HYDRODYNAMICS
BRIEFING NOTE No 3
Local Scour
January 2009 – Draft Rev B

Context

The preferred scheme for the new crossing of the River Mersey estuary upstream of the existing Silver Jubilee Bridge features a cable stayed structure over the central 1000 metre section supported from three towers within the tidal estuary. It should be noted that the full tidal estuary comprises the river plus salt-marshes on either bank. The salt-marshes are only covered on the highest tidal events while the remainder of the estuary is flooded to varying degrees on every tide.

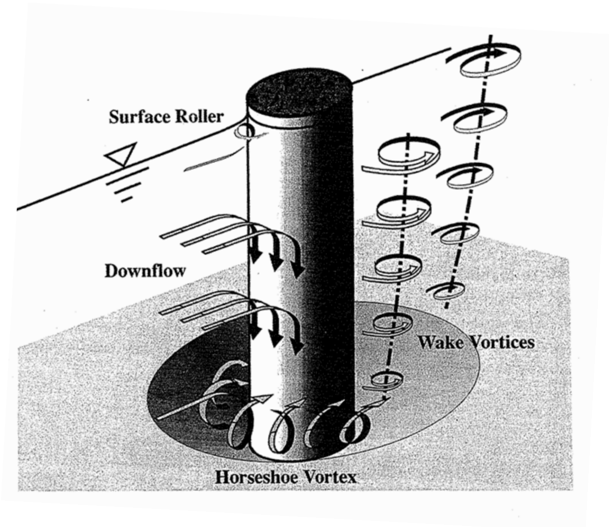
The estuary's major feature is shifting sand-banks that are typically at a level of approximately 4.0 metres above OD (Newlyn). [*Coincidently, at Widnes, Ordnance Datum is the same as Chart Datum (which simplifies the correlation between tide table predictions and land survey values). For convenience for this scheme, either datum will henceforth be referred to as "datum".*] The sandbanks are covered on most high waters but remain uncovered on every low tide and some neap tides. As tidal flows recede and approach low water, fluvial (river) flows become more evident. At low water, these fluvial flows progress through a system of channels between the sandbanks. The position of these channels changes in an unpredictable manner throughout the year, although there is evidence to suggest that these changes may be related to the magnitude and duration of fluvial flows. Nevertheless the main channel seems to normally prefer following either the north or the south bank. In the area of the proposed crossing, the lowest bed level of the main channel tends to be approximately at 0.5m above datum.

The salt-marshes will be crossed by viaduct with spans of up to 100 metres. The supporting piers will be supported on pile caps constructed below the general level of the salt-marsh. Scour around the intermediate piers is not seen to be an issue since flooding on the salt-marshes is a rare event and very shallow. The surface of the salt-marsh is effectively bound together by the root structure of the grasses - reducing local erosion. The towers for the cable stayed element of the bridge will be located away from the edge of the salt-marshes on either bank with one tower central to the tidal river and the others leaving end spans onto the salt-marshes of approximately 200 metres in length. Thus, normally, the towers will be within the sandbanks but occasionally one may be exposed within a shifting channel.

The towers will be supported on a large pile cap with a top level approximately 2.5m below the bed level of the estuary. Construction will be from within a ring coffer-dam which will be removed to top of pile cap level on completion but with the lower portion of the coffer dam left as a precaution against extraordinarily deep scour. The tower itself will then be taken to deck level as a circular or octagonal shaft with a maximum diameter of no more than 10 metres. It is this relatively narrow column that will be within the flowing waters.

Local Scour

Any feature within flowing water will produce changes in velocity within the water column. These changes initiate differential movement in the bed materials local to the feature, the magnitude of which varies with stream velocity, feature shape and bed character. Generally the stream bed is deepened at the nose of the feature with the material removed from the bed being deposited in the sheltered areas behind (or adjacent to) the feature. The process is known as scour. In certain conditions (high stream velocities, mobile bed materials, poorly streamlined structures etc) scour depths can be quite deep. The result can lead to structural failure.



