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Humber Suspension Bridge South Tower Caisson Foundations

Fondations en caissons de la tour sud du pont suspendu sur le Humber

Die Senkkasten-Fundation des südlichen Pylons der Humber-Hängebrücke

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The Humber Suspension Bridge, which will have the world's longest main span - 1410m - is situated about 300 km north of London, England. On the north side of the river, the bridge foundations presented relatively few problems, being located in chalk. The foundations on the south side, however, are located in Kimmeridge clay overlain by glacial and alluvial material, posing considerable design and construction problems.

Kimmeridge clay is an over-consolidated fissured silty clay. It is hard under the existing over-burden pressure but rapidly disintegrates under the action of water when this pressure is removed. The basis of the foundation design for both the south anchorage and south tower was therefore to minimise the heave of the clay and so keep the fissures closed to prevent the ingress of water.

The Consulting Engineers prepared two alternative designs for the tower pier foundations, one using large diameter bored piles, the other using caissons. Messrs John Howard, the Contractor, who constructed all the bridge foundations, submitted a lower price for the caisson scheme than for the piles.

The tower pier is located about 500m from the south bank of the river in water about 8m deep at high tide. The twin hollow circular caissons, each 24m dia, were sunk through an artificial "sand island". The level of the sand island top was about +4m and the founding level of the caisson was -36m, giving a penetration of about 7m into the Kimmeridge clay.

Caisson sinking was by excavating under water using grabs, since the founding level was too deep to permit the use of compressed air. To control verticality of sinking and prevent base heave, the lower 27m of each caisson was divided into one centre cell and six outer cells. Thus, after de-watering the caissons, bottoming and plugging could be carried out one cell at a time, if necessary, counterweighting by sand fill all but one unplugged cell.

Calculations based on shear box tests on consolidated samples of 10% bentonite suspension, indicated a skin friction of about 20kN/m^2 for sinking the caisson to -25m through sand. "Actual" skin friction values (using the results of divers' surveys to assess the end bearing of the caisson) were estimated as 25-28kN/m^2. A sinking effort of 28kN/m^2 was found to be satisfactory. Calculations estimated average skin friction to be approximately 40kN/m^2 if no bentonite were employed.

In sinking the caissons, considerable difficulty was experienced in the cohesive material. The only satisfactory way of removing the clay from beneath the haunched cutting edge was by means of high-pressure water jets, working at about 30kN/m^2, either lowered down holes in the caisson walls, or held in purpose-built frames in the cells. A sinking effort of 50kN/m^2, including kentledge proved necessary to sink in the Kimmeridge. This high figure was due to partial destruction of the bentonite annulus arising from difficulties encountered in the overlying glacial and alluvial material.

During de-watering and final bottoming, borehole extensometers were used to check the amount of heave below the foundation and give warning (although there was a time lag between the removal of load and full recovery), thus permitting the envisaged sand counterweighting procedure mentioned above to be dispensed with and saving considerable time thereby. After plugging, the caissons were ballasted with water to prevent generalised heave of the foundation area. The water was removed as the external applied load was increased by construction of the concrete tower.

SUMMARY

The foundations for the south tower of the Humber suspension bridge (1410 m main span) are in Kimmeridge clay overlain by glacial and alluvial deposits. Twin hollow caissons 24m dia divided into one centre and six outer cells sunk to a depth of 40m through a sand island in the river by use of grabs, high-pressure water jets and kentledge, the penetration into the clay being 7m. A sinking effort of 50kN/m^2 was required. After plugging the caissons were loaded with water, which was removed as the load of the tower increased during its construction.

RESUME

Les fondations de la tour sud du pont suspendu sur le Humber (portée centrale 1410m) sont fondées dans l'argile de Kimmeridge, située au-dessous des sédiments glaciaires. Des caissons jumelés creux de 24m de diamètre, formés d'une cellule centrale et de six cellules extérieures, étaient enfoncés, dans un îlot de sable construit dans la rivière, jusqu'à une profondeur de 40 m. On a lesté les caissons et excavé à l'intérieur avec des bennes et des jets d'eau à haute pression pour pénétrer de 7m dans l'argile. La pression d'enfoncement nécessaire était de 50 kN/m^2. Pour augmenter le poids, les caissons étaient d'abord bouchés et chargés d'eau. Puis, l'eau était évacuée à fur et à mesure que la construction avançait.

ZUSAMMENFASSUNG

Die Fundamente des südlichen Pylons der Humber Hängebrücke (Mittelöffnung 1410 m) stehen im sog. Kimmeridge Lehm, welcher von Gletschergeröll und alluvialen Anschwemmungen bedeckt ist. Hohle doppelte Betonsenkkästen von 24m Durchmesser, unterteilt in eine Mittel- und sechs Aussenzellen, wurden durch eine Sandinsel im Fluss mit Hilfe eines Greifbaggers, Wasserdruck und zusätzlicher Belastung 40m tief, davon 7m in den Lehm, versenkt. Eine Auflast von 50kN/m^2 war hierzu nötig. Nach Abdichtung der Senkkästen wurden sie mit Wasser gefüllt, welches während der Herstellung des Pylons sukzessive wieder entfernt wurde.