Basement car park design

A basement car park has to be design in this project to meet the property developers requirement. The car park will have 3 below ground level as the figure attached in the appendix (page 2). A site investigation has been completed and supplied as the information in this project. The construction technique for the basement walls has to be identified, then design the basement walls and produce a report justifying the solution.

1. 2 Project Aim and Objective

This project title is set up for student who is having their third year study in Civil and Structural Engineering. The objective of this project is to reflect the design and construction process of a geotechnical structure that students are likely to encounter in their future industry life.

There are several aim have to be achieved in order to meet the objective in this project. Those aims are:

To gain the overall thinking in a project construction and understanding those factors influence the development of the project.

To gain deeper knowledge in the geotechnical field such as type of retaining structure and soil profiles.

To develop the rational thinking and view of the constructability of the project.

To identify the engineering problems in a project and minimize it to the minimum.

To justify the proposed concepts into engineering fields.

To apply engineering thinking into a project and design the structure in accordance.

To communicate with the supervisor for seeking appropriate advice and self study to complete the project.

1. 3 Project Scope

This project had been separated into two main parts which are conceptual design and detailing design.

In the conceptual design part, the choices of pile have to be considered wisely and justify it before get into the detailing design part. In this project, there are several type of retaining structure can be used but just the most appropriate one will be chosen to carry out into the detailing design part. There are few factors have to be concerned while selecting the choice of retaining structure. Those factors are the type of soil, durability, constructability, estimated costs and others. By having a good comparison among type of retaining structure, then the most adoptable type of retaining structure will be selected to construct the retaining wall.

For the detailing design part, an adequate design calculation has to be produced in order to show that the retaining structure is satisfied with several circumstances and sufficient drawings have to be prepared if needed. The construction sequences have to indentify and list out clearly. Last but not least, a detailed method statement for the safe construction of the building including any supporting risk assessments, and an outline construction programs in the form of a bar have to be provided.

2. 0 Background Study and Constraints

The background study is the first stage of this entire project and a work must to be done before a project begin to progress on. The main purpose of this stage is to gather information as much as possible and analysis to figure out the restriction of the project.

There must be some restriction in every single project that has to be concerned and further rational thinking to manipulate a good design. The discussion of the constraints has to be done in the early part of the project then the better final design will be produced by passing through this process.

2. 1 Deep Excavation and Site

The site tolerance is limited due to a public highway located just next to the footpath which is 2m away from the site. There must be some disturbance will face by the public highway due to this significant issue. This point has to be considering while choosing the type of retaining structure to be construct and minimizing it to the minimum when the construction is going on.

Deep excavation has to be taking part in this entire project, so the hazards of deep excavation either supported or unsupported case has to be indicated and it is a considerable concern while making decision for the type of earth retaining structure. For example, the dewatering problems might be exist base on the water table and the excavation is variable base on different type of soil in the area as well.

2. 2 Soil Profiles

The soil profiles are the interesting and concerning part for the geotechnical engineering especially the engineering soils found beneath the topsoil [1].

The engineering properties and the behaviour of these soils are their concerning and interesting point [1].

Different type of soil profiles will be having different ability for a structure. Therefore, site investigation process has to carry out to determine the soil profiles. The layer and the type of soil or rock beneath the ground surface will be determined by this process. Its behaviour and the properties of each layer will be obtained as well to progress on.

In this project, there are three boreholes given from the site investigation data which named as BH-02, BH-03 and BH-09. The boreholes record is attached at the back of the report which in the appendix part (from page 1 to page 2). The location of BH-02 and BH-03 are shown inside the plan view of the site but there is nothing relevant to BH-09 can be figured out from the view. The plan view is attached in the appendix (page 1). A simple analytic of the height and depth of each layer have done which shown in the Figure 2. 1, 2. 2 and 2. 3.

C: UsersFuhDesktopZzz_Study thingsCIVE 3709ProjectIMG_0619. JPG

Figure 2. 1 Borehole Record, BH-02

C: UsersFuhDesktopIMG_0617. JPG

Figure 2. 2 Borehole Record, BH-03

C: UsersFuhDesktopIMG_0618. JPG

Figure 2. 3 Borehole Record, BH-09

From the figure of the three boreholes records, it shown that they are about the same. The soil profiles for the top layer is made ground then followed by clay and then mudstone as the bottom layer.

