NRA ADDENDUM TO

BD 31/87

BURIED CONCRETE BOX TYPE STRUCTURES

Standard BD 31/87 - Buried Concrete Box Type Structures - 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. 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.

4. At several locations:

   For: "Departmental Standard"
   Read: "Standard".

SPECIFIC

1. Page 2, Paragraph 1.1:
   Delete final sentence beginning, “Other specific requirement...” and replace with:
   “Other specific requirements for subways are given in TD 36 (DMRB 6.3.1).”

2. Page 2, Paragraph 1.2:
   Delete Paragraph 1.2.

3. Page 2, * Note, line 2:
   For: “the Department”
   Read: “the National Roads Authority”.

4. Page 7, Paragraph 4.5.1:
   Add at the end of Paragraph 4.5.1:
   “The maximum horizontal earth pressure shall act as a relieving force when considering longitudinal live loading forces, with the minimum horizontal earth pressure applied in the direction of the longitudinal live load force. The following partial safety factors shall be used in conjunction with the earth pressures in this situation:-

   i) $0.6\gamma H$: $\gamma_{fL} = 1.0$) relieving effect
   $\gamma_{f3} = 1.0$)

   ii) $0.2\gamma H$: $\gamma_{fL} = 1.5$) acting with longitudinal live load
   $\gamma_{f3} = 1.1$)

   The above factors refer only to the ULS. The γ_{fL} values at ULS and SLS for earth pressure only remain as stated in Table 1 of Appendix A to BD 37 (DMRB 1.3).”

5. Page 9, Paragraph 4.8.2, lines 2 and 3:
   For: “Technical Memorandum BE 5 and BS 5400: Part 2.”
   Read: “BD 52 (DMRB 2.3.3), BD 60 (DMRB 1.3.5) and BD 37 (DMRB 1.3).”

6. Page 9, Paragraph 4.9:
   After Paragraph 4.9 add:
   “4.10 **Mining Subsidence**
   In areas liable to be subject to mining subsidence, the design shall take account of the requirements of BD 10 (DMRB 1.3.14).”

7. Page 11, Paragraph 6.1.4, line 4:
   For: “DTp Specification for Highway Works (6th Edition)”
   Read: “NRA Specification for Road Works”

8. Page 13, Section 7, References:
Delete text and replace with:

“1. G N Smith, “Elements of Soil Mechanics”, Blackwell Science (UK), 1998.

2. NRA Manual of Contract Documents for Road Works, Volume 1: Specification for Road Works.

3. British Standards

BS 5400	Steel, Concrete and Composite Bridges Part 1: 1988 General Statement Part 2: 1978 Specification for Loads Part 4: 1990 Code of Practice for the Design of Concrete Bridges

4. Design Manual for Roads and Bridges (DMRB), as implemented in Ireland

NRA BD 24	The Design of Concrete Road Bridges and Structures: Use of BS 5400: Part 4: 1990 (NRA DMRB 1.3.1)
BD 15	General Principles for the Design and Construction of Bridges: Use of BS 5400: Part 1: 1988 (DMRB 1.3.2)
BD 60	Design of Highway Bridges for Vehicle Collision Loads (DMRB 1.3.5)
BD 10	Design of Highway Structures in Areas of Mining Subsidence (DMRB 1.3.14)
BD 37	Loads for Highway Bridges (DMRB 1.3)
BD 52	The Design of Highway Bridge Parapets (DMRB 2.3.3)
TD 36	Subways for Pedestrians and Pedal Cyclists. Layouts and Dimensions (DMRB 6.3.1)”.

9. Page 14, Section 8:
Delete text and replace with:
“8.1 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

THE HIGHWAYS AGENCY BD 31/87

THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
Y SWYDDFA GYMREIG

THE DEPARTMENT OF THE ENVIRONMENT
FOR NORTHERN IRELAND

Buried Concrete Box Type Structures

Summary: This Departmental Standard sets out the design and construction requirements for buried concrete box type structures.

