Box Culvert Association
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DESIGN STANDARDS FOR BOX CULVERTS

The Eurocodes

The relevant Eurocodes and associated National Annexes should now be considered as the primary documents to be adopted for reinforced concrete design. However, there is still a degree of apprehension to fully embrace their use, and this is no doubt attributed to their complexity, presentation and inter-relationship, compared to previous British Standards. Additionally, the application of Eurocodes to specific reinforced concrete elements is not as straightforward as the design of regular beams, slabs and columns.

The design of box culverts has always required reference and understanding of traffic loading on bridges, and this remains a fundamental requirement when undertaking a box culvert design. In addition to the Eurocodes EC0, EC1 and EC2, and NAs, there is now a specific Eurocode, *BS EN 14844:2006 Precast concrete Products – Box culverts*, dealing with aspects of design, manufacture and installation. This document in turn, cross references *BS EN 13369:2001 Common rules for precast concrete products.* Additionally there is non-contradictory complementary information in the form of *PD 6694-1:2011 Recommendations for the design of structures subject to traffic loading to BS EN 1997-1:2004*, and *PD 6687-2:2008 Recommendations for the design of structures to BS EN 1992-2:2005.*

Generally, within the Eurocodes, the principles of reinforced concrete design for ULS bending and shear are the same as for designs to British Standards. There are small differences in the allowable shear stresses but this does not significantly affect the design of box culvert units. However, the loadings now required by the Eurocodes are significantly greater than former British Standards, and this results in the need to provide a structure with increased structural capacity.

Summary of Most Relevant Documents

It is critical that Client requirements are clearly defined, and this demands a recognition and understanding of all loading parameters to be incorporated into the culvert design.

- **BS EN 1991-2:2003 - Eurocode 1: Actions on Structures – Part 2: Traffic Loads on Bridges**

  This document sets out the loading classes for road bridges and defines a series of Load Models (LM1-LM3),

  Load Model 1 – Concentrated and Distributed Load

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Load Model 2 – Single axle loads

Load Model 3 – Loads for Special vehicles

Load Model 4 – Crowd Loading

Each Load Model describes a configuration of wheel loading to represent different wheeled vehicles. It is significant that the wheel loads within these models is now 150kN (LM1) and 200kN (LM2) & 165kN (LM3). This is compared to the previous wheel load of 30HB at 75kN.

The design is progressed, generally adopting the worst case effects of these Load Models. The loads are applied to the culvert structure by considering the zones of influence as described in PD 6694 (Fig 11). PD 6694 (Table 7), also defines the horizontal surcharge pressures to be applied to the structure.

Horizontal loads in terms of braking and acceleration forces are defined within the Eurocode, and these are applied in conjunction with the relevant vertical loads.

- **BS EN 1992-1-1:2002 – Eurocode 2 : Design of concrete structures – Part 1-1: General rules and rules for buildings**

Having established the appropriate applied loads, and from an analysis to determine the resultant bending moments and shear forces, the detailed concrete design is undertaken, in accordance with this document.

- **BS 8500-1:2002 – Concrete - Complementary British Standard to BS EN 206-1, Part 1: method of specifying and guidance for the specifier**

The performance of the culvert structure and its defined working life will be determined by defining a suitable concrete specification, and by adopting suitable cover to the reinforcement.

Section 4 of Eurocode 2 deals with durability and cover requirements. The Exposure Classes are as EN 206-1, but in the UK we adopt BS BS8500-1, to define a suitable concrete specification, taking account of corrosion due to carbonation (XC), chlorides (XD), sea water (XS), & freeze/thaw (XF). Generally, XD2 is adopted for structures buried below 1.0m and XD3 for shallower structures. The required concrete specification is described by its strength class (e.g. C40/50), and an associated minimum cement content and water cement ratio.

For particular cases of exposure (high sulphate conditions), it may be necessary to refer to the BRE Special Digest 1:2005 – Concrete in aggressive ground, which gives guidance on concrete specification and additional protective measures.

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Intended working life is generally specified at 100years. However, the Highways Agency (IAN 95 07) accepts that adopting these parameters is deemed to provide a working life of 120 years.

Precast concrete generally adopts a higher concrete specification, when compared to insitu concrete. This allows the adoption of a lesser cover to the reinforcement, and when considered in conjunction with a smaller Dc value, (allowance for rebar deviation), will result in a more economic design.

- **BS EN 13369:2001 – Common rules for precast concrete products**

  This standard is a generic document, which sets out requirements to the range of products which are produced in a factory environment. It is intended to act as a reference document which provides guidance on the various issues associated with precast concrete elements and their manufacturing, (e.g. durability, tolerances material requirements, testing). It is intended to provide a more consistent approach to standardisation in the field of precast concrete products. General references to more specific Eurocodes are included.

- **BS EN 14844 – 2006 – Precast concrete products – Box culverts**

  In a similar manner to BS EN 13369, the standard provides guidance on materials, testing, and geometry etc., and production requirements, together with reference to design criteria, although this is generally in the form of cross references to the standards mentioned previously.

  This is a 'harmonized' standard and fully encompasses the requirements of the EC. Consequently this standard leads to the CE marking now required on box culverts.

As can be seen, there are numerous documents which need to be consulted to achieve an appropriate and compliant design for a box culvert. It is clear, that it is essential that the initial design parameters are clearly defined at an early stage, to ensure the Client is provided with a product which meets their requirements.