VOLUME 1 HIGHWAY STRUCTURES: APPROVAL PROCEDURES AND GENERAL DESIGN

SECTION 3 GENERAL DESIGN

PART 12

BA 42/96 AMENDMENT NO. 1

THE DESIGN OF INTEGRAL BRIDGES

SUMMARY

This Advice Note provides guidance on the design of continuous bridges with integral abutments.

INSTRUCTIONS FOR USE

This is an amendment to be incorporated in the Manual.

1. Remove existing contents sheet for Volume 1 and insert new contents sheet for Volume 1 dated May 2003.

2. Insert BA 42/96 Amendment No. 1 in Volume 1, Section 3, Part 12.

3. Please archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from The Stationery Office Ltd.

THE HIGHWAYS AGENCY

SCOTTISH EXECUTIVE DEVELOPMENT DEPARTMENT

WELSH ASSEMBLY GOVERNMENT
LLYWODRAETH CYNULLIAD CYMRU

THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND

The Design of Integral Bridges

Summary: This Advice Note provides guidance on the design of continuous bridges with integral abutments.

Volume 1 home page

REGISTRATION OF AMENDMENTS

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

REGISTRATION OF AMENDMENTS

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

VOLUME 1 **HIGHWAY STRUCTURES: APPROVAL PROCEDURES AND GENERAL DESIGN**

SECTION 3 **GENERAL DESIGN**

PART 12

BA 42/96 AMENDMENT NO. 1

THE DESIGN OF INTEGRAL BRIDGES

Contents

Chapter

1. INTRODUCTION

1.1 Expansion joints in bridge decks are prone to leak and allow the ingress of de-icing salts into the bridge deck and substructure, thereby resulting in severe durability problems. To overcome these problems, bridge decks up to 60 metres in length and with skews not exceeding 30° are generally required to be continuous over intermediate supports and integral with their abutments. (See BD 57, DMRB 1.3.7). This Advice Note covers the design of integral highway bridges without expansion joints.

1.2 Integral bridges are designed without any expansion joints between spans or between spans and abutments. Resistance to longitudinal thermal movements and braking loads is provided by the stiffness of the soil abutting the end supports and, in some cases by the stiffness of the intermediate supports.

Scope

1.3 This Advice Note is applicable to bridges of steel, concrete and composite construction, including precast and prestressed concrete, with thermally induced cyclic movements of each abutment not exceeding ±20mm and skews not exceeding 30°.

1.4 The Advice Note describes the movements and loads which may be used in the design of integral bridges, and provides requirements for some design details. It supplements the requirements of BD 30 (DMRB 2.1), in respect of integral bridges.

1.5 For bridges with full height frame abutments of overall length up to 15m and cover greater than 200mm, designers may use BD 31 (DMRB 2.2.12).

Definitions

1.6 The following are definitions of terms used in the Advice Note.

i) **Asphaltic Plug Joint**

An in situ joint in the pavement, complying with BD 33 (DMRB 2.3.6), comprising a band of specially formulated flexible material which may also form the surfacing.

ii) **Abutment**

The part of a bridge structure that abuts the roadway pavement and formation at the end of a bridge.

iii) **Bank Pad Abutment**

Bank seat end support for bridge constructed integrally with deck, acting as a shallow foundation for end span and as a shallow retaining wall for adjoining pavements and embankment.

iv) **Embedded Abutment**

End support for bridge comprising a diaphragm wall (including contiguous, or secant or sheet pile walls) with toe embedded in ground below lower ground surface.

v) **End Screen Abutment**

Wall structure cast monolithic with and supported off the end of bridge deck providing retaining wall for adjoining ground, but not acting as a support for vertical loads.

vi) **Frame Abutment**

End support for bridge constructed integrally with the deck and acting as a retaining wall for adjoining pavement and ground below.

vii) **Granular Backfill**

Selected granular material placed adjacent to the abutment wall and forming the subgrade for the adjoining pavement construction.

viii) **Integral Abutment**

Bridge abutment which is connected to the bridge deck without any movement joint for expansion or contraction of the deck.

ix) **Integral Bridge**

A bridge with integral abutments.

x) **Pavement/Abutment interface**

The interface between the pavement construction and the back face of the abutment.

xi) **Range**

Change (of temperature, strain) between extreme minimum and extreme maximum.

xii) **Stationary Point**

The point on a bridge in plan which does not move when the bridge experiences expansion or contraction during changes in bridge temperature.

xiii) **Sub-surface Drainage**

A system for draining water from within the surfacing.

xiv) **Surface**

The carriageway or footway surface.

xv) **Surfacing**

Carriageway or footway wearing course and base course materials.