VOLUME 2	HIGHWAY STRUCTURES: DESIGN (SUBSTRUCTURES AND SPECIAL STRUCTURES), MATERIALS
SECTION 2	SPECIAL STRUCTURES

BD 31/87

BURIED CONCRETE BOX TYPE STRUCTURES

Contents

Chapter

SYMBOLS

H	Height of cover above the structure to the finished surface level including any road construction depth.

γ	Bulk density of compacted fill or road construction materials, as appropriate.

γ_{fL}, γ_{f3} and γ_m are partial safety factors.

1. INTRODUCTION

1.1 This Departmental Standard specifies the structural design and construction requirements for buried concrete box type structures used as culverts, subways, cattle creeps etc or as bridges over minor roads. Other specific requirements for subways are given in TD 2/78 Pedestrian Subways - Layout and Dimensions and TD 3/79 Combined Pedestrian and Cycle Subways - Layout and Dimensions.

1.2 This Departmental Standard supersedes those parts of the following Departmental Standards which give requirements for rigid buried box type structures:-

BE 1/73	Reinforced Concrete for Highway Structures (Clause 1 paragraph 6)
BE 1/77	Standard Highway Loadings (Clause 8)
BD 14/82	Loads for Highway Bridges, Use of BS 5400: Part 2: 1978 (Clause 2.3)
BD 24/84	Design of Concrete Bridges, Use of BS 5400: Part 4: 1984 (Clause 3.3)

2. SCOPE

2.1 Buried concrete box type structures can be either precast or cast in situ and their structural forms can include single or multicell boxes, portal frames and propped and strutted abutments as well as those with simply-supported top slabs.

2.2 This Departmental Standard applies to buried concrete box type structures for which

(a) the depth of cover measured from the finished surface to the top of the structure is greater than 600 mm but less than 8m, and

(b) the internal clear span ie the perpendicular distance between the side walls of the box type structure, or between the two outermost walls of a multicell structure, is greater than 900 mm.

2.3 The provisions of this Departmental Standard are also applicable to buried concrete box type structures with depths of cover ranging from 200mm to 600mm except that for such structures all load requirements shall be fully in accordance with BS 5400: Part 2*. The additional deflection check described in clause 5.3 is of special importance for structures with low depths of cover.

*Note: Any reference to a part of BS 5400 in this document is to that part as implemented by the Department.

2.4 This Departmental Standard does not apply to structures installed by methods such as thrust boring or jacking.

3. DESIGN PRINCIPLES AND OBJECTIVES

3.1 Design of Structural Elements

3.1.1 Limit state principles have been adopted in this Departmental Standard for the design of the structural elements. The two limit states adopted are:-

(a) an ultimate limit state, represented by the collapse of the structural element concerned.

(b) a serviceability limit state, represented by the condition beyond which a loss of utility or cause for public concern may be expected and remedial action required.

3.1.2 For satisfactory design the following relation shall be satisfied:-

$R^* \geq S^*$

where R*, the design resistance = function $\left(\frac{f_k}{\gamma_m}\right)$

and S*, the design load effects = $\gamma f3$ (effects of $\gamma fL.Qk$)

In the above equation fk is the characteristic strength of the material and Qk the nominal loads as described in BS 5400 Part 1. γm, $\gamma f3$ and γfL are partial safety factors and are defined as follows:-

γfL - Partial safety factor that takes account of the possibility of an unfavourable deviation of the loads from their nominal values and of the reduced probability that various loadings acting together will all attain their nominal values simultaneously.

$\gamma f3$ - Partial safety factor that takes account of inaccurate assessment of the effects of loading, unforeseen stress distribution in the structure, and variations of dimensional accuracy in construction.

γm - Partial safety factor that takes account of variabilities in material strength and uncertainties in the assessment of component strength.

The values of γfL are given in Clause 3.1.4. The values of $\gamma f3$ and γm are given in BS 5400: Part 4.

3.1.3 Nominal Loads
The nominal values of the following loads, which are described more fully in Clause 4, are to be used in design:-

(a) Dead Load
(b) Superimposed Dead Load
(c) Temperature Effects
(d) Differential Settlement
(e) Earth Pressures
(f) Erection Loads
(g) Primary Live Loads
(h) Secondary Live Loads
(i) Hydrostatic Pressure

3.1.4 Partial Safety Factors for Loads

The partial safety factors for loads, γfL, applicable to the above loads shall be as given in BS 5400: Part 2, except where modified by Table 1.

