QED STRUCTURES
Consulting, Structural & Civil Engineers

77 AVENUE ROAD, LONDON

BASEMENT RETAINING WALL
STRUCTURAL OPTIONS REPORT

Project No. 09-102

Date – 17.07.2009

QED STRUCTURES
Consulting, Structural & Civil Engineers

INTRODUCTION

This report is presented to outline the options for the construction of the basement to the 77 Avenue Road, London Development. In order to construct a 2-storey deep basement a primary requirement is to devise a system of construction which will retain the surrounding earth and also isolate the ground water from the basement excavation.

There are a number of different methods for retaining the earth around the basement excavation namely secant piled walling, sheet piled walling or diaphragm walling. In essence each of these systems depends on installing a wall all around the perimeter of the site. The bottom of this wall must penetrate into an impermeable base layer, in this case it is anticipated to be London Clay. This clay layer will then form a water seal and prevent groundwater entering the bottom of the excavation with the temporary wall system chosen (be it diaphragm wall, secant pile or sheet pile) forming an impermeable wall surface, to cut off water from entering into the excavation. Once the temporary wall system is in place the basement can be excavated and the water can be pumped out to give a dry area for construction of the permanent basement works. This study focuses on the secant piled wall and sheet piled wall solutions as we believe a diaphragm wall is not suitable for a development of this size and location.

Depending on the method of wall construction chosen there are various ways of achieving the permanent solution both incorporating the temporary solution and also lining the temporary solution with internal concrete walls to form a fully watertight box to suit the use of the basement. The final use of the basement determines the degree of water tightness required from the retaining walls. A basement used solely for car-parking purposes does not need to be as dry as a basement which is used for retail purposes. There is a basement Code of Practice (BS8102) which defines the different grades of basement and the level of dryness which will be achieved. This report presents the options in terms of the degree of dryness required from the basement and also the possible construction methods for the basement retaining wall built in the temporary and permanent case.

QED STRUCTURES
Consulting, Structural & Civil Engineers

GROUND CONDITIONS

Prior to understanding the design of the basement it will be a requirement to be able to identify the exact soil strata including testing and foundation design parameters. This will be achieved via a soil investigation which will include a series of boreholes to depth. During these investigation works, the ground water levels will also be determined, this will aid the construction technique requirement with regards to dewatering of the basement. Contamination testing will also be required in relation to the disposal of materials off site.

BASEMENT GRADES TO BS 8102

The four different grades of basement are defined in BS 8102:1990 '*Protection od Structures against Water from the Ground*'. This code of practice defines the different usage types and level of moisture provided by various forms of construction. In addition to the grade numbering defined in BS8102, CIRIA Report 140 introduces terms for these grades. Table 1 from BS 8102 is appended to this document for information. The four grades are outlined below:-

Grade 1 'Basic Utility'
Basement usage is for car parking, plant rooms (excluding electrical equipment) and retail storage areas. The performance level allows for some seepage and damp patches to be tolerated.

Grade 2 'Better Utility'
Basement usage is fro workshops, plant rooms (requiring drier environment) and retail storage areas. The performance level allows no water penetration but high humidity is tolerated.

Grade 3 'Habitable'
Basement usage is ventilated residential and working areas including offices, restaurants and leisure centres. The performance level is a dry environment but with no specific control of moisture vapour.

Grade 4 'Special'
Basement usage is for archives and stores requiring a controlled humidity environment. The performance level is a totally dry environment with strict control of moisture vapour.

QED STRUCTURES
Consulting, Structural & Civil Engineers

SECANT PILED WALL OPTION

Description

A secant piled wall is a traditional method of ground retention to facilitate basement excavations and construction. Secant piling is an excellent form of ground retention on restricted city centre sites where there are adjacent roads and buildings tight against site boundaries. Bored secant piles would be augered down into the stiff clay layer.

Soft piles consisting of low grade concrete are bored first followed by hard reinforced concrete (RC) piles which interlock with the soft piles. The hard/soft pile interlock forms a water resistant perimeter retaining wall. The secant piles would be embedded into the impermeable stiff clay layer which should ensure ground water is cut off from outside the basement excavation. Ground water within the basement excavation will need to be gathered in local sumps and pumped out. To ensure verticality of the wall rotary drilling with casing is likely to be used and not continuous flight augering (CFA). Secant pile retaining walls can be used to carry vertical superstructure loads and hence form part of the permanent works.