Implementation

1.7 This Advice Note 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.

2. GENERAL

2.1 Integral bridges should support all the relevant dead loading and live loading including all longitudinal, and in the case of structures which are curved in plan, centrifugal loading, in accordance with BD 37 (DMRB 1.3.14). They should also accommodate the effects of thermal expansion or contraction without excessive deformation of the approach pavements.

Types of Integral Construction

2.2 This Advice Note has been drafted for the types of integral abutment illustrated in Figure 2.1 and described below:

i) The Frame Abutment which supports the vertical loads from the bridge and acts as a retaining wall for embankment earth pressures. It is connected structurally to the deck for the transfer of bending moments, shear forces and axial loads and supported on foundations. It may be assumed that the abutment will rock bodily on its foundation for the purposes of calculating thermal movements and earth pressure. If the back edge at the top of the abutment is behind the back of the foundation, the design of the pavement/abutment interface should provide for vertical movement of the abutment edge during contraction of the deck.

ii) The Embedded Abutment, such as a diaphragm wall, which extends to a depth below the retained fill and is restrained against rocking by the length of embedment.

iii) The Bank Pad Abutment, which acts as an end support for the bridge, moves horizontally during thermal expansion and contraction of the deck. The bank pad must have adequate weight, and the end span have adequate flexibility, to avoid uplift from live loads or from differential settlement.

iv) The End Screen Abutment acts only as a retaining wall for embankment earth pressures and transfer of longitudinal loads. The vertical loads on the deck are supported by separate supports. These supports are located within 2m of the end screen in order to limit the vertical movement of the end screen when the end span deflects. The end supports may be isolated structurally from horizontal movements of the end screen, or they may be connected to the deck, in which case they must be able to resist, or avoid, the earth pressures arising from their movement relative to the embankment.

Longitudinal Movement

2.3 Bridges should be designed to accommodate the effects of thermal expansion and other longitudinal forces, with thrusts from structural restraints, earth pressures and friction. They should also be designed for the effects of thermal contraction, with axial tension from structural constraint and sliding.

2.4 Multispan integral bridges should not have any expansion joints between spans. Wherever possible, bridge decks should be designed to accommodate the effects of continuity and axial thrust or tension. Various methods for achieving continuity between spans are outlined in BA 57 (DMRB 1.3.8).

2.5 The longitudinal movement of integral abutments should be limited to ± 20mm (nominal, 120-year return period) from the position at time of restraint during construction.

2.6 The effects of temperature difference, shrinkage, and creep should be considered in accordance with BS 5400: Part 4 [(3)], as implemented by BD 24 (DMRB 1.3.1), and BD 37, (DMRB 1.3.14).

Load and Material Factors

2.7 Integral bridges should be designed with the load factors specified in BD 37 (DMRB 1.3.14).

2.8 Passive earth pressure forces on abutments should be calculated in accordance with Section 3 and treated as a permanent load effect (Combination 1) with load factors γ_{fL} of:

1.5 @ ULS ***1.0 @ SLS***

2.9 Earth pressure coefficients on abutments should be multiplied by a material partial safety factor, γ_m, as follows:

i) disadvantageous forces from backfill $\gamma_m = 1.0$

ii) advantageous forces from backfill when resisting secondary load effects (e.g. braking), $\gamma_m = 0.5$.

Thermal Effects

2.10 The characteristic thermal strain (expansion or contraction) throughout the UK can be taken as

steel	(Groups 1 & 2) ± 0.0006
steel with concrete deck	(Group 3) ± 0.0005
concrete	(Group 4) ± 0.0004

For the definition of the above-mentioned groups, see Figure 9 of BD 37 (DMRB 1.3.14). However, the 1.3 factor on the design range of movement at the ultimate limit state given in Clause 5.4.8.1 of BD 37, should not be applied to the characteristic thermal strains given above.