Clay is a naturally occurring material composed primarily of fine-grained minerals, which is generally plastic at appropriate water contents and will harden with dried or fired. Although clay usually contains phyllosilicates, it may contain other materials that impart plasticity and harden when dried or fired. Associated phases in clay may include materials that do not impart plasticity and organic matter [14]. In the other hands, mudstone is a fine grained sedimentary rock which is formed by clays or muds with the pressure over long time. It looks like hardened clay but depending on the situation when it was formed.

2. 3 Water level

Groundwater observation where the water seeps or ingress has to be recorded in the site investigation logs as they link with the casing and the boreholes depth [2]. Groundwater observation is the concern for geotechnical engineering due to the water pressure too. The water pressure is an issue that will affect the decision of the choice of retaining structure and the depth of the pile as well.

The water table is not given in this particular project specification therefore proper consideration is needed before making any assumption. The water level is to be assumed one meter below ground level after a long consideration and communication with supervisor. This should be the best assumption and go on for the later part of design.

2. 4 Time, Cost and Quality

As a designer, the concern of the property developer has to be taking into consideration while designing a project. Time, cost and quality are playing the important roles for a single project which will be the concern of the developer. These three elements are the key issues and related to each other. The cost of the project will be increased if a project construction time getting longer. Base on this, the shorter the construction period the lower the cost of the project so a proper planning of the construction method and procedure is needed to minimize the construction cost but the quality of the project must be still maintain in a satisfy adoptable level.

3. 0 Type of Earth Retaining Structure

Earth retaining structures are mainly used to support the soil and structure due to the difference in elevation of the ground surface. It can be either propped or cantilever. There is various type of earth retaining structures which are used in geotechnical field for civil engineering. Those retaining structure more commonly used in basement car park and more suitable for this project are:

Sheet Pile Walls

Diaphragm Walls

Bored Pile Walls

There is different capable of each type of wall, the typical applications of walls have shown in the figure below.

Figure 3. 1 Typical applications of embedded walls ([8] pages 98)

3. 1 Sheet Pile Walls

Sheet pile walls are made of timber or precast concrete previously but nowadays sheet pile walls are more commonly made of steel. Sheet pile walls are formed by individually driven sheet pile into the ground and form the series of interlocking piles to support the soil and the structure [1]. Sheet pile wall can be category into two main types which are cantilever wall and anchored wall.

Sheet piles are light to handle and being robust. It can handle the high compressive loads whiles it driven into a hard ground surface [3]. It has the ability of being driven into deep penetration to reach a bearing stratum or to develop a high frictional resistance [3].

There are two method of driving sheet piles into stratum which is:

Pitch and Drive

This is the simplest method, each sheet pile or pair of piles will be driving into the finished level (full depth) before repeating the next sheet pile. By the way, this method is preferable for loose soils and short piles only.

Panel Driving

In this method, the first pair of piles has to be pitched carefully, plumbed and driven partly to form adjacent piles. Then, the remaining of piles are pitched and interlocked. Finally, the last pair of piles pitched into the panel are then driven partially and followed by the partial driving of the rest of the panel, working back towards the first pair in the panel [4].

The piles is arranged as whole panel, therefore it is no need to drive all piles fully to maintain the piling operations. The risk of driving problem and difficulties of de-clutching will be minimised too [5]. This method is suitable for dense sands and stiff cohesive soils.

http://www. earthwork. us/files/DSCN2063. JPG

Figure 3. 2, Sheet Pile Walls

There are few issues have to be discuss while considering to be used sheet pile walls for design. Firstly, the deep of the basement has to be constructed. If the depth of the basement too deep which mean the length of the pile will be quite long and the ability of transporting, pitching and driven those piles has to be taken into consideration especially in urban area. Cost will be affected in this issue as well because it is hard to manufacture a big size of sheet piles.

Basement car park recently constructed in urban area to fully utilize the space in the cities. While sheet pile walls can be act as a permanent structure or temporary work in a construction project, but there is a concern if the sheet piles act as the temporary work. The ability to remove the sheet piles after constructed the retaining structure has to be think twice base on the limited spaces around the cities for the crane to remove it.

Even there is some improvement of the technology on the noise and vibration problems for sheet piles while driven it into the stratum but vibration and noise are still exit which is the disadvantages of sheet piles. The improvement just mainly overcomes the problem on some type of soil

layer only, such as by using some hydraulic pressure equipment to press the sheet piles into stiff clay layer. Refer to this entire issue; there must be rational consideration if steel pile has to be used specially in the urban area.