Temporary Works

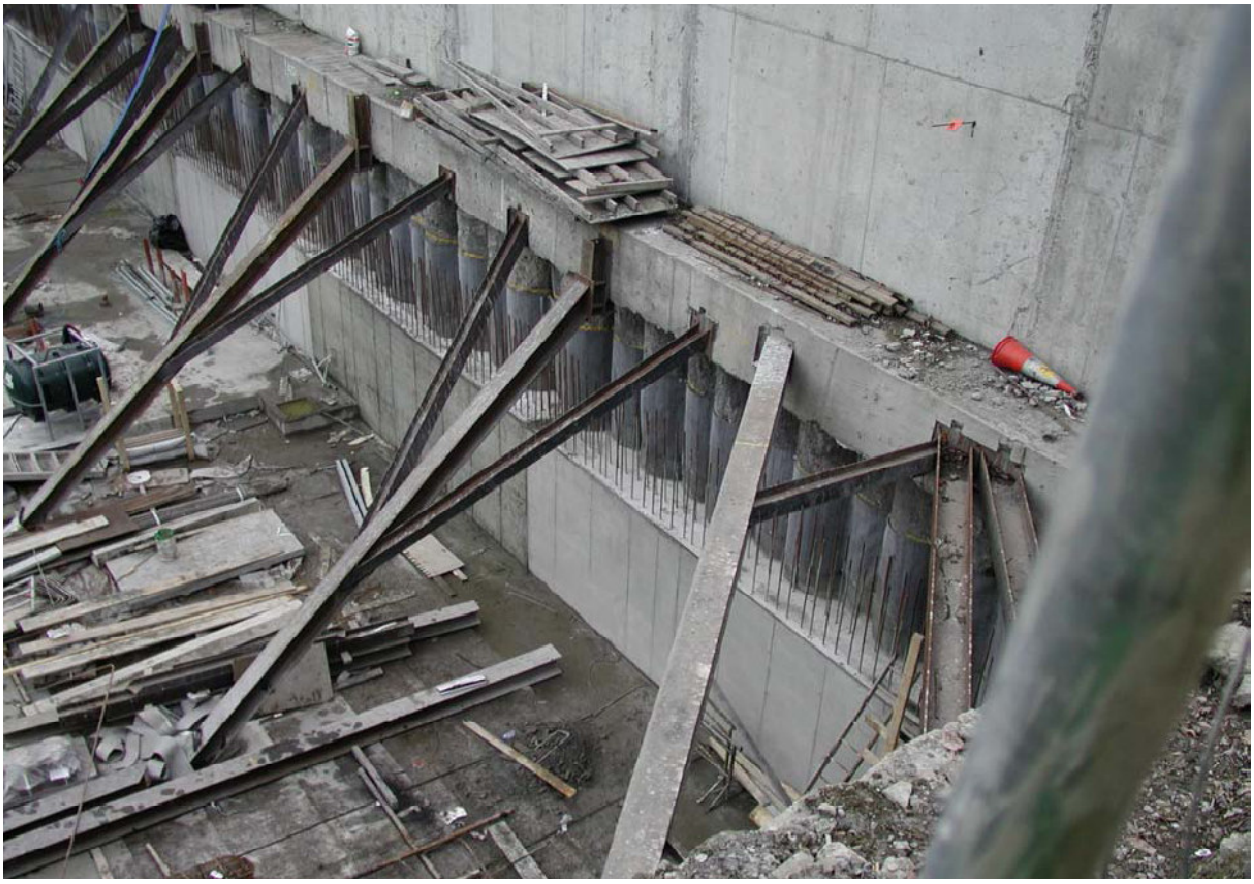
Temporary propping of the wall during the basement excavation would be required. In the permanent situation the floors of the basement support the wall in resisting lateral earth and water pressures. Subject to detailed design it is envisaged that two rows of props would be required for the two storey basement, one located near the top of the wall and the other at mid height of the excavation depth.