2.11 The above characteristic strains are based on the following assumptions:

i) The bridge spans and abutments are joined during construction at a temperature within ± 10°C of the mean between extreme minimum and extreme maximum shade air temperatures as specified in BD 37 (DMRB 1.3.14).

ii) For concrete and composite decks, concrete with a coefficient of thermal expansion of 0.000012/°C has been assumed.

More detailed estimates of thermal strain may be appropriate, based on data in BD 37 (DMRB 1.3.14), if the design specification does not limit the temperature at the time of joining as above, if other materials are used, or if special circumstances apply.

2.12 Lightweight aggregate concrete, and other materials, can have coefficients of thermal expansion markedly lower than 0.000012/°C and will therefore expand and contract proportionately less than the strains in paragraph 2.10. Where justified, a lower coefficient of thermal expansion may be used in such instances.

2.13 Special attention should be given to prevent early thermal and shrinkage cracking resulting from restraint to the longitudinal movement of deck slabs, by integral abutments.

2.14 Bridges which are curved, or not symmetric, experience thermal movements relative to a stationary point. The position of the stationary point can be determined from a stiffness analysis employing horizontal stiffnesses at supports and abutments. (See Reference 6).

Piers

2.15 Intermediate supports of integral bridges can be designed to move horizontally with the superstructure or with a bearing which allows lateral movement beneath the deck. In the former case the pier has to be sufficiently flexible to accommodate the thermal movement to which it would be subjected. Designers should be aware of the inherent maintenance problems associated with the use of bridge bearings and make provision for their maintenance and future replacement. For further information see Design for Durability, BA 57 (DMRB 1.3.8).

Pre-tensioned Concrete Decks

2.16 In precast pre-tensioned concrete construction, it is often not possible to comply with Class 1 serviceability requirements of BD 24 (DMRB 1.3.1) in hogging regions. At integral abutments and over continuous supports, it is acceptable to design prestressed pre-tensioned beams as reinforced concrete providing due allowance is made for compressive stresses due to prestess.

Bearings

2.17 Where integral bridges are adopted, which include bearings in their design, proper provision should be made in the design for inspection, any necessary testing or monitoring and future replacement. These provisions should be included in technical approval submissions for the initial design of the structure. Replacement of bearings should be safely accomplished without the need to resort to any traffic restrictions on the road carried by the bridge, or the need for structural modifications. Details of the bearings should be such as to only require minimal jacking to remove the load from the bearings, to allow safe replacement. They should also include provision for 'jacking points' and sufficient access space around the bearings to permit inspection, and replacement. Detailed method statements for bearing replacement must be included in the Maintenance Manual for the structure, forming part of the as-built records.