LOAD	SLS	ULS	COMBINATIONS
	γfL	γfL	
Superimposed Dead Load	1.0	1.2	All combinations
Hydrostatic Pressure	1.1	1.1	All combinations

SLS: serviceability limit state
ULS: ultimate limit state

TABLE 1 - Partial Safety Factors for Loads (where different from BS 5400: Part 2)

3.1.5 Load Combinations

The various load combinations to be considered in design shall be as given in BS 5400: Part 2 and Table 1. Hydrostatic pressure, when present, is applicable to all combinations.

3.2 Design For Soil-Structure Stability

Even when the structural elements are designed to their required strength, the structure as a whole can fail due to overloading of the soil-structure interface or excessive soil deformations. In order to prevent such failures the following two additional limit states are to be considered in design.

3.2.1 Ultimate Limit States for Soil-Structure Behaviour

These are:

(a) Sliding of the structure on its base.

(b) Overturning of the structure about one of its bottom edges.

Loads applicable to these limit states are the dead load, the superimposed dead load, secondary live loads and the horizontal earth pressures on the side walls. These loads shall be as described in Clause 4 and both maximum and minimum values are to be applied to obtain the worst design cases. The nominal values of the applied loads shall be used in the calculations. The structure shall have an overall factor of safety of at least 2 against both sliding and overturning.

3.2.2 Serviceability Limit State For Soil-Structure Behaviour

Differential settlements of the surrounding soil are to be assessed using the site investigation data. The structure must be able to accommodate these settlements through either movements at the structural joints or through adequate structural strength.

4. DESIGN LOADS

4.1 Dead Loads

The nominal dead load consists of the weight of the materials and parts of the structure that are structural elements excluding superimposed materials such as the road construction and the soil cover.

4.2 Superimposed Dead Load

The nominal superimposed dead load consists of the weight of the road construction materials and the soil cover above the structure and shall be applied as a uniformly distributed load. As a result of the negative arching of the fill material the structure may be subjected to loads greater than the weight of the fill directly above it. This effect is taken into account in the following formulae:-

Maximum superimposed dead load intensity = 1.15 γH
Minimum superimposed dead load intensity = γH

where y = bulk density of compacted fill or road construction materials, as appropriate.
H = height of cover from the top of the structure to the finished surface level.

4.3 Load Effects Due to Temperature

4.3.1 Temperature Effects During Construction
Temperature effects shall be considered for the erection condition of all buried structures in accordance with BS 5400: Part 2.

4.3.2 Temperature Effects in Service
Buried structures with widths less than 5 times the span are to be considered as being open to the atmosphere and the effects of temperature are to be taken into account in accordance with BS 5400: Part 2.

For buried structures of a width greater than or equal to 5 times their span, the requirements of BS 5400: Part 2 are to be modified as shown in Table 2. For buried structures of spans less than or equal to 3m, temperature effects shall be disregarded.

Span metres	Fill depth metres	Temperature °C Range	Temperature °C Difference
>3	>0.6 but <=0.75	10 ± 10	0.5 x Fig 9 Values*
	>0.75 but <=1.0	10 ± 6	0.33 x Fig 9 Values*
	>1.0 but <=2.0	10 ± 3	Zero
	>2.0	Disregarded Temperature Effects	

*BS 5400: Part 2, Figure 9, Group 4

TABLE 2

4.4 Differential Settlement

Any differential settlement of the soil which is likely to affect the structure in whole or in part shall be taken into account.

4.5 Earth Pressures

4.5.1 The nominal horizontal earth pressures on the side walls of the structure shall be taken as follows:-

Maximum horizontal earth pressure = 0.6 yH
Minimum horizontal earth pressure = 0.2 yH

where y = bulk density of compacted fill or road construction materials, as appropriate.
H = height of cover above the point of calculation.

It is to be assumed that either the maximum or the minimum earth pressure can act on any side wall irrespective of the magnitude of the earth pressure on the other side wall.

