

CARES Technical Approval Report TA2 5056

Issue 3



Invisible Connections FERBOX Reinforcement Continuity System

Assessment of the
Invisible Connections
FERBOX Reinforcement
Continuity System Product and
Quality System for Production



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Product

Invisible Connections FERBOX reinforcement continuity system

Product approval held by:

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1 Product Summary

FERBOX is a reinforcement continuity system, designed to maintain structural continuity across construction joints in reinforced concrete structures.

The FERBOX casing houses suitably proven reinforcement, which is factory pre-bent and factory-fitted.

On the construction site, the FERBOX unit is secured inside the formwork at the front face of the structural member (often a wall), in advance of the concrete pour.

The FERBOX casing is designed to remain embedded in the concrete, providing a useful rebate and key for the subsequent concrete pour. The galvanised and indented profile of the embedded casing obviates the need for traditional scabbling at the joint interface.

After striking the formwork, the casing lid is revealed and removed, providing access to the connection legs (starter bars) which lay inside. These legs are bent outwards (at 90 degrees) by the contractor, then ordinarily lapped with loose reinforcement of the subsequent structural member/concrete pour.

1.1 Scope of Application

This approval covers use of the FERBOX reinforcement continuity system in reinforced concrete structures designed in accordance with Eurocode 2: BS EN 1992-1-1:2004 which are subject to static loading in non-cryogenic environments.

1.2 Design Considerations

In general the recommendations of EC2 apply directly, but there are two areas in which some elucidation of them is needed. One is the design of the anchorages of continuity bars in walls, for which the intentions of EC2 are not very clear. The interpretation used in the present assessment is detailed in 6.3.1 of this report. The other is the longitudinal shear resistance of joints and in particular those within walls. EC2 treats such shear at concrete-to-concrete interfaces and a similar form of expression has been derived from test results for the interfaces between the galvanised casings and concrete.



1.3 Conclusion

It is the opinion of CARES that the Invisible Connections FERBOX system is satisfactory for use within the limits stated in paragraph 1.1 when installed and used in accordance with the manufacturer's instructions and the requirements of this certificate.

L. Brankley
Chief Executive Officer
June 2021



2 Technical Specification

2.1 General

FERBOX consists of suitably proven reinforcement, factory pre-bent and factory-fitted into purpose designed carrier casings. The manufacturing processes are undertaken in a CARES quality assured environment in compliance with ISO 9001.

There are two types of carrier casing, both of which are heavily indented to improve bond when cast in concrete. The first is fabricated from light-gauge galvanised steel sheet and described as 'SD' (for 'square dimple') and provides scope to bespoke the casing to specific application requirements. The second casing style (described as 'RD' for 'round dimple') is automatically rolled from light-gauge galvanised steel coil and is available in a standardised range of widths and depths.

The FERBOX product is available in bar diameters 10mm, 12mm and 16mm. Only ductility class 'B' or 'C' material is used. The reinforcement is grade B500B/B500C to BS4449:2005+A2:2009 and is manufactured by the 'hot rolled and cold stretched' or 'quenched and self-tempered' process routes. Prior to fabrication, the maximum permissible yield strength 'Re' is 580 MPa (hot rolled and cold stretched material) or 600 MPa (quenched and self-tempered material) and the minimum permissible 'Agt' is 7% (hot rolled and cold stretched material) or 9% (quenched and self-tempered material). The material is CARES approved and is regularly tested and monitored for its continued compliance and suitability. Full traceability is maintained at all times.

In all cases, the bends which are to be rebent on site, unless otherwise instructed, will be formed using 6ϕ (minimum) mandrels in accordance with established mechanical performance testing and safe practice.