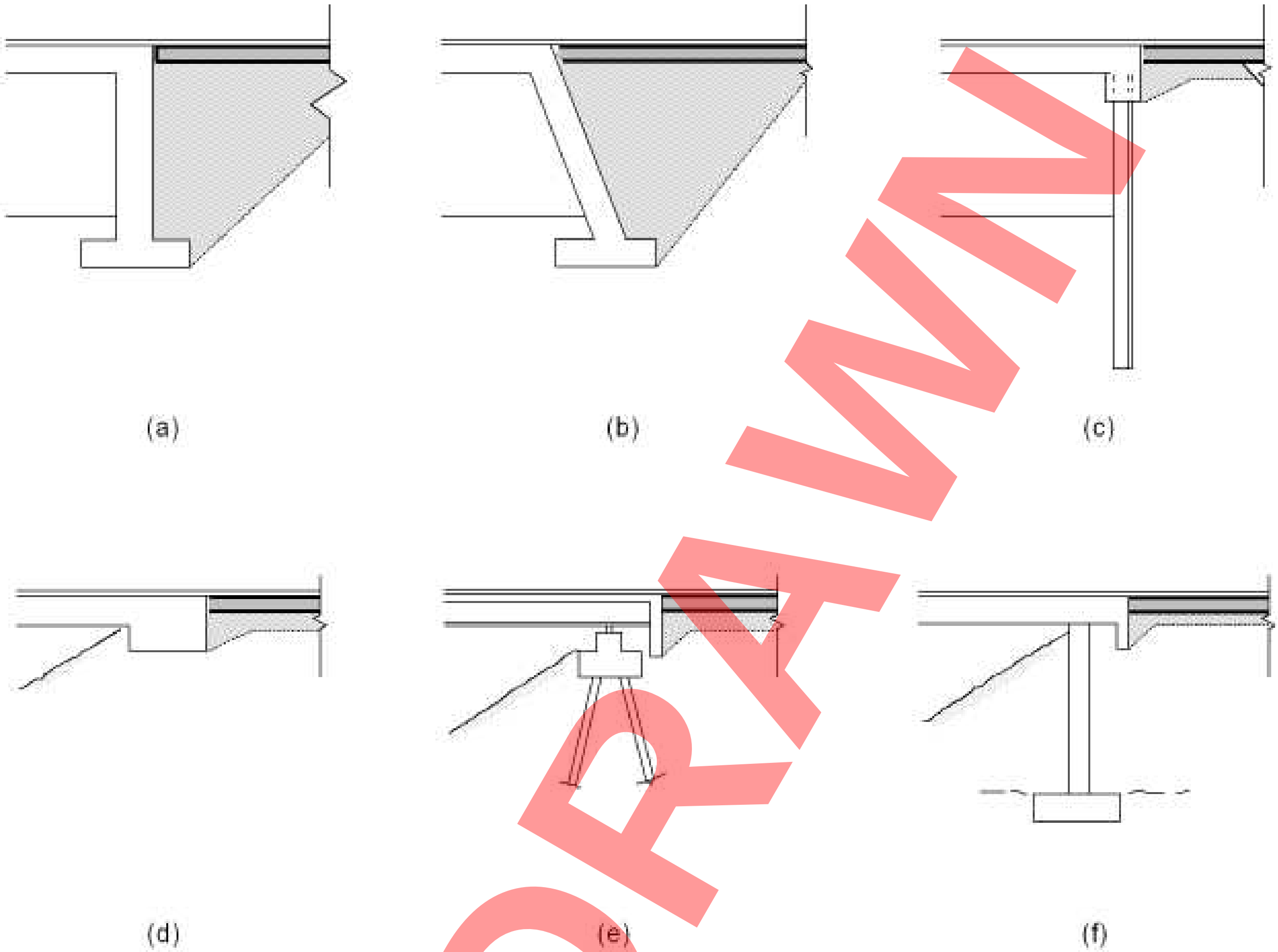

Figure 2.1 Types of Integral Abutments

(a) & (b) Frame abutments
(c) Embedded abutment
(d) Bank pad abutment
(e) & (f) End screen abutments

Volume 1 home page

3. EARTH PRESSURE

General

3.1 Based on experimental and analytical data the following design recommendations are made for the magnitude of lateral earth pressures to be adopted in the design of integral bridge abutments in the U.K.

Soil Strength and Wall Friction

3.2 An increase of stiffness of granular soil occurs due to densification of the fill under the thermal cyclic movements induced by deck expansion. Even if the fill is placed in loose condition, it will be densified during the lifetime of the structure [12]. Therefore representative c'_{peak} and ϕ'_{peak} for the fill material, compacted at the optimum moisture content to a dry density of 95% of the maximum dry density determined in accordance with BS 1377: Part 4[5] using the vibrating hammer method, should be used throughout the design.

3.3 In a conventional retaining wall, following BS 8002[4], design $\tan\phi'$ would then be calculated using a mobilization factor M = 1.2, on representative $\tan\phi'_{peak}$ and applied to calculate active and "at rest" earth pressure coefficients. However, the passive earth pressure mobilised by a granular backfill on an abutment of an integral bridge moving towards the backfill would act in an unfavourable manner. For this reason, the approach of Eurocode 7[8] Clause 2.4.2 is adopted in which the factor of M = 1/1.2, i.e. a value of < 1, is applied to representative $\tan\phi'_{peak}$ to determine design $\tan\phi'$ for passive earth pressure calculations. The factor M is applied to the representative value of $\tan\phi'_{peak}$ to allow for variation in the backfill properties and to ensure that an upper bound value for passive earth pressure can be determined. Where the source of the backfill material is known and the upper bound values of ϕ'_{peak} have been established, the designer may justify an increase in the value of M up to unity. When this is done, site testing must be carried out on the backfill material to verify its properties remain within the design upper bound values of ϕ'_{peak}.

