Forth Estuary Transport Authority

Feasibility Study for the Replacement (or Augmentation) of the Main Cables of the Forth Road Bridge – Preliminary Findings

01 June 2007

1 Purpose of Report

1.1 To advise members on the preliminary findings of the feasibility study to replace or augment the main suspension cables of the Forth Road Bridge, all subject to ratification in the final report.

2 Background

2.1 The main cables are the primary load bearing members of suspension bridges. On the Forth Road Bridge they each carry around 14,000 tonnes, 86% of which is the load applied by the dead weight of the suspended structure.

2.2 A significant level of corrosion was found in the main cables following the first internal inspection carried out in accordance with the U.S. National Co-operative Highway Research Program (NCHRP) Report 534. The inspection work was carried out during the second half of 2004 and through 2005. From the inspection and later examination of extracted wire samples in the laboratory it was determined that the loss of strength lay between 8% and 10%. Extrapolation of the results indicated that the safety factor would drop below 2, the commonly accepted minimum figure, in around 2014 if corrosion continued and that some intervention would be required to remove a proportion of live (traffic) load from the bridge.

2.3 If corrosion continued at the anticipated rate, complete closure of the bridge could follow some 5 years later.

2.4 An independent review of FETA’s consultant’s conclusions, carried out by the Scottish Executive appointed consultants, generally concurred with the study’s findings.

2.5 In order to obtain more information on the rate of future wire breaks, a system of acoustic monitoring was commissioned in August 2006. A total of fifteen “microphones” were positioned on each cable with the ability to detect wire breaks. At the time of writing seven breaks had been detected in panels not previously inspected.

2.6 In order to attempt to halt any further deterioration of the main cables or at least reduce the ongoing rate of corrosion, a contract has commenced to install a dehumidification system. Research indicates that effective corrosion protection is achieved if the relative humidity of the atmosphere inside the cable is held at around 40%. Once fully established in late 2009, the dehumidification system will be allowed to run for a period of between 12 and 18 months following which further internal cable inspections are planned to assess the effectiveness of the system.

2.7 Whilst there is some experience in Europe and Japan of dehumidification as a preventative treatment on suspension bridge main cables, no guarantees can be given that the dehumidification of the main cables on the Forth Road Bridge will halt, or sufficiently reduce the progress of the corrosion found in 2004.

2.8 Members approved the appointment of a consortium headed by WA Fairhurst and Partners (Glasgow) to undertake a feasibility study into the replacement (or augmentation) of the main cables in the event that the dehumidification is unsuccessful. Fairhurst's team includes structural engineering consultants Cowie Consult (Denmark) and Amman & Whitney (USA), traffic modelling consultant SIAS (Edinburgh) and economic consultant Roger Tym & Partners (Glasgow).

2.9 One of the objectives of the study is to identify the most appropriate construction methods to be adopted should the main cables require to be replaced or strengthened. Such works require taking account of not only the structural options, but also the impact of these works on traffic and the economy of the surrounding area.

2.10 The complexity of the project is compounded by the fact that the towers have already been strengthened and the stiffening truss supporting the carriageways is highly stressed. Also included in the study is the investigation of the structural integrity of the cable anchorages.

2.11 The study encompasses a range of multi-disciplinary functions and activities including (but not limited to) the following:

- Structural assessment of existing and proposed cables
- Structural assessment of other elements of the bridge including
    - Hanger assemblies
    - Deck
    - Towers
    - Saddles
    - Anchorages
- Risk assessment
- Construction feasibility and safety assessment
- Traffic management assessment
- Economic assessment
- Capital cost and programme

3 The Study

3.1 A peer review panel has been established to scrutinise each stage of the study development which includes Transport Scotland, represented by the Chief Bridge Engineer and their engineering consultant Flint & Neill.

3.2 An Objectives Workshop was held on 16 January 2007 with key stakeholders (identified as the adjacent local authorities, Sestran, Tactran, Transport Scotland, the Scottish Executive and Network Rail) setting the objectives of the study as:

- Feasibility of replacement or augmentation to deliver the original 120-year design life.
- Establish timescales for implementation that acknowledges the condition of the existing bridge and the progress of an additional crossing.
- Minimise the effects of the works by optimising the periods the bridge remains open and maximising the available capacity to all its users whilst open.
- Develop an option, which maximises safety for bridge users & workers during construction.
- Maximise use of financial levers to minimise the adverse effect on the economy.
- Maximise use of value for money of project options.
- Minimise any adverse environmental impact.
- Manage the impact of the works on the strategic and local transport network.
- Achieve broad political and stakeholder support to project recommendations both locally and nationally.