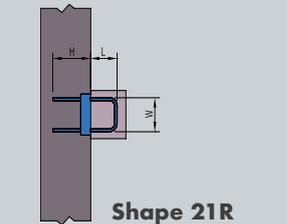
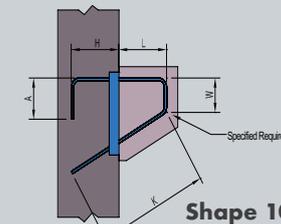
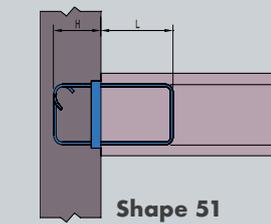
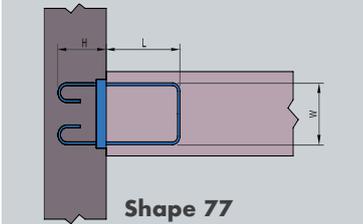
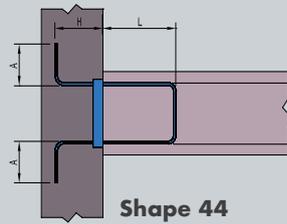
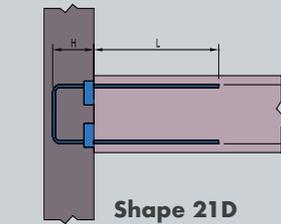
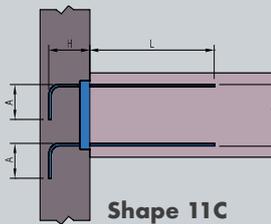
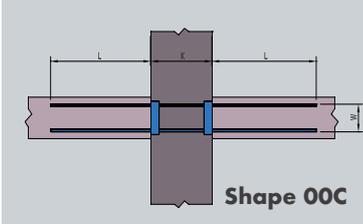
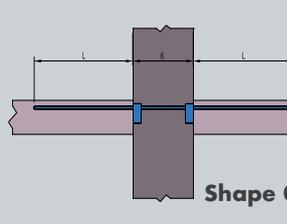
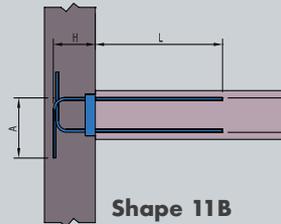
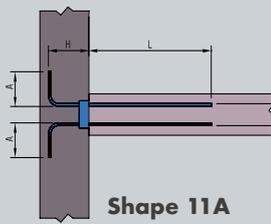
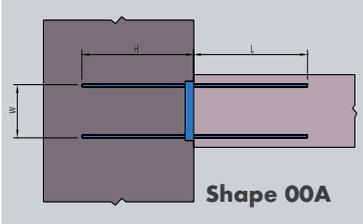
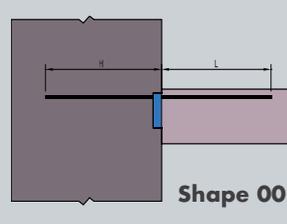
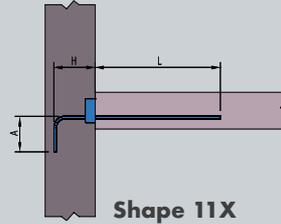
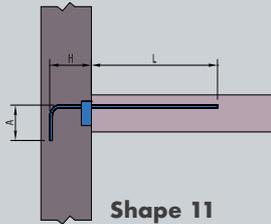
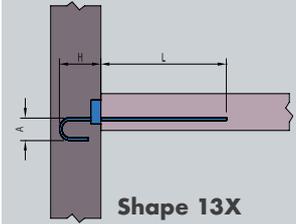
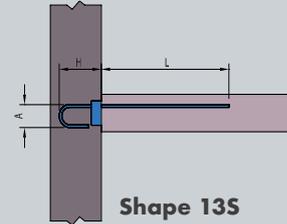
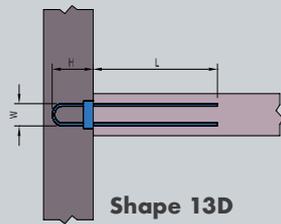
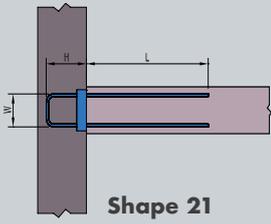
Unless otherwise instructed, the anchorage bends (i.e. those embedded in the first concrete element and not rebent) will be formed using 4ϕ (minimum) mandrels as required by EC2 clause 8.3 (and its effective cross-reference to the local UK bending standard BS8666:2005) to avoid damage to the reinforcement.