Wall friction should be taken as δ = design $\phi'/2$.

Earth Pressure Distribution for Different Structural form

3.4 During displacement towards the backfill, integral abutments with back faces inclined forwards, as in Figure 2.1 (b), mobilise much lower passive earth pressures than vertical walls during displacements; whereas abutments inclined backwards mobilise higher pressures [7]. K_p also increases very rapidly at higher angles of friction ϕ'.

An underestimate of ϕ' could very seriously underestimate earth pressure loading during thermal expansion. An overestimate of ϕ' could very seriously overestimate the abutment's resistance to longitudinal braking forces. With these caveats and provided that the detrimental effect of using a better quality fill is avoided by site control, there is no need for a further onerous material factor, γ_m. The appropriate γ_m to be applied to passive earth pressure coefficient is given in 2.9. Values of K_p, based on ϕ'_{peak} and δ, should be selected from Eurocode 7 [8] or similar tables based on a curved failure surface.

3.5 A summary of the proposed design earth pressure distributions with depth for the different structural forms is now given. Design of structural elements for serviceability and ultimate limit states should use the appropriate γ_{fL} as given in Clause 2.8.

(a) Shallow height bank pad and end screen abutments

3.5.1 The typical height of a bank pad or end screen abutment is up to 3 metres and, therefore, the total force generated by passive excitations is usually readily accommodated within the design. Account should be taken of the mode of movement, ie. translation, rotation or a combination of the two, Darley et al [9], [13]. The shear strains in the backfill will be high. The following equation to calculate the relationship between K*, the retained height (H) and thermal displacement of the top of the abutment (d), should be used [14]:

$$K^* = K_0 + (d / 0.025\,H)^{0.4}\,K_p$$

where K_0 is the at rest earth pressure coefficient and the passive earth pressure coefficient K_p is based on $\delta = \phi'/2$ and taken from Eurocode 7[8].

Volume 1 home page

(b) Full height frame abutment

3.5.2 The height of the abutment means that the magnitude of passive pressures acting on the back of the wall is likely to be significant [10]. Careful design of the abutment is therefore important to ensure the structure is strong enough to resist lateral pressures that could build up behind the wall, and yet flexible enough to accommodate movement.

3.5.3 For a portal frame structure the earth pressures on the retained side can be represented by a distribution analogous to that employed for calculating compaction stresses in backfill [11]. However for integral bridges the use of wall friction will lead to higher earth pressures at the top of the wall which will extend to a greater depth than compaction effects. The suggested distribution (see Figure 3.1) comprises:

- a uniform value of K* over the top half of the retained height of the wall, with
- lateral earth pressure then remaining constant with depth as K* drops towards K_0
- if the lateral earth pressure falls to K_0 then below that depth pressures are according to the insitu value K_0.

The following equation which is based on wall friction δ of φ′/2 has been used to calculate the relationship between K*, the retained height (H) and thermal displacement of the top of the abutment, (d):

$$K^* = (d/0.05H)^{0.4} K_p$$

3.5.4 Although it is recognised that this formula is derived from static tests and on its own will lead to an underestimate of stresses in a cyclic situation, allowance for this has been made by adopting suitable soil strength parameters as given in 3.2. However, K* should not be taken as less than the ‘at rest’ earth pressure, $K_o = 0.6$.

3.5.5 For a portal framed structure hinged at the base of its legs, the earth pressure distribution given in 3.5.3 should be applied with the following equation [12] to calculate the relationship between K*, the retained height (H) and thermal displacement of the top of the abutment (d):

$$K^* = K_0 + (d / 0.03\ H)^{0.6} K_p$$

where K_0 is the at rest earth pressure coefficient and the passive earth pressure coefficient K_p is based on $\delta = \phi'/2$ and taken from Eurocode 7[8]. Monitoring of this form of structure has been reported by Barker et al [15].

(c) Full height embedded wall abutment

3.5.6 Embedded walls are installed in undisturbed ground and are more likely to be used in clayey conditions. If the clay is over consolidated, less movement will be required to mobilise full passive pressures: however this is compensated for by initial concrete shrinkage of the deck which will help to relieve the high in-situ soil stresses.