4.5.2 The load factors and the load combinations applicable to earth pressures shall be in accordance with BS 5400: Part 2.

4.6 Erection Loads

4.6.1 All possible combinations of loads applicable during the construction process shall be taken into account. It should be noted that under low cover conditions which prevail during construction, the structure may be subjected to load conditions which are more severe than those experienced in normal service.

4.6.2 Both temporary and permanent erection loads shall be applied in accordance with BS 5400: Part 2.

4.7 Primary Live Loads

4.7.1 The nominal live loads shall be the HA wheel load and the HB vehicle which shall be applied in accordance with BS 5400: Part 2. For structures which have a requirement for only HA loading, a minimum of 25 units of HB loading shall also be applied. The appropriate load factors shall be as given in BS 5400: Part 2.

4.7.2 To determine the nominal vertical live load pressure, dispersion of the wheel loads may be assumed to occur from the contact area on the carriageway to the top of the buried structure at a slope of 2 vertically to 1 horizontally as shown in Figure 1. Each HA and HB wheel load shall be assumed to be uniformly distributed over a circular or a square area with an effective pressure of 1.1 N/mm2. Wheel loads not directly over the structure shall also be considered if their dispersion zones fall over any part of the structure.

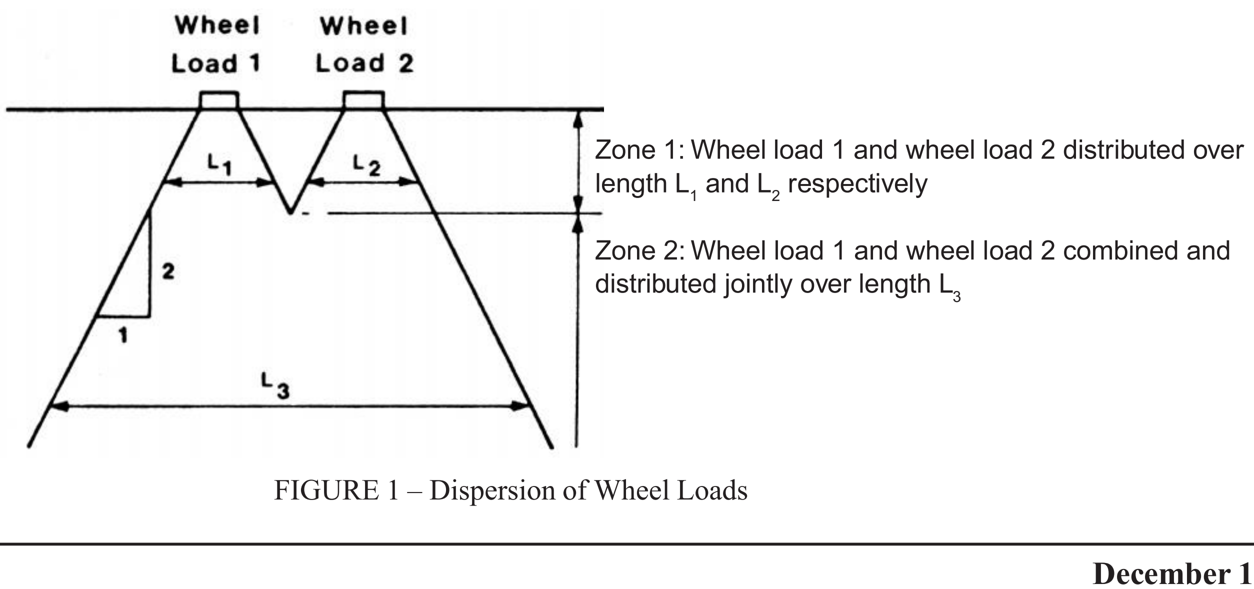

FIGURE 1 – Dispersion of Wheel Loads

4.7.3 As an alternative to Clause 4.7.2, the nominal vertical live load pressure may be derived from Boussinesq's theory of load dispersion[1].