Regarding the performance requirements of anchorage bends, EC2 clauses 8.3 and 8.4 (particularly bond and bearing stress) should be considered by the structural designer, to determine whether a larger mandrel diameter should be specified to avoid damage to the concrete within the bends (6ϕ is the normal practical limit).

FERBOX is available in a wide range of customer-specified shape options as per the illustrations in Figure 1. The reinforcement and casing dimensions (particularly when in 'SD' format) are almost infinitely variable according to application requirements, and normally only limited by the physical geometry of leg layouts within the casing.

FERBOX sales literature offers scheduling advice and useful design consideration prompts for the engineer and contractor.

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First Pour
 Second Pour

Figure 1 - Shapes



3 Product Performance and Characteristics

3.1 Reinforcement Tensile Properties

Mechanical tests on the reinforcement showed that the material, after bending and straightening, complied with the tensile requirements of BS4449 Grade B500B or B500C, exhibiting values for Total Elongation at Maximum Load (A_{gt}) of greater than 5% (B500B) or 7.5% (B500C).

3.2 Structural Performance

Structural tests of wall/floor sub-frames and push-off specimens simulating joints between adjacent parts of walls showed that:

1) The shear strengths of the slabs, which were without shear reinforcement, could be safely calculated in accordance with EC2 (eqn 6.2a). There were no shear failures associated with the joints.

2) The flexural strengths of the wall/floor connections could be safely calculated on the basis of EC2's section 6.1 (Bending with or without axial force) and section 8 (Detailing of reinforcement) with the latter interpreted as in this report.

3) The widths of openings, that may develop at the rear faces of casings and between the ends of floor slabs and the faces of walls at the serviceability state, could be calculated as:

$$w = \frac{(y - x) \sigma_s^2 \phi}{(d - x) 4E_s \tau}$$

where

- σ_s is the stress in the tension reinforcement of the slab at the face of the wall
- ϕ is the bar diameter
- E_s is the elastic modulus of steel (200×10^3 MPa)
- $\tau = 0.5 f_{ck}^{2/3}$ for short-term loading or $0.4 f_{ck}^{2/3}$ for long-term loading
- x is the cracked-elastic neutral axis depth
- d is the effective depth of the reinforcement (measured from the underside of the slab)
- y is the vertical distance from the underside of the slab to the level for which the width of the opening is calculated

4) The design resistance to shear at vertical joints between adjacent wall panels could be taken as:

$$V_{Rd} = 0.035 f_{ck}^{2/3} + 0.5 \rho f_{yd} \leq 0.1 (1 - f_{ck} / 250) f_{ck}$$

where

V_{Rd} is the design shear resistance (stress in MPa) and

ρ is the ratio of continuity reinforcement, with both V_{Rd} and ρ calculated with reference to the area of the back face of the casing

f_{yd} is the design yield stress of the reinforcement, which should be adequately anchored at both sides of the casing

The upper limit is based on the range of test data and not on any known physical limitation.

The equation applies to both types of casing, in view of limitations of the test data. It is probably rather conservative for the heavily dimpled nature of both casing styles.

4 Installation

4.1 Fixing Into Position

On timber-faced formwork, proprietary wire nails can be driven directly through the FERBOX casing and into the timber. Additionally or alternatively (especially applicable to steel-faced formwork) the FERBOX unit can be secured by wiring the FERBOX anchorage reinforcement to adjacent main reinforcement. Whichever method is adopted, the FERBOX unit should ideally be tightly 'sandwiched' between the formwork face and the main reinforcement cage (see Figures 1 - 2), providing maximum resistance to displacement during the concrete pouring and vibration processes.