3.5.7 For an embedded wall, the earth pressure distribution [11] may be represented (see Figure 3.2) by:

- a uniform value of K* over the top two-thirds of the retained height of the wall, with
- lateral earth pressure then remaining constant with depth as K* drops towards K_0
- if the lateral earth pressure falls to K_0 then below that depth pressures are according to the insitu value K_0.

K* should be determined from the equation in 3.5.3.

3.6 Live load surcharge on backfill should be ignored when calculating the passive earth pressure mobilised by thermal expansion of the deck. Earth pressures under live load surcharge in the short term should be checked at ‘at rest’ earth pressure conditions with $K_0 = (1 - \sin\phi')$, where φ′ is the effective angle of shearing resistance from 3.2.

3.7 Active earth pressures on abutments during thermal contraction of the deck are very small as compared to passive pressures and may be ignored.

Backfill

3.8 Backfill material to integral abutments should be free draining selected granular fill with properties and grading complying with Classes 6N or 6P of Table 6/1 of Specification for Highway Works. Backfill material shall be compacted in accordance with Clause 612 of the Specification for Highway Works [2] to limit the settlement of backfill due to the effects of thermal movements of the structure.

3.9 The backfill to integral abutments should be a designed material with specified properties validated during construction. The specification involves a compromise between stiffness and flexibility. In general granular materials comprising compacted rounded particles of uniform grading can have a peak angle of internal friction, ϕ´, as low as 35°, and may accommodate thermal expansion without high earth pressures. However, they are somewhat vulnerable to settlement. Fill of compacted well graded hard angular particles can have a peak angle of internal friction as high as 55° with very high resistance to thermal expansion and are less vulnerable to settlement. Granular backfill to integral bridges exceeding 40m length should have a peak angle of internal friction j´ not greater than 45°, when tested in accordance with the Specification for Highway Works.

3.10 The zone of granular backfill should extend up from the bottom of the abutment wall to at least a plane inclined at an angle of 45° to the wall.

Pavement

3.11 Road pavements should be constructed in accordance with the Specification for Highway Works right up to the back faces of integral abutments. The surfacing can be laid as a continuous layer over the approach roads and over the deck waterproofing.

3.12 Asphaltic plug joints complying with BD 33 (DMRB 2.3.6) may be used in the surfacing at the interface between the back edges of integral abutments and adjoining flexible pavements.

Drainage

3.13 Gullies should be located in roadside channels on the uphill side at integral abutments to catch surface water that might flow across the pavement/abutment interface.

3.14 Flexible pavements should have a sub-surface drain below the surfacing along the pavement/abutment interface. The sub-surface drainage system should have a fall of at least 2% and shall be easily cleaned.

3.15 Integral abutments should have a permeable backing as specified for earth retaining structures in Clause 513 of the Specification for Highway Works [(2)]. Clause 513 is a general specification for permeable backing and permits the use of three materials. Granular material complying with the requirements of Clause 505 for Type A and Type C material will always be suitable permeable backing behind integral bridge abutments and should be properly compacted. However, the strength of porous no fines concrete cast insitu and precast concrete hollow blocks should be checked to ensure they will provide adequate resistance to the design passive pressures before being used behind integral bridge abutments. The permeable backing should be drained with a pipe of at least 150mm diameter which has a fall exceeding 2% and can be cleaned readily.

Foundations

3.16 Integral abutments can be founded on spread footings or on piles.

3.17 Piles should be designed to accommodate lateral movement and/or rocking of the abutment while supporting axial loads, and to support forces from movements of the piles and/or movements of the ground. Raking piles should not be used for foundations that move horizontally.

3.18 Bearing pressures under foundations which slide while supporting vertical loads, such as bank pads, should be not greater than 50% of the presumed bearing capacity of the ground for a non-sliding foundation subject to the same loading, in order to avoid settlement during sliding.

Wing walls

3.19 Wing walls attached to abutments should be kept as small as possible to minimise the amount of structure and earth that have to move with the abutment during thermal expansion of the deck. Where large wing walls are used in conjunction with long integral bridges, abutments should be allowed to rock or slide independently from the wing walls.