There are a number of ways in which the temporary propping can be achieved, including:-

1. Soil anchors can be used, which would be installed through the retained earth. Soil anchors have the advantage of leaving no obstructions within the basement excavation. In the permanent condition the soil anchors would be decommissioned by distressing the tension forces present in the anchors. This is to ensure they do not impede any future development works outside the site boundaries. However, given the proximity of the adjacent properties and road and potential complications with regards to inserting these anchors under existing foundations and with the added risk of underground services/sewers/tunnels etc, this option has been discounted.
2. Traditional temporary steel props back into the excavation. These props are typically placed at 5m-6m centres on plan. Whilst not as expensive as soil anchors, this solution has the slight disadvantage of providing an obstruction during the basement works. Careful consideration during the sequencing of the works is required both during excavation and

construction of the basement floors. Please refer to Photographs 1 and 2 below showing this type of propping:-

Photograph 1



Photograph 2

QED STRUCTURES
Consulting, Structural & Civil Engineers

SHEET PILE WALL OPTION

Description
Steel sheet piles are driven into the stiff clay stratum to cut off ground water from the excavation. Temporary propping of the sheet pile wall during the basement excavation is required. This can be either rock anchors which we have previously discounted or conventional steel props as outlined in the secant piled wall option above.

Installation
The key issue with sheet piling is 'driveability' during installation. It is crucial that the enabling works contract is set up so that the contractor takes on board the risk associated with the use of sheet piling. The sheet pile section would need to be sized in order to be able to deal with the driving of the sheet pile into the strata. Obstructions during driving can cause the interlocks to tear apart during driving. Where refusal problems are encountered during driving selective use of augering equipment can be adapted to break up the ground. When piling next to existing structures silent vibration free plant may be required. Where the sheet piles are to be left exposed as part of the permanent works, vertical tolerances have an impact on the method and speed of driving.

Prevention of Water Seepage
Steel sheet pile walls comprise a sequence of interconnected sheet pile sections which are joined together at the interlocks. Water seepage can occur at the interlocks as the steel plate is totally impervious to water ingress. If the gaps are filled with a preapplied hydrophilic sealant or welded, the wall can be made fully watertight. Where preapplied sealants are used, the integrity of the vertical interlock joint is very much dependent on the driving conditions and the installation techniques used, i.e. preapplied sealants are prone to damage during driving. For this reason, site welding of the interlocks is usually carried out where it is intended to leave the sheet pile wall exposed in the permanent condition. However, site welding is labour intensive, time consuming and requires strict quality control on site. Welding is also difficult where water seepage through the interlocks occurs. Where there is water seepage a two stage weld is required, the first to seal the interlock followed by the main structural weld. To reduce the amount of site welding sheet piles are often shop welded together and delivered to site in pairs. This is only possible where driving conditions are favorable but has the advantage of halving the amount of site welding. Welding the sheet piles together has the added advantage of increasing the vertical load carrying resistance of the wall as full 45 degree load dispersal through the wall can be assumed. Please see Photographs 3, 4, 5 and 6 for below for sheet pile walls:-

QED STRUCTURES
Consulting, Structural & Civil Engineers

Photograph 3

Photograph 4

Fire Protection
Where the sheet piles are left exposed in the permanent case it is possible to avoid applying a painted fire protection by 'fire engineering' the sheet pile. This is achieved by taking into account the cooling effect of the adjacent earth in conjunction with providing a sufficiently thick sheet pile section to give the required rating. For aesthetics exposed sheet piles are often sand blasted and then painted, see photographs 7 and 8 below:-

Photograph 5

Photograph 6

The alternative to welding the interlocks is to pour a Reinforced Concrete (RC) wall in front of the sheet piling. The sheet pile would hence form a permanent shutter to the RC wall. Although this increases the overall retaining wall thickness it has the advantage of not requiring site welding of the sheet pile interlocks. The connection between the steel sheet pile wall and RC basement slab also needs careful attention to ensure water tightness. One solution is to weld a steel plate to the sheet piles and place a hydrophilic (water swelling) seal between the steel plate and the underside of the basement slab.