Once the formwork is struck, the FERBOX lid (which can be light-gauge steel or PVC) should be visible on the concrete surface. If it isn't (possibly because it may have become slightly displaced/set-back during the concrete pour) then the thin film of concrete can be tapped-off with a hammer.

The lid is removed by cutting the tapes which secure it, then placing the claw of a hammer at one end (i.e. behind the lid and into the soft polystyrene stop-end) and pulling it away (i.e. separating it) from the embedded part of the casing. The lid can then be safely discarded. This process reveals the connection legs (see Figure 3).

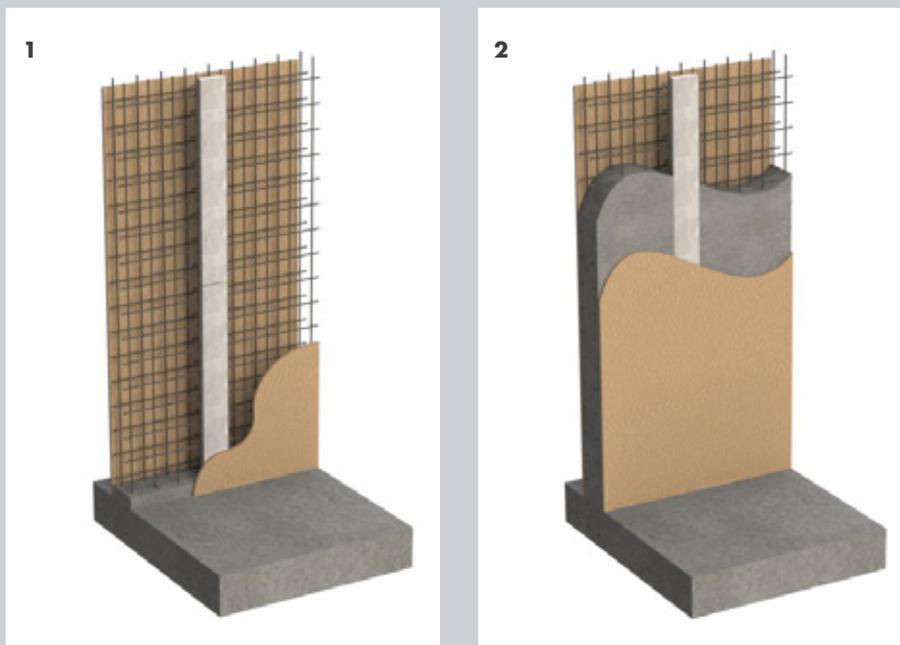


Figure 2 - Installation



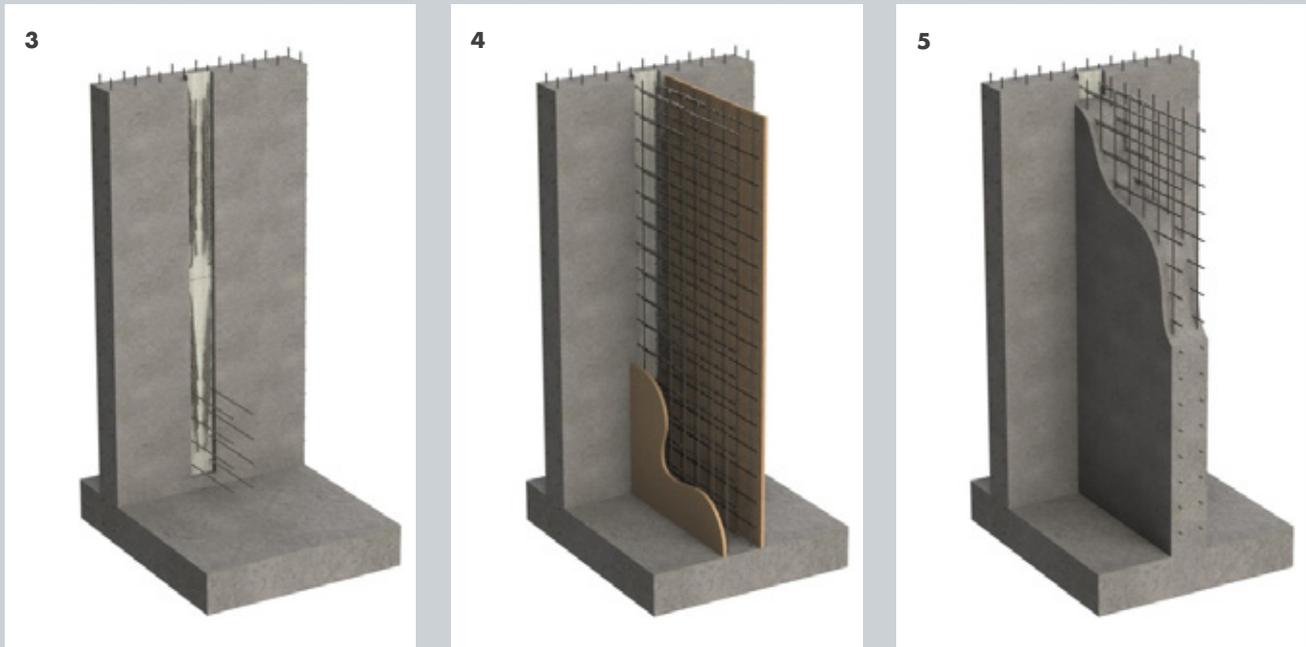


Figure 2 - Installation

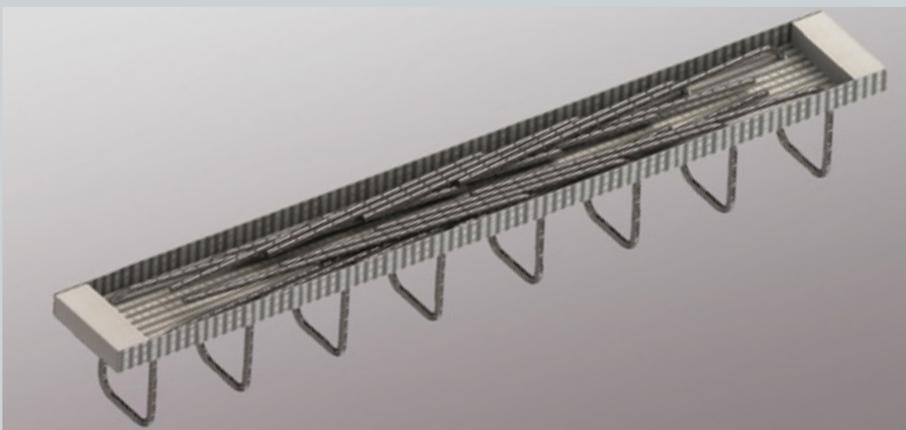


Figure 3 - Lid removed revealing connection legs

4.2 Straightening of Bars

Once the concrete is sufficiently cured (ideally no less than 7 days after pouring), and with the ambient and reinforcement temperature above 5 degrees (occurring naturally or with use of indirect heat), a safe working area (platform) around the embedded FERBOX unit should be prepared.

Whereas it is impossible to create perfect straightness in a rebent bar, the FERBOX straightening tool (Figure 4) is a simply shaped and sized device which promotes best practice and straightness. The tool is manufactured from seamless cold drawn precision steel tube. It is available in two diameters; one to suit 10mm and 12mm bars, and the other to suit 16mm bars. The tube wall thickness is selected to ensure that the internal diameter is only slightly greater than the bar to be bent, as well as to ensure the tube itself will not flex under load. The tool/tube length is sized to provide adequate leverage for the operator. The 'working' end of the tube is specially shaped to provide continuous support to the bend during the straightening process and to limit point contact on the bar. For reasons of identification and comfort in use, the tube is supplied in a white powder-coated finish and is fitted with a PVC handle grip.