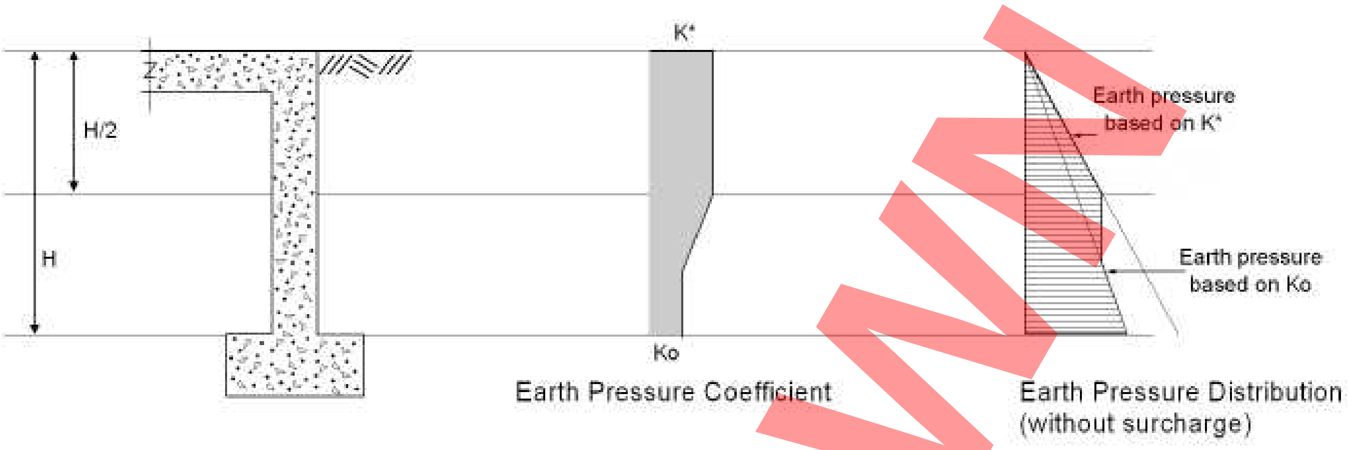

Figure 3.1 Earth Pressure Distribution for Frame Abutment

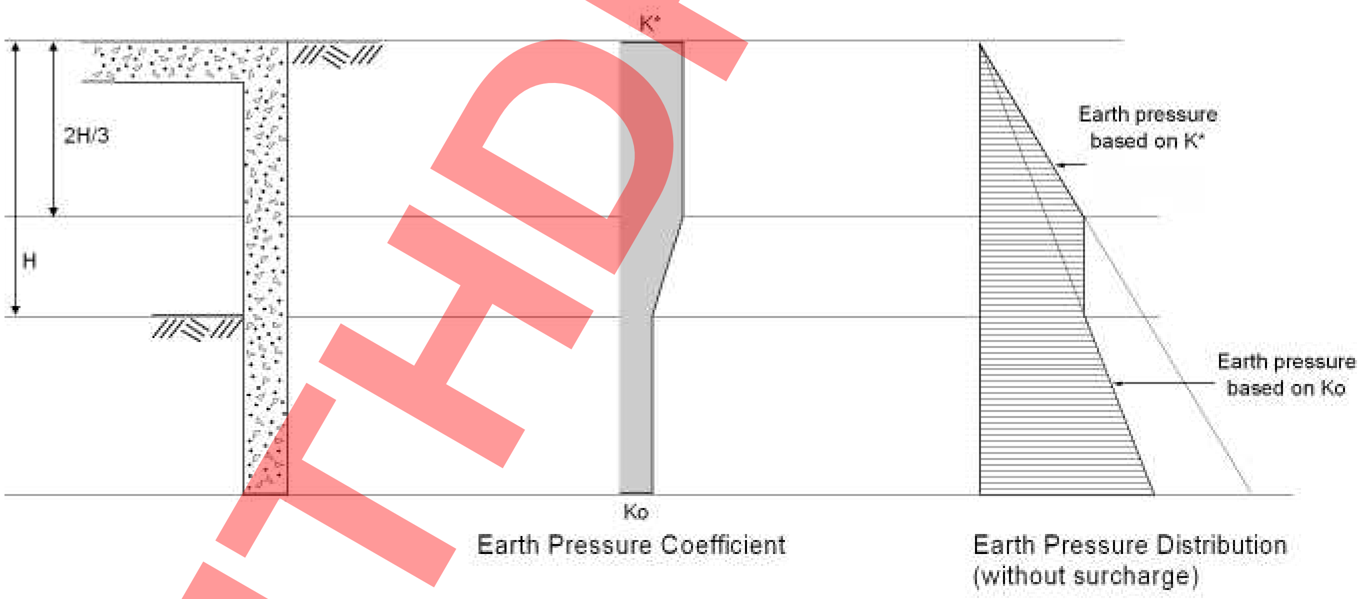

Figure 3.2 Earth Pressure Distribution for Full height Embedded Wall Abutments

4. REFERENCES

1. Design Manual for Roads and Bridges (DMRB): TSO

BD 24 Use of BS 5400: Part 4: 1990. (DMRB 1.3.1)

BD 28 Early Thermal Cracking of Concrete. (DMRB 1.3)

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

BD 31 Buried Concrete Box Type Structures. (DMRB 2.2.12)

BD 33 Expansion Joints for Use in Highway Bridge Decks. (DMRB 2.3.6)

BD 37 Loads for Highway Bridges. (DMRB 1.3.14)

BD 57 Design for Durability. (DMRB 1.3.7)

BA 26 Expansion joints for use in highway bridge decks. (DMRB 2.3.7)

BA 57 Design for Durability. (DMBR 1.3.8)

2. Manual of Contract Documents for Highway Works (MCHW): TSO

Specification for Highway Works. (MCHW)

3. British Standard BS 5400: Part 4: 1990. Code of Practice for the Design of Bridges. BSI

4. British Standard BS 8002: 1994. Code of Practice for Earth Retaining Structures. BSI

5. British Standard BS 1377: Part 4: 1990. British Standard Methods of Test for Soils for Civil Engineering Purposes; Compaction related tests. BSI

6. Hambly E C (1991). 'Bridge Deck Behavior'; 2nd ed., E&FN Spon.

7. Kerisel J and Absi E (1990). 'Active and Passive Earth Pressure Tables', Balkema, Rotterdam.

8. Draft for development DD ENV 1997-1: 1995. Eurocode 7: Geotechnical design, Part 1.General rules (together with United Kingdom National Application Document).

9. Darley P, D R Carder and G H Alderman (1996). Seasonal thermal effects on the shallow abutment of an integral bridge in Glasgow. TRL Project Report 178. Crowthorne: Transport Research Laboratory.