3. 2 Diaphragm Walls

A diaphragm wall basically is the combination of reinforced concrete wall and sheet pile wall. It has the ability of the combination of reinforced concrete and sheet pile wall. A diaphragm wall are formed and fixed by vertical reinforced concrete slab in position with the same manner to support the soil. In the other hand, the sheet pile held in the lower part of the diaphragm wall by the passive and active soil pressures that act upon it [1].

Most of the diaphragm walls are the reinforced concrete wall that cast in situ by a machine digging a trench in panels of limited length. It acts as temporary support during construction and a permanent wall, sometimes with lining [8]. The stability of the excavation to the required depth is filled by the use of a drilling fluid, usually is bentonite slurry [6]. This slurry has thixotropic properties, as it forms into gel when left undisturbed but becomes a liquid when disturbed [1]. The bentonite slurry initially penetrates into the soil and the virtually impervious skin of bentonite particles is formed [1]. It is only about few millimetres thick on the sides of the trench. There is no penetration of the slurry into clays, sand and silt water. The main purpose of the use of slurry is to prevent collapse of the trench by creates lateral pressures that act on the side of the short trench panel.

When the excavation is done, the required steel reinforcement is place into the trench panel. The walls are constructed by filled with concrete in discrete

panel lengths ranging typically between 2. 5m and 7. 0m using purpose in appropriate circumstances. Those displaced slurry being collected for cleaning and further use. Standard widths of diaphragm walling equipment are 600, 800, 1000, 1200 and 1500mm although greater can be provided as required. Depths of the diaphragm wall are constructed up to 50m by using grabs and up to 80m using standard hydromills (milling machines). The remaining intermediate panels are excavated and constructed to fully complete the wall when the concrete has developed sufficient strength. The length of each panel is limited to the amount that the soil will arch, in a horizontal direction, to support the ground until the concrete has been placed [6].

A simplified Figure 3. 3 has been attached to shown the various construction stages. In the Figure 3. 3, the processes of each stage are:

Guide-wall construction

Panel excavation in progress

Installing stop ends

Panel concreting

Figure 3. 3, the stage of construction a diaphragm walls.

http://www. stroyinject. com/images/gallery/pics_new. 08. 08/thumb_SZ_2. JPG

Figure 3. 4, Diaphragm Walls

There still exists another type of diaphragm walls which are precast reinforced concrete diaphragm walls. The use for this type of diaphragm wall is nearly the same with diaphragm wall that reinforced concrete cast in situ. It provides both temporary and permanent soil support but with limited depth.

There must be some advantages and disadvantages for every single earth retaining structure. Therefore the discussion of pros and cons for this type of retaining structure has to be done, while considering of using diaphragm walls.

The construction time and cost of diaphragm wall is generally efficient where it is used for both permanent and temporary subsoil retention for walls of medium, and greater, depth [8]. Diaphragm walls also allow the effective transfer of vertical load from the building superstructure to subsoil below basement level. The vertical load transfer is not added in the wall design while the early of diaphragm wall in UK. The reluctance of designers to allow such load transfer was due no doubt to lack of published test results. This situation changed gradually when the diaphragm more commonly use in the construction of basement [8].

While constructing the diaphragm walls, it has the minimum noise and vibration disturbance. This is an advantage of using diaphragm walls as a retaining structure. The noise and vibration in diaphragm wall installation are about the same compare with the normal civil engineering equipment, such as cranes and generators. Base on this, it suitable to be constructed in urban area. Diaphragm walls can be constructed under groundwater condition so

there is not any affection in groundwater problems for this kind of structure. Diaphragm walls have the advantages of high bearing capacity and good in horizontal or vertical bearing capacity. The allowances of settlement for this kind of structure are small which is good for superstructure [9].

Although there are many advantages of using diaphragm wall but there is some limitations for this structure to be used. It could not be use either in very soft soil such as soft clay due to trench stability problem or very stiff rock.

The principal disadvantages of diaphragm walling are the risk of loss or spillage of bentonite slurry, the relatively high cost of cleaning and the disposal of the slurry, the site space needed for large reinforcement cages and the large cranes needed to handle them. Above all, the need for continuity in the construction process from excavation through concreting to removal of temporary stop formers is a disadvantage of the method [8].

A good quality control is needed in the diaphragm wall construction. Diaphragm walls are the new type of retaining structure which is more modern and construct by some modern equipment. Those skilful and more specialist workers needed while installation the walls.