The tube should be placed over the bar and made to slide as close as possible to the start of the bend. The tube should be rotated to ensure that the longest part of the shaped end is ready to support the outside of the bend. After securing a good footing, the bar should be smoothly and progressively straightened until it projects 90 degrees from the concrete element. During this process, the tube should be made to slip progressively around the gradually straightened bend, to provide continuous support. When the bar is totally rebent, the end of the tool should be in actual contact with the embedded casing. After withdrawal of the tool, the bar should be checked for adequate alignment (with due regard for concrete cover) and adjusted (with the tool) if necessary.

Once all the FERBOX bars have been bent outward and checked for alignment, the main reinforcement for the subsequent pour can then be lapped onto them. If there is likely to be an appreciable delay before the main reinforcement is lapped, and there is a perceived risk of injury from the now projecting FERBOX bars, then they should have proprietary safety caps placed over their ends.

Note: For the bar straightening process, the use of scaffold tubes is not recommended, as the large internal diameter promotes an undesirable goose-neck effect in the rebent bar. Also, the hammering of bars is expressly condemned.

4.3 Storage

FERBOX units should be safely stored on site on pallets and protected from corrosion and mechanical deterioration by waterproof sheeting.

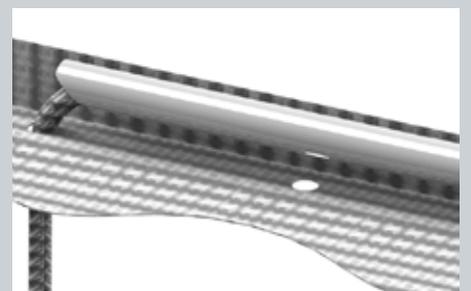


Figure 4 - Straightening tool



5 Safety Considerations

Protective gloves should be worn at all stages when handling FERBOX units. This is particularly important when removing sharp-edged steel lids. Safety glasses should also be worn when straightening the bars.

Heavy units (i.e. those above 25 kg) should be handled by two operatives.

As previously stated, if there is likely to be an appreciable delay between straightening the FERBOX bars and lapping the main reinforcement, and there is a perceived risk of injury from projecting FERBOX bars, then they should have proprietary safety caps placed over their ends.

6 Product Testing and Evaluation

6.1 General

The FERBOX reinforcement continuity system was evaluated in two stages:

- 6.1.1** The reinforcement was subject to independent mechanical testing to establish its suitability for bending during the prefabrication process and rebending through 90 degrees during the straightening process on site without surface rupture and for subsequent compliance with the tensile requirements of BS4449.
- 6.1.2** FERBOX reinforcement continuity system samples were subject to a programme of full scale structural testing in concrete to evaluate the performance of the construction joints.

6.2 Mechanical Testing

The selected reinforcement was tested to determine the appropriate bend radii.

Reinforcement was subject to the CARES bendability test, which consisted of bending the reinforcement through 90 degrees over a steel former, straightening and examination of the inside of the bend for signs of fracture. The test was conducted twice on each sample.

Reinforcement was also subjected to the CARES tensile test regime, which consisted of bending the reinforcement through 90 degrees over a steel former and straightening with the FERBOX tool prior to tensile testing to measure the Ultimate Tensile Strength, Yield Strength and Elongation at Maximum Load (A_{gt}). The selected reinforcement was found to comply with the tensile requirements of BS4449 Grade B500B or B500C. (Clause 7.2.3, Table 4).

The products are subject to a programme of periodic testing to ensure that they remain within the performance limits of this technical approval.

6.3 Full Scale Structural Testing

Construction joints formed using the FERBOX reinforcement continuity system samples were subject to a programme of structural testing. Several wall to floor slab joints were subjected to vertical shear and bending and several wall to wall joints were subjected to longitudinal shear. The tests were full scale in terms of bar sizes and member depths.

In the wall/slab specimens the continuity reinforcement was 16mm diameter deformed bar, apart from one specimen where the continuity reinforcement was 12mm deformed bar.

The 16mm bar was chosen for the majority of tests as being the largest bar size used in the FERBOX reinforcement continuity system and that which imposes the greatest stresses on the surrounding concrete and the most severe demands on the reinforcement in relation to bending and straightening.

The main conclusions are given in section 3.2.



