9 Durability, Inspection and Maintenance

9.1 Durability

The durability of the main crossing is of paramount importance considering the aggressive marine climate, large capital investment required for construction and the great cost and difficulty that can be associated with extending the life of, or replacing, such a major structure if it deteriorates to an unacceptable level once in use. The durability issues which have become apparent with the existing Forth bridges underline this point.

Requirements for durable structures make recognition of the fact that durability is not an absolute property of a material but can be affected by both design and construction factors. Definitions of design life require that the design criteria are achieved, not that materials or components remain in the same condition unchanged for the design period, and imply maintenance and some repair for its achievement. Thus an assessment of durability would require that the processes of deterioration be examined and the means of protection (by durability design) and mitigation (by maintenance) are assessed in order to ensure that the design life can be achieved with a reasonable degree of confidence. The design life of the structure will be 120 years. For the major structural elements this is usually interpreted to mean the design life without replacement, for other secondary elements, systems and components where replacement is feasible a shorter service life is usually assumed.

Whilst a full durability assessment of the structure has not yet been carried out a number of principles have been established as well as a number of potential measures to ensure adequate durability:

- Specification of appropriate materials and finishes
- Provision of comprehensive facilities for the inspection and maintenance of the structure
- Design for ease of replacement of secondary elements and systems (e.g. stay cables, bearings, movement joints, deck furniture, etc.)
- Use of dehumidification where appropriate to protect the interior spaces of fabricated steelwork (e.g. deck, tower anchor boxes)
- Special measures to protect the reinforcement in the outer layers of reinforcement in the intertidal and splash zones of the towers and piers to extend the life of these structures in the most aggressive of microclimates. At this stage, stainless steel reinforcement has been assumed in these areas but provision for cathodic protection is an alternative to be considered.
- Use of stainless steel guide pipes and/or facia plates in the upper tower to reduce the maintenance requirements for these high elevation and difficult to access locations

9.2 Inspection & Maintenance

A comprehensive set of facilities for inspection and maintenance of the structure will be included in the design. In addition to fixed access facilities throughout the bridge (walkways, stairs, ladders etc.), a suite of motorized access machines will be recommended which may include under-deck inspection gantries, lifts within the towers, an internal deck shuttle (for box girder decks), a stay cable inspection gantry and an access platform to be suspended from a maintenance unit at each tower top.

The overall approach is to ensure that, as far as possible, normal inspection and maintenance activities can be carried out with minimum disturbance to the traffic. At the same time easy and safe access for maintenance personnel must be provided.

9.3 Lane closures for stay replacement

In common with typical international practice, closure of areas of the carriageway is anticipated for stay cable replacement and these will be specified in the design manual for the project. It is anticipated that the minimum requirement will be closure of the lane adjacent to the stay cables - either the hard shoulder for stay cables anchored along the deck edge, or the running lane adjacent to the central zone for centrally anchored stay cables. This will provide a working area as well as reducing the design loading carried in the stay cables and deck during the replacement operation. It is possible that it may be economical to specify a wider zone of closure in order to further reduce the design loads in the bridge but this will be considered in more detail during the Stage 3 design development.

9.4 WASHMS

Complementary to the physical inspection and maintenance facilities, a Wind and Structural Health Monitoring System (WASHMS) is proposed to provide real time data and also to allow investigation of the structure to be undertaken after an extreme event such as a major wind storm or an earthquake.

The real-time data can be used to assist with inspection and maintenance by immediately highlighting anomalies that could indicate a fault (for example oil-pressure out of range on hydraulic buffers) or else by tracking long term changes in bridge behaviour (for example gradual increase of effective friction coefficient on bearings).

A four-level system architecture is envisaged:

1. Data Collection Level - System collects data from sensors and forwards to pre-processing.

2. Data Pre Processing and Transmission - Data Acquisition Units (DAU's) distributed through the bridge pre-process the data prior to transmission to central processor (signal conditioning and conversion of analogue data to digital). As well as the fixed DAU's, there can also be a system of Portable Data Acquisition Systems which can be used in conjunction with removable accelerometers for specific field vibration measurements.

3. Data Processing and Analysis Level - Collection, processing, analysis, display, archiving and storage of all data by a centralized Data Processing and Control System.

4. Structural Health Evaluation Level - Analysis and interpretation of measured data, comparison with criteria for inspection and maintenance, display archive and storage of analyzed or interpreted results, production of structural health evaluation reports.

The range of sensors that can be included at the data collection level is very extensive and may include monitoring of climatic conditions external and internal to the bridge, structural displacements, accelerations and strains, direct measurement of chloride ingress into concrete structures, traffic measurements, etc. as well as sensors specific to any bridge equipment that may be installed (e.g. to monitor hydraulic buffer stroke position, effective friction between bearing sliding partners, etc.). The detailed specifications of the WASHMS will be developed in consultation with Transport Scotland, with a view to ensuring that any equipment provided is of practical use and not just academic interest.