Three important documents have been issued that will lead to significant improvements in the durability of reinforced concrete road bridges and structures exposed to marine environments and/or subject to the application of road de-icing salts. Penetration of chloride ion from these sources is widely recognised as the principal cause of corrosion of steel reinforcement, often resulting in spalling of concrete and expensive repair and liability costs. The three documents are:

1. **BA 84/02: Use of stainless steel reinforcement in highway structures**

   Prepared for the Highways Agency by Arup Research and Development, BA 84/02 identifies those structural elements most at risk from corrosion, and hence where the high corrosion resistance of stainless steel reinforcement will be beneficial. In most structures, only a small proportion of the total reinforcement needs to be in stainless steel, giving greatly increased durability for a small increase in capital expenditure. A structure reinforced solely with stainless steel can be used where very high durability is required and where it is justified by whole-life cost analysis.

   However, selective substitution has been accepted by the Highways Agency as a cost-effective method of increasing the durability of most bridge structures — a practice also adopted by authorities in the USA, Canada, Sweden and Denmark. It should be noted that, where stainless steel reinforcement is in direct contact with carbon steel reinforcement, electrical insulation between the differing steels is not necessary, as tests have shown negligible galvanic reaction between them in concrete.

   **BA 84/02** categorises bridges where stainless steel reinforcement is desirable:
   - heavily trafficked highway bridges and those over railway lines
   - exposed piers and columns in central reserves
   - deck slabs where access for maintenance is difficult because of high traffic volumes
   - soffits and edge beams exposed to spray where de-icing salts are used
   - all structural elements above low water spring tide to a height of 5m above high water spring tide.

   Stainless steel reinforcement also allows the strict durability rules that would be necessary for carbon steel to be relaxed, and three specific points are made in the BA:
   - concrete cover can be reduced to 30mm irrespective of concrete quality or exposure conditions
   - allowable crack width can be increased to 0.3mm
   - silane treatments applied to the concrete are not required where stainless steel is used.

   Reinforcement with a UK CARES certification is a requirement by the UK Highways Agency for all highway bridge contracts, and European stainless steel reinforcement producers are in the process of obtaining this certification.

   **Figure 1**: Column in the Broadmeadow project showing the 40mm-diameter stainless steel reinforcing bar.

   **Figure 2**: One of the piers in the Lidingo crossing showing attachment of the new stainless steel reinforcement.
BS 6744: 2001 Stainless steel bars for the reinforcement of and use in concrete

The new Standard, which supersedes the 1986 version, includes several significant changes, in particular an increased number of grades, two strength levels, and range of bar diameters and lengths now available. The range of stainless steel grades has been widened to six, and guidance is given for appropriate selection according to the likely service conditions.

Two strength levels are included:
- 500MPa for bars of 3–50mm diameter
- 650MPa for bars of 3–25mm diameter.

While the strengths of stainless steel reinforcement bar are higher than for carbon steel, the fatigue requirements are the same for both, i.e. $5 \times 10^6$ cycles.

BS 8666: 2000 Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete

This fabrication standard replaces the old bending and cutting standard, BS 4466: 1989(4), but both will be operative during the changeover period. The new Standard reduces the number of shape codes from 27 to 16 and generally tightens the diameter of the formers to $4d$ for bars up to 16mm diameter, and $7d$ for bars up to 40mm diameter for Grade 460 carbon steel.

The high ductility of stainless steel allows it to be formed to the reduced radii in the revised Standard.

Implementing BS 6744: 2001 and BA 84/02

The effects on capital cost of implementing the new standard and HA guidelines have been studied in depth by Arup Research and Development using two current bridge designs, one single-span and one multi-span. The study demonstrates the small initial cost difference in using stainless steel for...
individual bridge elements. The cost model, which allows designers to select the reinforcement grade and strength, and to enter their own reinforcement cost, is available on CD-Rom from the British Stainless Steel Association. Only capital cost effects are analysed; whole-life costs – i.e. future repair costs, maintenance, traffic disruption and lane-closure costs – are not considered in the analysis.

**Typical applications of stainless steel reinforcement**

The following two case studies, one a new construction and one of repair, illustrate the effectiveness of using stainless steel reinforcement.

**Broadmeadow Bridge, Swords, Republic of Ireland**

Currently under construction, the M1 Northern Motorway in the Republic of Ireland crosses the Broadmeadow Estuary at a point where the mudflats merge with more stable areas of marshland and landfill. Avoidance of corrosion in the columns was a key element in the design. The structure carries the main motorway columns was a key element in the design. The structure carries the main motorway carriageway across the estuary and consists of twin bridges 313m long with a maximum span of 69m. Each deck consists of a three-cell prestressed concrete box with a curved soffit profile. Parapets are precast and incorporate a 16mm-diameter stainless steel starter bar. A 25mm-diameter stainless steel starter bar was cast into the deck for the connection.

Stainless steel reinforcement, both 40mm and 32mm diameter, is used in the construction of the slender 1500mm diameter columns, which are typically 11–12m high (see Figure 1). Altogether, 169 tonnes of stainless steel reinforcement will be used in this project. The engineers, Arup consulting engineers, commented that the stainless steel reinforcement added 8% to the cost of the reinforcement for the complete project but the increase in total construction cost was only 2.9%.

**Lidingo Bridge Repair, Stockholm, Sweden**

This 1100m-long steel-and-concrete bridge in Stockholm, built in 1971, is suffering from corrosion of the carbon steel reinforcement in the tidal zone. It is now undergoing a two-year repair of the 24 piers at a cost of €1.5m (see Figures 2 and 3).

The existing concrete cover is being removed from the bottom 2m height of the pier using high-pressure water jets. A new outer layer of 16mm diameter stainless steel reinforcement is wrapped around the piers, and given a cover of 65mm aerated concrete for frost protection.

**Concluding remarks**

The durability of marine structures reinforced with stainless steel reinforcement has been proven. The newly introduced BS 8666: 2000 helps clarify those environments where stainless steel reinforcement could prove beneficial, and should result in increased use of the material (see Figure 4). The publication of BS 6744: 2001 and BS 8666: 2000 helps clarify the specification of stainless steel reinforcement, making it easier to integrate within design (see Figure 5). In terms of whole-life cost analysis, stainless steel reinforcement is a cost-effective method of ensuring structural longevity in harsh marine environments.

**Further information:**

A summary report on the use of stainless steel reinforcement in concrete bridge structures and the cost model CD-Rom is available from the British Stainless Steel Association tel: +44 (0)114 267 1260, website: www.bssa.org.uk. Stainless steel information is available from the Nickel Development Institute at www.nidi.org.

**References:**