3. 3 Bored Pile Walls

Bored pile walls are an earth retaining structure that form by bored cast in situ piles either small or large diameter. This technique often used in deep basements and underground structure as a temporary or permanent retaining structure. It commonly used for those structures with limited working space or constraint of adjacent existing structures that prevent

excessive bulk excavation and help to control the movement of the ground [6].

The construction method of bored pile walls are slightly different compare to the diaphragm wall, initially a casing has to be driven into the ground by using the vibro-hammer and leaving 1 metre length of the casing above the ground. Casing can be ignored where the soil profiles are firm to stiff cohesive soils [11]. The power-driven rotary auger (a drilling tool) will be used to cut and remove the soil within the casing to form a borehole. The range of diameters and depths possible is considerable, from 300 to over 5000mm and down to 100. The used of the casing is to support the surrounding soil. If the length of the casing not enough long to reach the required depth in the ground, bentonite slurry could be used to support the soil below the casing. The steel reinforcement will be lifted up and placed into the borehole by crane. If the depth of the boreholes too deep, reinforcements have to be over lapping and welding if possible. The concrete is poured into the borehole to form the bored pile. Finally, the bored pile is formed by using the vibro-hammer to withdrawn the casing [3][10].

A bored pile wall has its own characteristic that have to take into consideration while selecting the type for retaining structure. The presence of the advantages and disadvantages of the bored pile walls have to be taken into consideration if bored pile walls chosen to be used.

The length of bored pile walls can be varied to suit the varying ground condition which is more adoptable for most of the design project. Moreover, the soil can be inspected and if necessary sampled or in situ tests made

when it is cut and removed from the boreholes. By using this method, the large excavations and subsequent backfill are eliminated. The noise and vibration are existed while constructing the bored pile but it is acceptable and will not disturb the adjacent pile or structure [12].

Basically, the disadvantages of bored pile wall are not much. The transportation of the casing could be one of it. The unable to place the concrete under the ideal condition and cannot subsequently inspected are one of the disadvantages as well.

Figure 3. 5, the steps of constructing contiguous bored pile walls.

Bored pile walls are categorised into two types, which are:

Contiguous Bored Pile Walls

Secant Bored Pile Walls

Several factors have to be concerned while choosing the type of bored pile walls. Those factors are:

Soil Type

The ground water profile

Construction time available

Propping requirements

Cost

Life span

3. 3. 1 Contiguous Bored Pile Walls

A single row or double row of piles pitched and constructed next to each other with leaving some gaps. Alternative piles are cast first and the intermediate piles are then installed. Figure 3. 6 and Figure 3. 7 are attached for more detail and understanding. For this type of retaining structure, the water will flow through the gaps between piles [1]. This type retaining structure suitable where the soils are between firm to stiff and the water level is below the depth of excavation. This method is the fastest method and most economic option to construct.

Figure 3. 6, an example for the plan view of contiguous bored pile wall

http://www. sbe. napier. ac. uk/esm/images/bored_pile_small. jpg

Figure 3. 7, contiguous bored pile wall

3. 3. 2 Secant Bored Pile Walls

Secant bored pile walls are similar with the contiguous bored pile wall, except that the gap of the piles are either filled with concrete or secondary pile are cut into the primary piles as shown in Figure 3. 8 and Figure 3. 9. This technique is suitable for high water level due to the continuous wall had formed and it is a watertight condition that stops the inflow of water. The procedure of this method is slightly more complicated compare to bored pile wall.

Figure 3. 8, an example of plan view of secant bored pile walls

http://www. amplusltd. com/upldimages/ISecant%20piled%20wal%20-%20Battricks%20-MG_0042. jpg

Figure 3. 9, Secant bored pile walls

4. 0 Comparing and Selecting Of Retaining Structure.

By using a simple matrix analysis table as shown in Table 4. 1, it can be determined the best selection of retaining structures as in general concept. The selection of the retaining structures can be determined by rational comparisons by applying the weighting into the matrix table. The weighting in the matrix table are represented with numerical numbers from 1 to 3 in which the higher the value, the more beneficial for the route while the lower the value indicates as otherwise.

From the table, it shown that each type of the retaining structures is about the same, they have their own characteristic and advantages in different aspects. Secant bored pile walls gained the most point in the weighting but it might not be the best choice because this is just a general concept comparing within the type of retaining structures so a proper comparison that fit with this entire project issues will be done later on.