4.7.4 For structures with depths of cover ranging from 200mm to 600mm, full highway loading as given in BS 5400: Part 2 shall be applied. The HA KEL shall be dispersed below the depth of 200mm from the finished road surface at a slope of 2 vertically to 1 horizontally.

4.8 Secondary Live Loads

4.8.1 The structure shall be designed to resist longitudinal loads and accidental skidding loads unless provision has been made for the transfer of such loads by the road slab. These loads shall be in accordance with BS 5400: Part 2 and only HB loading is to be considered. The load shall be multiplied by the following factor before it is applied directly to the top of the structure:

$$\text{Factor} = \frac{\text{span} - \text{height of cover}}{\text{span} - 0.6\text{m}} \quad \text{but} \not> 1 \text{ and} \not< 0$$

4.8.2 Where parapets are attached to the structure, loads due to vehicle collision and their application shall be in accordance with Technical Memorandum BE 5 and BS 5400: Part 2.

4.9 Hydrostatic Pressure

When appropriate the effect of hydrostatic pressure inside as well as outside the structures shall be taken into account. The design loadings due to hydrostatic pressure shall be taken as y_{fL} times the nominal values. (y_{fL} shall be taken as 1.1 for both ultimate and serviceability limit states. Where necessary, the effect of buoyancy shall be taken into account.

5. DESIGN

5.1 General

5.1.1 Reinforced and prestressed concrete shall be designed in accordance with BS 5400: Part 4.

5.1.2 The following three construction and in-service stages are to be considered:-

(a) Backfill placed and compacted to the top of the side walls.

(b) Backfill placed and compacted to an intermediate height above the top of the structure. This design condition is considered to determine the height of fill required before any heavy loads such as construction machinery are allowed on top or in the vicinity of the structure.

(c) In-service condition.

5.1.3 All load combinations and the maximum and minimum limits of those loads for which such limits are given in Clause 4 shall be applied to the above three stages in order to obtain the worst load effects.

5.2 Joints

5.2.1 The structure shall be designed to accommodate all long term differential movements and/or resist the forces set up by such movements. When the predicted movements are excessive it may be necessary to allow for some articulation in the structure by providing joints.

5.2.2 Joints between sections whether they are in a cast in-situ structure or are in a structure consisting of precast units, shall be designed to either:

(a) accommodate all movements resulting from the differential settlement of the soil as well as the deflection of any unit (or section) under maximum live loading when the adjoining units (or sections) are not similarly loads, or

(b) adequately allow for the transfer of forces between the units (or sections).

5.3 Deflection

In order to prevent the occurrence of excessive movements at joints which can seriously damage the carriageway, the vertical deflection of any unit (or section) of the structure under the application of primary live loads at the serviceability limit state must be less than 0.015H, where H is the height of cover above the structure.

6. MATERIALS AND CONSTRUCTION

6.1 Excavation and Filling

6.1.1 Excavation for blinding or bedding shall extend at least 200mm for a precast structure, or 75mm for a cast in-situ structure, below the base of the structure, and at least 300mm beyond the outside wall faces. A greater depth of excavation is required for precast structures; otherwise they are more likely to be subjected to uneven ground support. Excavation shall, where possible, be benched to a minimum slope of 1.0 horizontally to 1.0 vertically to a height of not less than 500mm above the top of the structure or to the carriageway formation level, whichever is lower.

6.1.2 Excavation in rock shall extend at least 125mm for a precast structure, or 75mm for a cast in-situ structure, below the base of the structure, and at least 225mm beyond the outside wall faces.

6.1.3 In the embankment situation, when the embankment is built first, the embankment fill shall be benched to a minimum slope of 0.6 horizontally to 1.0 vertically to a height of not less than 500mm above the top of the structure or to the carriageway formation level, whichever is lower. When the structure is backfilled prior to constructing the embankment, in addition to the above benching requirement the top of the backfilling shall have the same width as that required when the embankment is built first.

6.1.4 Backfilling material, whether for filling the excavation or in the embankment situation, shall comply with the requirements for selected granular fill for backfilling to structures, Class 6N and 6P as described in the DTp Specification for Highway Works (6th Edition)[2], hereafter referred to as the Specification. This backfilling material shall be used up to a height of 500mm above the structure or to the carriageway formation level, whichever is lower.