3.3 Following this, an Optioneering Workshop was held on 30 and 31 January 2007 which was attended by all the team involved in the study to determine those options that could be taken forward. Following the Optioneering Workshop the team has focused on three Augmentation and three Replacement Options. These options then had to be tested for “buildability” before studying the traffic management options which lead in turn to user delay and financial impact on the business community. Transport Scotland and Flint and Neill attended both days of the Optioneering Workshop.

3.4 To establish the feasibility of constructing new anchorages, a topographical survey has been carried out around both the north and south anchorage areas and a geotechnical investigation is underway.

3.5 Work continues on the development of a local traffic model and it’s interface with Transport Scotland’s Traffic Model for Scotland (TMfS).

4 Preliminary Findings and Options

4.1 The options identified in the Optioneering Workshop for the augmentation or replacement of the existing main cables were as follows:

Augmentation
- New cable above existing main cable.
- New cable to the side of the existing main cable.
- New twin cables located either side of the existing main cable.

Replacement
- New cable above existing main cable.
- New cable to the side of the existing main cable.
- New twin cables located either side of the existing main cable.

4.2 When considering all of the above options the most important aspect is that of safety. A method of working will have to be devised that will ensure that the bridge users, the workforce and the bridge are kept safe at all times. In order to protect the bridge users, full bridge closures and carriageway closures will inevitably be required at particular times during the work and the selection of the preferred option is likely to be decided by the extent to which these closures can be minimised.

4.3 Although augmentation requires a lower load to be supported by the new cable, the temporary works required to provide safe access for the construction of all the options will essentially be the same resulting in a similar disruption to the bridge. The only significant difference between augmentation and replacement is the need, as part of the replacement options, to remove the existing main cables, which will inevitably require more bridge and/or carriageway closures.

4.4 Since the Workshops in January 2007 the study team have reviewed the various options and have reduced the six proposals down to three which are being further developed at the present time. The options rejected were:

- New twin cables (for both augmentation or replacement) as the extent of temporary access would be significantly greater, with associated increase is disruption to bridge use, for little or no gain structurally

- Replacement cable to the side of the existing main cable as maintaining the integrity of the existing Main Towers during load transfer was not proving structurally feasible.

4.5 Options remaining and being developed are:

Option 1 -Replacement cable located above the existing cable – See Appendices

Comment: Connection to the main towers is the critical detail to be resolved. Existing cables to be removed.

Option 2 - Augmentation by a new cable above the existing cable.

Comment: Similar to the replacement option (1) but existing cables retained.

Option 3 - Augmentation of main cable with a new cable to the side

Comment: The capacity of this option is determined by the amount of load which can be transferred from the existing Main Towers without compromising their integrity. It is considered at this early stage that the added strength could be limited to between 20 and 30% of the existing cable load. (The precise amount of strength gain required cannot be determined until after the assessment of the effectiveness of the de-humidification project)

4.6 Another key area will be the anchorages. Whilst the team has not seen anything that gives cause for concern, it is considered prudent to carry out a structural assessment in light of recently uncovered construction documents.

5 Traffic Impacts

5.1 Option 1

An initial review of the principal construction sequences indicates the need for around 50 complete weekend closures of the bridge (Friday evening to Monday morning), together with 3 separate blocks of 32, 12 and 24 weeks, (spread over 4 years) of carriageway closures requiring contra-flow traffic operation. Contract duration would be about 7 years.

5.2 Option 2

Similarly, there would be 50 complete weekend closures of the bridge and 2 separate blocks of 32 and 24 weeks (spread over 3 years) of carriageway closures requiring contra-flow traffic operation. Contract duration would be about 6 years.

5.3 Option 3,

Albeit limited in terms of the cable size provided, this work could possibly be carried out during two separate blocks of 32 and 24 weeks (spread over 3 years) of carriageway closures requiring contra-flow operation with a further 48 weeks of discreet carriageway closures for specific tasks (assume 50% of time). Contract duration would be about 5.5 years