Figure 5 - Structural testing



6.3.1 Assessment of Anchorage

In the evaluation of the results of tests the interpretation of the Eurocode used in this assessment is as follows in terms of design stresses. In evaluations experimental stresses have been compared with values obtained from the expressions for characteristic stresses with actual values of f_c and f_y replacing f_{ck} and f_{yk}

1. The applied stress $f_{s,Ed}$ at the loaded end of an anchorage is calculated from the design moment M_{Ed} at the section at the inner face of the wall.
2. The anchorage is taken to begin at the rear face of the casing.

3. The stress $f_{s,Rd}$ that can be resisted by an anchorage, of either of the types shown in Figure 6, is the lesser of two values, one corresponding to the limit on the compression stress in the concrete at the start of the bend (EC2 eqn 8.1) and the other corresponding to the bond capacity of the active anchorage length.

4. The bond resistance available throughout the active anchorage length is taken as

$$f_{b,Rd} = f_{bd} / \alpha_1 \alpha_2$$

where

f_{bd} is obtained from EC2's equation (8.2) using the strength of the wall concrete

$\alpha_1 = 0.7$ for a bent anchorage with $c_d \geq 3\phi$ (EC2 table 8.2)

$\alpha_2 = 1 - 0.15 [(c_d/\phi) - 3] \geq 0.7$ (EC2 table 8.2)

where

c_d for bent bars is the lesser of half the clear bar spacing and the clear side cover

5. The bar force which can be resisted at the start of the bend follows from equation (8.1) as

$$F_{bt,Rd} = \frac{\phi \phi_m f_{cd}}{0.5 + \phi / a_b}$$

where

ϕ is the bar diameter

ϕ_m mandrel diameter (= 2 x internal radius of bend)

a_b lesser of distance from centre of bar to a concrete face parallel to the plane of the bend and half the centre to centre spacing of the bars

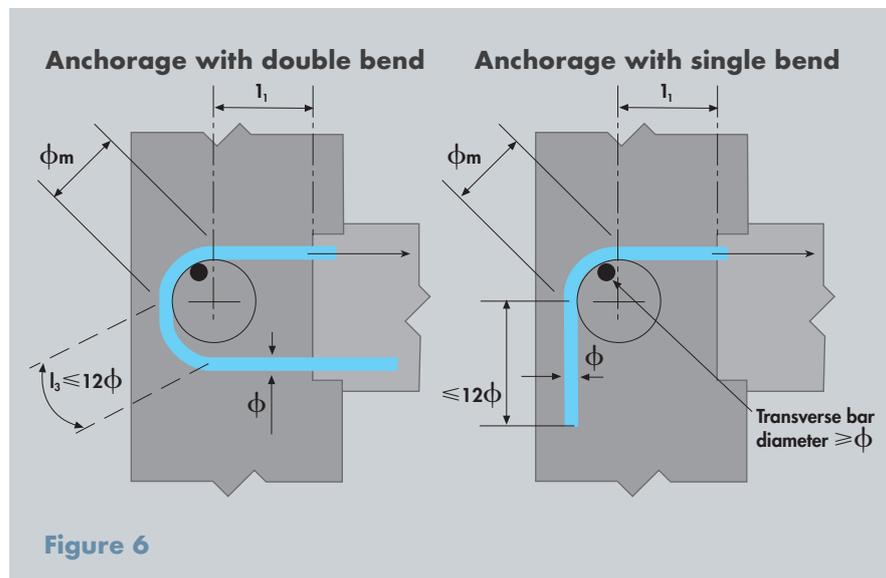


Figure 6

6. The additional force that can be developed between the rear face of the casing and the start of the bend is $f_{b,Rd} \times \pi \phi l_1$, where l_1 is the length from the rear of the casing to the bend.