6.2 Blinding and Bedding

6.2.1 The structure shall be formed on a suitably prepared blinding or bedding layer that shall extend at least 300mm, or 225mm when the excavation is in rock, beyond the outside wall faces of the structure.

6.2.2 Cast in-situ structures shall be constructed on a blinding layer of Grade C7.5P concrete, as described in the Specification, with a minimum thickness of 75mm.

6.2.3 Precast units shall be laid on a two layer bed, the lower 150mm being of selected well graded material (Class 6K) and the upper 50mm being of selected uniformly graded material (Class 6L) as described in the Specification. When founding on rock the lower layer shall be replaced by a blinding layer with a minimum thickness of 75mm.

6.3 Reinforced and Prestressed Concrete

Reinforced and prestressed concrete shall comply with the Specification. The necessity for the provision of sulphate resisting cement as required by the Specification shall be determined from the properties of the general embankment fill as well as from those of the backfill material.

6.4 Waterproofing

6.4.1 The top surface, and the top of the adjoining vertical external surfaces to a level of 200mm below the soffit of the top slab, shall be protected with an approved waterproofing membrane. The surface to receive the membrane shall be prepared, and the membrane laid in compliance with the Specification.

6.4.2 All other concrete surfaces in contact with soil shall be protected with at least two coats of a material approved for waterproofing below-ground concrete surfaces and which complies with the Specification.

6.5 Permeable Drainage Layer

A permeable drainage layer complying with the Specification shall be provided adjacent to all vertical buried concrete faces of structures which do not carry water of effluent. A perforated drainage pipe shall be incorporated at the bottom of the drainage layer with adequate facilities for rodding. This drainage pipe shall be connected to a positive outfall.

6.6 Joints

6.6.1 Joints in precast box structures intended to be used as dry structures, such as subways, shall be made watertight with an approved compression sealant strip placed in the joint prior to the butting of adjacent box segments. This provision is also applicable when groundwater is to be protected from any leakage of the effluent carried by the structure. For all structures any gaps in the joints at both internal and external surfaces, where not covered by a waterproofing membrane, bedding or blinding, shall be filled with a flexible sealant, to prevent the entry of backfilling materials and other debris into the joints.

6.6.2 A supporting compressible joint filler shall be inserted prior to laying the waterproofing membrane or flexible sealant.

6.7 Scour Protection

In the case of culverts the design shall contain adequate provision for preventing scour at the inlet and outlet of the structure. This may include the use of lateral training walls.

6.8 Design Details

The Contract Drawings shall include details of the foundation layers, the extent of the backfill as well as the details of parapets, wing walls etc when applicable.

7. REFERENCES

1. G N Smith, "Elements of Soil Mechanics for Civil and Mining Engineers", Crosby Lockwood Staples, London 1978.

2. Specification for Highway Works - 6th Edition, Department of Transport, HMSO 1986.

British Standards

BS 5400 Steel, concrete and composite bridges
Part 1: 1978 General statement
Part 2: 1978 Specification for loads
Part 4: 1984 Code of practice for design of concrete bridges

Departmental Standards

BE5 The Design of Highway Bridge Parapets
TD 2/78 Pedestrian Subways - Layout and Dimensions
TD 3/79 Combined Pedestrian and Cycle Subways – Layout and DimensionsBD 14/82 Loads for Highway Bridges – Use of BS 5400: Part 2: 1978
BD 15/82 General Principles for the Design and Construction of Concrete Bridges – Use of BS 5400: Part 1: 1978
BD 24/84 Design of Concrete Bridges – Use of BS 5400: Part 4: 1984

8. ENQUIRIES

Technical enquiries arising from the application of this Departmental Standard to a particular design should be addressed to the Technical Approval Authority for that scheme.

General Technical enquiries or comments should be sent in writing to:

Head of Bridges Engineering Division
Department of Transport
St Christopher House
Southwark Street
LONDON
SE1 0TE

Quoting reference:
BE 21/16/018

Orders for copies of this Departmental Standard should be accompanied by the remittance shown on the cover and addressed to:

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