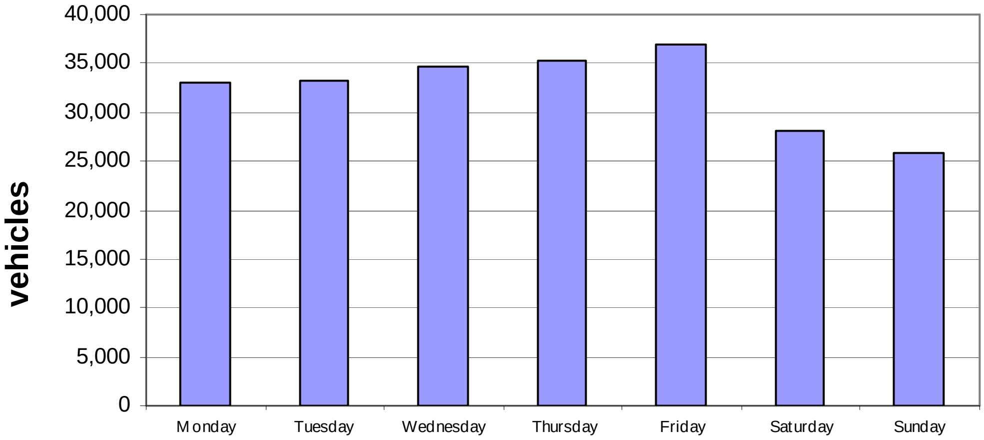
5.4 All three options will include the erection and dismantling of a dropped object canopy at the towers requiring a series of either full weekend or overnight bridge closures within a 24 week period at the beginning and again at the end of the works.

5.5 The team also considered the option of closing the bridge completely to carry out cable replacement. This would require a continuous closure over a period of some 3.5 years within a contract of duration 4.5 years.

5.6 It is emphasised that this is an interim report and the traffic restrictions are indicative only.

5.7 In terms of traffic delay the impact of one carriageway closure can be compared to the current weekend conditions for carriageway resurfacing. Current delays are of the order of 60-90 minutes despite volumes being 30% down on the corresponding weekends last year.

5.8 It should be noted however that weekend traffic is significantly less than weekday traffic (as shown below) and carriageway closures requiring contra-flow running during the working week would cause significantly greater delays.



Average Daily Traffic Totals 2006

5.9 In order to carry out works during the week, there would be a requirement to reduce the weekday traffic levels by as much as 50% to have a manageable delay in the network.

How the reduction in demand is achieved is the critical question. Several measures would need to be put in place to reduce the vehicular flow such as:

- Significant increased public transport provision (both bus and rail).
- Introduction of HOV lanes to increase car occupancy, currently at 80% single occupancy.

Paradoxically, the complete closure of the bridge would not cause the same level of congestion in and around the bridgehead as there would be no benefit of vehicles approaching the bridge as they could not cross. There would however be significant increases in traffic flow levels on the Kincardine Bridges and on the M9 in Stirling. In addition the increase in use of the trains would create congestion both on the trains and at the car parks serving the stations. Depending on the duration of the closures there will most definitely be a number of non-essential trips which will no longer be made. The greatest percentage of non-essential trips is at the weekends and therefore the complete closures are best contained within this period.

5.10 A survey of businesses to establish the economic impact of the traffic management measures on the bridge will be carried out in order to assess the broader economic impact of the works.

6 Conclusion

6.1 The replacement or augmentation of the main cables on the Forth Road Bridge presents significant engineering challenges but is achievable. However, the impact of the traffic management measures required to carry out the works safely, result in significant delays to the strategic roads network.

6.2 It must be emphasised that this is a preliminary report based on initial findings and that further detailed analysis of the options listed may result in significant changes to the schemes and timetable.

6.3 It should also be noted that it has been assumed that (a) there is no new crossing available during the duration of the replacement/augmentation project and (b) that it is possible to devise a safe system of work that does not require bridge or carriageway closures to fit new suspender ropes.

7 Recommendations

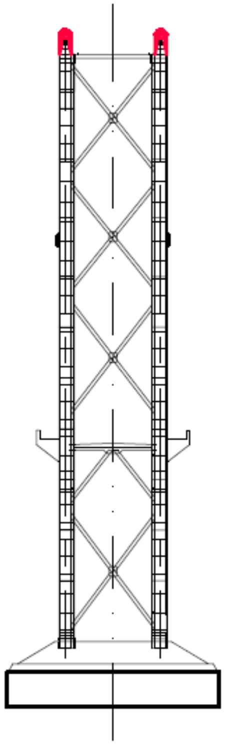
It is recommended that members note the content of this preliminary report recognising that all findings are subject to ratification in the final report.