Thus the resistance as governed by consideration of bearing stresses is

$$F_{s,Rd1} = F_{bt,Rd} + f_{b,Rd} \cdot \pi \phi l_1$$

7. The value of $F_{s,Rd2}$, the resistance determined by the overall bond capacity, is

$$F_{s,Rd2} = f_{b,Rd} \cdot \pi \phi (l_1 + l_2 + l_3)$$

where

l_2 is the length within the bend $(\pi/8)(\phi_m + \phi)$

l_3 is the effective length beyond the end of the bend or first bend

For anchorages with two bends l_3 can be taken as the length from the end of the first bend to the end of the second bend $\leq 12\phi$, provided that the lower straight section is not relied upon as compression reinforcement. For anchorages with single bends l_3 can be taken as the actual length $\leq 12\phi$.

The design resistance calculated as the lesser of $F_{s,Rd1}$ and $F_{s,Rd2}$ is the force that can be transferred from a bar to the concrete in contact with it and is specific to the details of the continuity reinforcement and the concrete surrounding it. The further transmission of this force and the others at the end of the slab to the parts of the wall above and below it depends on the distributions of these forces and on the wider detailing of the wall/floor joint, which may be approached by strut and tie modelling or other appropriate methods.

7 Quality Assurance

The Invisible Connections FERBOX reinforcement continuity system is produced under a BS EN ISO 9001 quality management system certified by CARES. The quality management system scheme monitors the production of the continuity system and ensures that materials and geometry remain within the limits of this technical approval.



8 Building Regulations

8.1 The Building Regulations (England and Wales)

Structure, Approved Document A

The Invisible Connections FERBOX reinforcement continuity system, when used in EC2 based designs using the data contained within this technical approval, satisfies the relevant requirements of The Building Regulations (England and Wales), Approved Document A.

Materials and Workmanship, Approved Document

This technical approval gives assurance that the Invisible Connections FERBOX reinforcement continuity system complies with the material requirements of EC2.

8.2 The Building Regulations (Northern Ireland)

Materials and Workmanship

This technical approval gives assurance that the Invisible Connections FERBOX reinforcement continuity system complies with the material requirements of EC2 by virtue of regulation 23, *Deemed to satisfy provisions regarding the fitness of materials and workmanship*.

8.3 The Building Standards (Scotland)

Fitness of Materials

This technical approval gives assurance that the Invisible Connections FERBOX reinforcement continuity system complies with the material requirements of EC2 by virtue of *Clause 0.8*.

Structure

The Invisible Connections FERBOX reinforcement continuity system, when used in EC2 based designs using the data contained within this technical approval, satisfies the requirements of *The Building Standards (Scotland) clause 1*.

9 References

- BS 4449: 2005: Steel for the reinforcement of concrete - Weldable reinforcing steel - Bar, coil and decoiled product - Specification.
- BS 8666: 2005: Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete - Specification.
- BS EN 1992-1-1:2004 Eurocode 2 Design of concrete structures - General rules for buildings.
- BS EN ISO 9001: Quality management systems - Requirements.
- CARES Appendix TA2 Quality and Operations Schedule for the Technical Approval of Reinforcement Continuity Systems.



10 Conditions

1. The quality of the materials and method of manufacture have been examined by CARES and found to be satisfactory. This Technical Approval will remain valid provided that:
 - a) The product design and specification are unchanged.
 - b) The materials, method of manufacture and location are unchanged.
 - c) The manufacturer complies with CARES regulations for Technical Approvals.
 - d) The manufacturer holds a valid CARES Certificate of Product Assessment.
 - e) The product is installed and used as described in this report.
2. CARES make no representation as to the presence or absence of patent rights subsisting in the product and/or the legal right of Invisible Connections to market the product.
3. Any references to standards, codes or legislation are those which are in force at the date of this certificate.
4. Any recommendations relating to the safe use of this product are the minimum standards required when the product is used. These requirements do not purport to satisfy the requirements of the Health and Safety at Work etc Act 1974 or any other relevant safety legislation.
5. CARES does not accept any responsibility for any loss or injury arising as a direct or indirect result of the use of this product.
6. This Technical Approval Report should be read in conjunction with CARES Certificate of Product Assessment No 5056. Confirmation that this technical approval is current can be obtained from UK CARES.



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