The soil profiles of this project are made ground, firm to stiff clay and mudstone which adoptable for all of the retaining structure mentioned above except sheet pile walls. In this soil conditions, sheet pile walls are not suitable to be driven into the ground due to the hardness of the mudstone layer. This problem can be solved by providing bigger size of sheet pile which significantly increased the cost and waste of materials. Therefore,

sheet pile walls are not recommended and if possible choose other type of retaining structure into design.

Water level is a problem which will be affected the decision of selecting retaining structures. The water level is to be assumed at 1m below ground level. It is quite high and proper consideration has to be done base on this issue. Diaphragm walls, sheet pile walls and secant pile walls are capable to construct in high water level condition. Contiguous pile walls are not able to construct below ground water condition due to the gaps between the piling which allowed the inflow of the water. This might a concern while selecting this as the retaining structures.

Diaphragm walls are a good retaining structure among all of the retaining structure. It allowed the highest depth of excavation which is about 7 to 30m length but 8m of excavation is sufficiently enough in this entire project. In the other hand, the other retaining structures are more adoptable which allowed 4 to 15 or 20m depth of excavation length. This will be an issue while selecting the choice of retaining structures.

Basically, there is specific difficulty of constructing each type of retaining structures just in different restriction. There is not much to comment on the ease of construct issue but it must be fit with the site restriction. The durability of each type retaining structure is about the same and it could be ignored while comparing with each other. The cost of construction must be minimizing to the minimum if possible because it is a concern of the project developer and economical problem.

Sheet pile walls are rejected in this project due to several concerns. First, the main concern of using sheet pile is the size and area of the pile to be used due to the depth and area of excavation are quite big. It is hard to manufacture such big size of sheet pile in the factory and hard to transport large number of them to the site. If sheet pile chosen into design for basement car park, it will commonly act as temporary work and the ability to withdraw the sheet piles after the construction is an issue because a highway just located 2m away from the boundary of the site. Moreover, the soil profile contains lot of the mudstone which cause the sheet pile hard to be driven into the ground. There will be some vibration which will be affected the public highway either on the foundation or the whole structure while the sheet pile is driven into the ground.

Diaphragm walls are good to be used in basement construction which is commonly in urban area. Honestly, it is capable with all the construction constraints in this entire project such as it is able to construct under groundwater condition and there isn’t any vibration problem in diaphragm walls construction. Even it is so good compare with other retaining structures but it still will not be selecting as the retaining structure. First, large amount of steel reinforcements needed for a diaphragm walls, it have to be tied up before they lifted up by crane and placed into the panels. Base on the number of materials and skilful workers needed, the cost of the construction will increased directly. It is also relatively high cost of cleaning and the disposal of the slurry. Diaphragm walls are good enough which is a bit over for this project because some of the advantages is not needed in this project. Consequently, diaphragm walls are not suitable for this project and some

other retaining structure will do because the overall estimated construction cost is too expensive compare with others.

Bored pile walls are the most adequate retaining structure to be used in this project compare to the others. Even there are some disadvantages in this type of retaining structure but the advantages of using it are higher after proper consideration and comparing. Then, the vibration and noise of constructing bored pile walls are in the acceptable range and will not affect those structure next to it especially the public highway. Bored pile walls are able to consort with the soil conditions in this project too. It is the cheapest retaining structure as well. Bored pile walls are chosen either secant bored pile wall or contiguous bored pile wall.

As a conclusion, secant bored pile wall is chosen as the retaining structure in this project because it offers a watertight alternative compare with contiguous bored pile walls.

4. 1 Selected Retaining Structure â€” Secant Bored Pile Walls

Secant bored pile walls basically are bored cast in situ piles either small or large diameter. It will be constructed in a line and the gap between piling will be filling with cement or concrete to form a watertight condition for preventing the inflow of water. The filling technique will be mentioned in the later part of report.

Secant bored pile walls are categorised into 3 types which are:

Hard / Soft Secant Pile Wall

Hard / Firm Secant Pile Wall

Hard / Hard Secant Pile Wall

4. 1. 1 Hard / Soft Secant Pile Wall

The female pile has a characteristic compressive strength of 10-20 N/mm2, which is retarded to reduce the strength of the mix while the mail piles are drilled between the female piels.

4. 1. 2 Hard / Firm Secant Pile Wall

4. 1. 3 Hard / Hard Secant Pile Wall