Alastair A.S. Andrew
General Manager & Bridgemaster

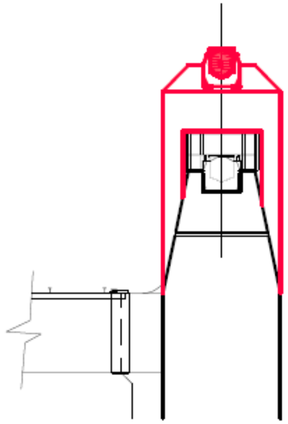
Appendices **Sketches of Options**

Contact/Tel Alastair Andrew / 0131 319 3092

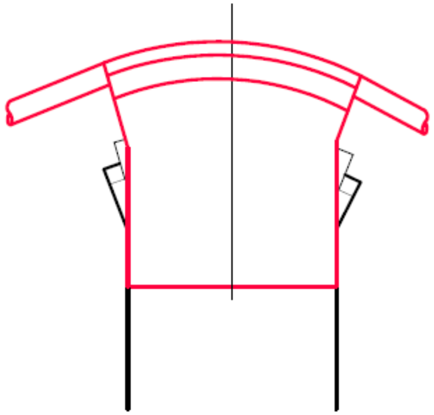
Background Papers



FRONT ELEVATION
OF MAIN TOWER



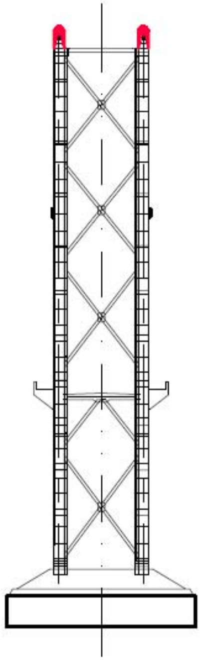
DETAIL AT TOWER TOP



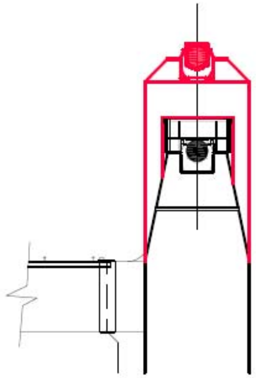
ELEVATION

Option 1

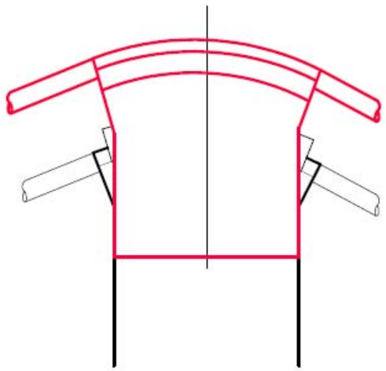
REPLACEMENT
NEW CABLE ABOVE EXISTING CABLE



FRONT ELEVATION
OF MAIN TOWER



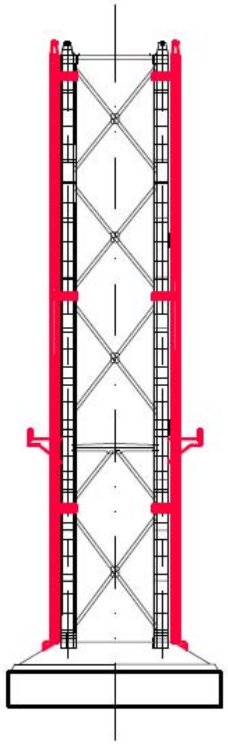
DETAIL AT TOWER TOP



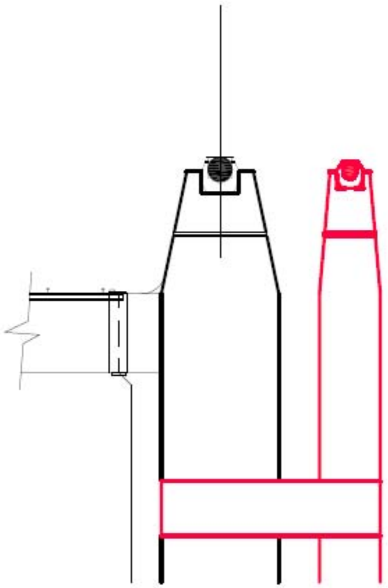
ELEVATION

Option 2

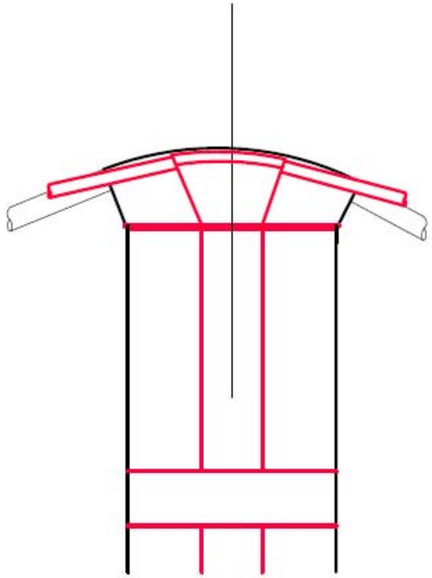
AUGMENTATION
ADDITIONAL CABLE ABOVE EXISTING CABLE



FRONT ELEVATION
OF MAIN TOWER



DETAIL AT TOWER TOP



ELEVATION

Option 3

AUGMENTATION
ADDITIONAL CABLE TO SIDE OF EXISTING CABLE