Subsidence
Secant piled walls or sheet piled walls provide the lateral resistance to the earth in both the temporary and permanent condition. Providing a series of lateral props to the retaining walls as the excavation proceeds will reduce the risk of subsidence to any adjacent structures.

Groundwater
By creating a physical barrier for the construction of the basement by the use of either a secant piled wall or sheet piled wall, this would help reduce any movement of the perched water on top of the clay (assuming it is London Clay) in the short to medium term during the construction works. Once the basement has been constructed the perched water would then find its natural level.

SUMMARY COMPARISON

Both the secant piled wall and sheet piled wall will require temporary propping in order to excavate the two storey basement. Both systems have their own advantages and disadvantages. Please see below a summary of the main advantages and disadvantages of each system:-

SECANT PILED WALL

Advantages
Relatively short lead time compared to sheet piling.
Secant piling is effectively an insitu concrete form of construction so there are no transport issues.
Bored secant piles can be installed with little vibration and are hence often used in city centre sites where there are existing buildings right on the site boundary.
In shallow basements secant piles 'as formed' can satisfy the BS8102 requirements of a Grade 1 Basic Utility basement.

Disadvantages
More expensive than sheet piling
Slower form of construction than sheet piling.
Larger overall wall thickness than sheet piling.
Excavated soil needs to be disposed of. Any contaminated soil needs removal to a specialist landfill. This is a very expensive process.
Secant piles 'as formed' have a rough appearance and for aesthetics an RC wall is often poured in front of the piles.

QED STRUCTURES
Consulting, Structural & Civil Engineers

SHEET PILED WALL

Advantages

Permanent steel sheet pile walls can work out cheaper than more traditional concrete secant piles.
Construction time is quicker than that for secant pile walls.
Permanent steel piling is a narrow form of construction, which can be installed close up to the site boundary, maximising usable site space.

Steel sheet piles are generally suitable for all types of soil.
There is no excavated soil to dispose of. This is a big advantage on a site where contamination is possible.
Steel sheet piles are factory quality as apposed to site quality.
Steel sheet piles can easily be made aesthetically pleasing.
Immediate load carrying capacity is present i.e. there is no requirement to wait for concrete to gain its 7 day strength.
Steel sheet piles are a sustainable product as they can be extracted easily and recycled.
Welding of the sheet pile interlocks should ensure an exposed sheet pile wall satisfies the BS8102 requirements for a 'Grade 3' habitable basement.

Disadvantages

Site welding of the sheet pile interlocks (for water tightness) is labour intensive, time consuming and requires strict quality control on site. Welding is also difficult where water seepage through the interlocks occurs.
Pouring a reinforced concrete wall infront of the sheet piles (to avoid site welding the interlocks) increases the overall wall thickness.
Where there are limits on noise and vibration, sheet piles have to be installed using high frequency vibrator and pressing techniques. These are slightly slower and more expensive than conventional impact driving.
Similar to above careful consideration needs to be given to the installation method to avoid interlock tearing, refusal problems and to ensure a plumb and vertical wall.
Steel sheet piles have a slightly longer lead time in that they have to be manufactured and delivered from the UK.

QED STRUCTURES
Consulting, Structural & Civil Engineers

CONCLUSION

Constructing multiple basements is very common and achievable with the modern techniques available today. We have identified two options which we believe would be suitable for this project to be able to construct a two storey basement. It is recommended that a full site investigation is undertaken prior to any detailed study and calculations being undertaken to ascertain the most suitable option. Both options identified are similar in that they require temporary propping during the construction phase, a careful sequence of works would need to be adopted during the construction phase to deal with this. However, given the location and size of the proposed development we would recommend that the secant piled wall option be adopted. This would have less impact on the surrounding area with regards to noise, transportation and buildability. Even though sheet piling is a quicker form of construction, the use of a secant piled wall for the construction of this size of basement would be very quick, resulting in limited impact on the surrounding area. Please refer to Appendix A for a structural concept scheme for the secant piled wall system.

QED STRUCTURES
Consulting, Structural & Civil Engineers

APPENDIX A

STRUCTURAL CONCEPT SCHEME FOR A SECANT PILED WALL SYSTEM