An illustration of the flow contributing to local scour at a circular pier, adapted from Melville and Coleman (2000)

Scour Protection

Engineering solutions to the problem of scour are well established and can take a variety of forms. Normal solutions tend to centre around any or all of the following:

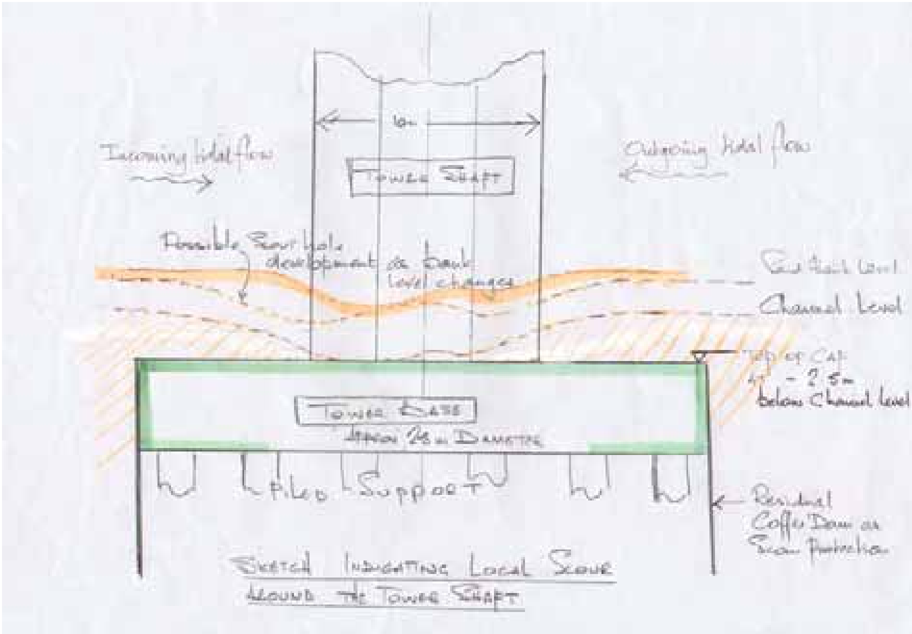
1. choosing an appropriate sectional geometry for the structure in order to minimise scour effects
2. reinforcement of the bed of the estuary locally to prevent scour initiating (eg rip-rap stone)
3. physical interception of the developing scour hole limiting its propagation.

Discussion

In the case of the Mersey Gateway, flows around the tower will be affected by tidal conditions. Flow direction will reverse on each tide. Scour-hole development will therefore tend to be reversed twice every day. Flow velocities will change depending upon the state of the tide and bed levels adjacent to the tower.

When a tower is located within a sand-bank, it will only be surrounded by tidal waters on the highest tides. Even then water depths are shallow and velocities are relatively low. The depth of any resulting local scour hole will also therefore be shallow.

Should a tower become located within a channel, however, exposure to tidal flows will be longer and velocities higher. This will tend to deepen the local scour hole. However, should a scour hole form to a depth of 2.5m below the local bed level then it will encounter the top of the pile cap. The concrete surface will halt any further deepening of the scour hole. Given the proposed diameter of the pile cap (25m), only if this scour hole can extend laterally to more than 6.5 metres from the face of the tower will the edge of the cap be exposed. In such circumstances, scour would recommence at the edge of the pile cap (see sketch below). However, this is thought to be unlikely with the proposed arrangement of tower and pile cap, and the depth below bed level to the pile cap. Backfilling over the tower base with coarser materials will assist in preventing such scour hole development.



More detailed physical modelling may be required to determine final details; however, it is considered highly unlikely that any additional measures will be required to limit scour over and above the envisaged construction methodology described above.

Construction Conditions

In order to construct the tower bases within the tidal estuary, temporary cofferdams are likely to be required (see Report No B4027/OA/200: *The Mersey Gateway Project – Construction Methods;* Section 3.4). These are thought likely to be up to 30 metres in diameter and formed from steel sheet piling. They will be maintained in position until completion of the tower and the deck suspended from the tower – a period of approximately 2 years. Once construction is completed, the surplus lengths of sheet piling will be removed and the area above the pile cap filled with selected materials as described above.

Just as in the case of the permanent towers, flows around the cofferdams could induce scour. The important difference being that the situation will be continuously monitored by the contractor.

Scour local to the cofferdam provides a threat to its stability and, as a consequence, to the safety of operatives working within it. The contractor will monitor bed levels around the cofferdam to ensure they remain above a level for which the cofferdam has been designed. Should it become evident that scour is developing that might take bed levels below the defined safe level, appropriate corrective actions will need to be taken. These are likely to take the form of filling the developing scour hole around the cofferdam with granular materials of a size sufficient to ensure stability within the prevailing velocity regime generated around the cofferdam.

It is very unlikely that a cofferdam will be designed for a bed level much below those observed within the existing channels. Sheet piling is expensive and pile lengths are a multiple of the free length above bed level. There is a strong inducement for the contractor to minimize scour.