

MULTIPLE ANCHORS HOLD DOWN THE MILLENNIUM MAN

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1.0 Introduction

The New Millennium Experience Company (NMEC) commissioned a large new sculpture by Anthony Gormley for siting on the River Thames adjacent to the Millennium Dome.

The Millennium Man is a 28m high steel sculpture based on the form of a man. Constructed from a matrix of steel square hollow sections the image of a man is not immediately obvious and only when viewed from a distance, does the form of the sculpture become apparent (Photo1). When viewed from close up, the sculpture is intended to resemble a random arrangement of interconnected elements.

It was necessary to avoid any tensile loading in the caissons forming the foundations and the patented SBMA system of ground anchorages wa employed to counteract any uplift forces.

2.0 The Structure and Usage of Existing Jetty Caissons.

The primary concept of the sculpture is to create a structure with no obvious signs of load transfer and which avoids the usual laws of sedimentation (decreasing structure with height).

The structure was analysed using LUSAS finite element structure analysis



Photo 1. The Millenium Man

system, and the tetrahedral units forming the structure were designed to meet at predetermined cast node connections. This detail was developed to overcome the possibility of a lockout situation arising during construction.

The sculpture is formed from a total of three hundred and fifty 1.5m long elements, including four hundred and seventy four full tetrahedral units. A number of different materials were considered for use in the sculpture and galvanised grade 50D mild steel was considered to be the most cost effective.

The new platform for the sculpture was constructed on 4 existing caissons of grey cast iron construction, each with a mass concrete

infill and with internally bolted flanges. The caissons did not have capacity for tensile loads and therefore the structure required designing to avoid any uplift forces within the caissons.

The new Millennium Pier is attached to and located alongside the Millennium Man. There is a triangulated system of bracing tying the tops of the caissons together. This system is used to transfer lateral loads from the pier pontoon into the caisson groups.

3.0 New Load Requirements on the Caissons

Initially, load requirements were estimated as 1000kN prestress per caisson leg. The main requirement of this prestress was the elimination of the possibility of the cast iron caissons being subjected to tensile stresses. This could, in principle, be effected by the incorporation of the anchors within the caisson concrete. However, concern was raised with regard to the unknown quality of the old mass concrete fill within the caisson legs.

After successful testing and use of the Single Bore Multiple Anchor System by Keller Ground Engineering, for the foundations of the Millennium Dome and for the retention of lengths of sheet piling along the Thames Bank around the Dome, the System was offered to distribute the fixed length of the anchors both within the lower caisson concrete and to remote depths in the underlying strata. A 900kN working load was offered without the installation of trial anchors.

4.0 Anchor Design and Design Flexibility

No ground information was available at the jetty location, thus interpolation of information from the quay wall works and the Dome foundations was necessary. Initially design was based on the probable encounter of 3m of Thames Ballast at the base of the 16m

long caisson, the anticipated presence of a 22m depth of London Clay underlain by Woolwich and Reading Beds. Having previously founded a Single Bore Multiple Anchor in each of these stratum, the main shortfall in information was material thickness and the extent of interfacial weakening. Clearly, assumed values of working and ultimate bond from previous trials had to be utilised. Owing to the tight programme and the offshore location no opportunity for preliminary trial anchor works existed.

The actual diameter of the bore in the underlying stratum was determined by the size of drill casing which could be advanced by rotary percussive action through the insitu concrete within the caisson legs. It was considered probable that the old and possibly weakened and weathered concrete may collapse during penetration and this, combined with the drilling accuracy requirements, demand the installation of a fully cased bore.



Photo 2. Casagrande drill rig.

A Casegrande C6S rig, complete with Klemm rotary percussive drill head advanced 178 drill casing through a 1.5m guide sleeve and into the depth of the caisson (Photo 2). Water flush was provided by a high volume pump sited on the access barge. Prior to anchor works, the Main Contractor for the Millennium Man works, Tubeworker Ltd., prepared a scaffold deck boarded out with sleepers to support the 12^T rig at each corner location. All access to the platform for plant and materials was by barge. The provision of cranes, and access and transportation barges demanded considerable planning to ensure minimum delays to the main Millennium Man construction works (Photo 3).



Photo 3. Barge access

It was acknowledged by SBMA in their preliminary design that the encountered ground conditions and quality of concrete in the caisson were likely to vary from those anticipated. It was in this regard that the refined anchor system demonstrated its versatility. A 133 drill casing was advanced through the 178mm bore formed in the caisson, through underlying soils to full depth by rotary percussive action. The 133mm size limit restricted the number of multiple anchor units that could be installed into the bore to six. The preliminary design founded one of the six units in the base of the caisson, one unit in the thin layer of Thames Ballast, three units in the London Clay and one unit in the Woolwich

and Reading. Each unit was to provide a 150 kN working load to provide a total prestress of 900kN. This mode of anchor prestress effected a dual purpose; to ensure the caisson iron was always maintained in compression mode and to provide resistance to uplift due to overturning (wind and impact loading from river vessels).

Drilling of the first anchor revealed differences in materials thicknesses;

0-16m	Caisson concrete
16-23m	Thames Ballast
23-28m	Soft to firm clay
28-41m	Stiff London Clay
41m – 45m	Woolwich and Reading Beds

This demanded that distribution of the unit anchors be changed to found one unit anchor in the caisson concrete, two units in the Thames Ballast, no anchors in the soft to firm clay, two units in the stiff clay and one unit anchor in the Woolwich and Reading.

All other anchor systems are designed to found the entire anchor in a single stratum and thus normal systems could not have accommodated the variation in the encountered ground nor provided 900kN working load when founded in one of the, relatively thin soil materials.

The installation of the four anchors, one to each leg, including penetration of the insitu caisson concrete took two weeks, following by a three week period of preparation of the caisson head concrete and anchor heads. All anchor tendons were fully protected against corrosion using the double plastic coating system that complies with the demands of any International Codes.

5.0 Anchor Testing

Anchor stressing utilised six hydraulically synchronised jacks (one on each

unit anchor). This systems guarantees uniform and simultaneous loading of all 6 units but clearly owing to the vast difference in unit anchor free lengths (14 to 41metres) each jack ram travel varied enormously between the six jacks. However, this system allows each of the unit anchors to be very accurately monitored.

Each unit anchor satisfied three acceptance criteria, two related to load hold capacity and one related to load/extension behaviour. Hence, the 6unit anchor involved compliance with 18 acceptance criteria prior to an anchor being accepted into the works.

Foundations Consultants:	Beckett Rankine Partnership
Main Contractor;	Tubeworkers
Anchor Specialists	Keller Ground Engineering
Anchor system	SBMA Systems Ltd

6.0 Summary

The enterprising utilisation of a 100year old offshore, cast iron structure demanded reassessment of the foundations when subjected to new loading conditions. The physical dimensions required the provision of the high holding down anchor forces to be limited to only four corner anchors, each founded in the Caisson Base and in the underlying stratum. Strict time constraints prevented the ground conditions being fully investigated. The flexibility of the Single Bore Multiple Anchor System allowed the final “design” to be implemented as anchor drill logs were produced. This was effected by the distribution of the unit anchors within the stronger beds of ground materials encountered.

7.0 Acknowledgements

Client; New Millennium Experience Company

Construction Manager: MLJV

Architect/Artist; Anthony Gormley

Design Engineer; Elliott Wood Partnership