore pressure distributions should be confirmed by investigation and testing.

(9) Clause 3.10. Care must be taken to assess the K_o likely to be present at the time of assessment. The initially present in-situ value of K_o will have been subsequently influenced by the construction process, the flexibility of the retaining wall system and the in-service period. Assessment by calculation should use the most appropriate limit equilibrium approach described in Clause 3.10.

(10) Clause 4.3. Drainage systems should be examined to assess their effectiveness. Account should be taken of any malfunction of the drainage system.

(11) Chapter 5. Assessment for durability should take account of possible member deficiencies due to corrosion, cracks, damage, etc observed during the inspections required by BD 21 (DMRB 3.4.3).

(12) Clause 6.8. Where a hard-soft piling system is used, a visual examination of the structure should be made to assess if there is evidence of any undue seepage through the soft piles.

(13) Clause 6.9. Integral bridges are designed using the guidance given in BA 42 (DMRB 1.3). For such structures, the abutments should be examined for signs of cracking caused by movements resulting from the thermal expansion and contraction of the bridge deck.

(14) Clause 7.5. A visual inspection of the prop slab (or the carriageway over it) should be carried out to assess if there is any sign of movement.

(15) Clause 8.4. For doubly-propped structures, such as cut-and-cover tunnels, a visual inspection of the tunnel roof and the lower prop slab (or the carriageway over it) should also be carried out.

(16) Clause 9.5. For structures with a stabilising base, a visual inspection of any carriageway over the base should be carried out. If there is movement, cracking is likely to develop above the end of the base remote from the wall.

(17) Chapter 10. Use of the Observational Method is only applicable if there are signs of movement which need to be monitored and controlled.

(18) Chapter 11. Not appropriate.

Foundations

3.5 Foundations in general should be assessed by using BD 74 (DMRB 2.1.8) with the following qualifications:

(1) Structural elements of concrete and steel piles should be assessed using BD 44 (DMRB 3.4) and BD 56 (DMRB 3.4), the assessment version of BS 5400: Part 4 and Part 3, respectively.

(2) Load transferred from the structure above, and the appropriate load factors, should be in accordance with BD 21 (DMRB 3.4.3). Only Load Combination 1 should be considered.

Reinforced Concrete Arch Bridges

3.6 Reinforced concrete, spandrel filled, arch bridges should be assessed using the same requirements as any other type of concrete bridges, except that the restraining action of the surrounding fill should be taken into account in the analysis as appropriate.

Reinforced Earth and Corrugated Steel Buried Structures

3.7 Reinforced earth, anchored earth or corrugated steel buried structures need not be assessed by calculation unless there are signs of distress such as bulging at the facing or evidence of corrosion of the reinforcement. When assessing such structures, special guidance should be sought. It should be noted that these structures have potentially catastrophic failure modes, although such events are rare and extremely unlikely for structures designed to Departmental Standard BE 3 (DMRB 2.1) and BD 12 (DMRB 2.2). The factors of safety used in assessments should not therefore be lower than those used in design, although realistic, rather than design, values of soil parameters may be used.

4. INTERIM MEASURES AND STRENGTHENING

4.1 In general, substructures etc covered by this Advice note need not be assessed by calculation unless there is already evidence of movement, cracking or other forms of distress, or the bridge involved is going to be incorporated into a new or improved road scheme (see 2.8) . In such cases, even when the substructures etc are assessed to have adequate capacity, they should continue to be observed carefully for signs of progressive deterioration. If this continues, at some point appropriate remedial action will be necessary.

4.2 If the structures etc are assessed to be inadequate and also show signs of distress, they should be considered as inadequate and strengthened or replaced as necessary.

4.3 The need and the urgency for any interim measure and its form should be determined on the basis of the severity of the signs of distress, the nature of the deficiency and the factors of safety (ie reserve of strength) available in the relevant aspects of structural response. For instance, if a crack indicates a potential shear failure of the stem of an abutment, urgent action may be required. On the other hand, in another situation, if the calculated factor of safety is only marginally less than that required, no urgent action may be deemed to be necessary.

5. REFERENCES

1. Design Manual for Roads and Bridges, The Stationery Office

Volume 1: Section 3: General Design

BD 24 (DMRB 1.3.1) - Design of Concrete Bridges. Use of BS 5400: Part 4: 1990

BD 37 (DMRB 1.3) - Loads for Highway Bridges

Volume 2: Section 1: Substructures

BE 3 (DMRB 2.1) - Reinforced and Anchored Earth Retaining Walls and Bridge Abutments for Embankments [Revised 1987]

BD 30 (DMRB 2.1) - Backfilled Retaining Walls and Bridge Abutments

BD 42 (DMRB 2.1.2) - Design of Embedded Retaining Walls and Bridge Abutments.

BD 74 (DMRB 2.1.8) - Foundations. Use of BS 8004:1986.

Volume 2: Section 2: Special Structures

BD 12 (DMRB 2.2) - Corrugated Steel Buried Structures and corrigendum dated January 1990

BD 31 (DMRB 2.2) - Buried Concrete Box Type Structures

Volume 3: Section 4: Assessment

BA 16 (DMRB 3.4.4) - The Assessment of Highway Bridges and Structures

BD 21 (DMRB 3.4.3) - The Assessment of Highway Bridges and Structures

BD 34 (DMRB 3.4) - Technical Requirements for the Assessment and Strengthening Programme for Highway Structures. Stage 1 - Older Short Span Bridges and Retaining Structures

BA 34 (DMRB 3.4) - Technical Requirements for the Assessment and Strengthening Programme for Highway Structures. Stage 1 - Older Short Span Bridges and Retaining Structures

BD 44 (DMRB 3.4) - The Assessment of Concrete Highway Bridges and Structures

BD 56 (DMRB 3.4) - The Assessment of Steel Highway Bridges and Structures.

BD 61 (DMRB 3.4.16) The Assessment of Composite Highway Bridges and Structures

2. Code of Practice

Institution of Structural Engineers (Joint Committee) Civil Engineering Code of Practice No. 2 (1951) CP 2 - Earth Retaining Structures.

6. ENQUIRIES

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

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