10. Darley P and G H Alderman (1995). Measurement of thermal cycle movements on two portal frame bridges on the M1. TRL Project Report 165. Crowthorne: Transport Research Laboratory.

11. Springman S M, A R M Norrish and C W W Ng (1996). Cyclic loading of sand behind integral bridge abutments. TRL Project Report 146. Crowthorne: Transport Research Laboratory.

12. England G L, Tsang N C M and Bush D I. Integral Bridges – A fundamental approach to the time-temperature loading problem. Thomas Telford, 2000.

13. Darley P, Carder D R and Barker K J. Seasonal thermal effects over three years on the shallow abutment of an integral bridge in Glasgow. Transport Research Laboratory Report 344, 1998.

14. Goh C T. The behaviour of backfill to shallow abutments of integral bridges. PhD Thesis University of Birmingham, 2001.

15. Barker K J and Carder D R. Performance of an integral bridge over M1-A1 Link Road at Bramham Crossroads. Transport Research Laboratory Report 521, 2001.

5. ENQUIRIES

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

Divisional Director Room 913 Sunley Tower Piccadilly Plaza Manchester M1 4BE	Andrew Jones Divisional Director

Chief Road Engineer Scottish Executive Development Department Victoria Quay Edinburgh EH6 6QQ	J HOWISON Chief Road Engineer

Chief Highway Engineer Transport Directorate Welsh Assembly Government Llywodraeth Cynulliad Cymru Crown Buildings Cardiff CF10 3NQ	J R REES Chief Highway Engineer Transport Directorate

Assistant Director of Engineering Department for Regional Development Roads Service Clarence Court 10-18 Adelaide Street Belfast BT2 8GB	D O'HAGAN Assistant Director of Engineering