

EXCAVATION APPARATUS AND METHOD

FIELD OF THE INVENTION

The present invention relates to the building and construction industry. In a particular form, the present invention relates to a method and apparatus for excavating large scale basement or underground regions for a building structure.

BACKGROUND OF THE INVENTION

In many types of building structures such as an office building or the like there is a requirement to form a large underground region that forms a basement area for the structure. This extends the useable space of an office building without further increasing the size of land required. This area may be used as an underground car park or in many cases may include additional office or storage areas. Often these underground regions will extend to a number of storeys or levels underground making their excavation a difficult and costly task in the construction of a building and its foundations.

To form these large scale underground regions, a diaphragm or retaining wall is first installed which defines generally the perimeter of the underground region to be excavated. In one example, the retaining wall is formed by a number of contiguous bored piles which together form a wall structure. Excavation interior to the retaining wall then commences. However, as would be apparent to those skilled in the art, the retaining wall requires support to prevent it collapsing inwardly. In some circumstances where the soil is suitable, a system of ground anchors may be employed which consists of a number of bracing or tethering cables which are secured at one end to anchor points drilled into the ground surrounding the retaining wall and at the other end to the retaining wall at discrete locations.

In many instances however, the soil is unsuitable and cables cannot be suitably anchored and as such this system will not provide a sufficient retention force to the retaining wall. In addition, these anchors will encroach into adjacent properties and

often the necessary approvals to install the anchors will not be available as the owners of these properties may not give permission for their installation.

5 In this case, it is then necessary to install a system of temporary vertical, diagonal and horizontal steel or concrete struts which are located interior to the retaining wall in the region being excavated with these struts positioned to support the retaining wall. Whilst this system is adequate it suffers from a number of serious disadvantages.

10 One disadvantage is that it requires the fabrication and installation of numerous individual struts which are time consuming to install. A further serious disadvantage is that the series of bracing and supporting struts are located in the region being excavated, thereby limiting access to the excavation site and requiring the structure to be adjusted as the underground region is formed. Another disadvantage is that a support structure of this nature is vulnerable to failure of a single strut or member,
15 thereby raising the risk of failure of the support structure as a whole.

It is an object of the present invention to provide a method and apparatus to aid in the excavation of an underground region capable of being used where soils are not
20 suitable for the anchoring of retaining walls by conventional means.

It is a further object of the present invention to provide a method and apparatus to aid in the excavation of an underground region where substantial areas interior to the retaining wall are left substantially vacant to facilitate the excavation process.
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SUMMARY OF THE INVENTION

In a first aspect the present invention accordingly provides a support structure for a retaining wall, said retaining wall forming an outer boundary for an underground region to be excavated, said support structure extending inwardly from said
30 retaining wall and over said underground region to be excavated, said support structure further including an aperture to allow access to said underground region,

wherein said aperture is adapted to resist compressive loads exerted by said retaining wall on said support structure thereby supporting said retaining wall during excavation of said underground region.

- 5 In a second aspect the present invention accordingly provides a method for excavating an underground region, said method including the steps of :
- constructing a retaining wall forming an outer boundary for said underground region to be excavated;
 - forming a first support structure for supporting said retaining wall, said first support structure extending inwardly from said retaining wall and over said
 - 10 underground region to be excavated, said first support structure further including an aperture to allow access to said underground region, wherein said aperture is adapted to resist compressive loads exerted by said retaining wall on said support structure; and
 - 15 excavating a first portion of said underground region.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the present invention will be discussed with reference to the accompanying drawings wherein:

- 20 FIGURE 1 is a top perspective view of a construction site employing an excavation method according to a preferred embodiment of the present invention;
- FIGURE 2 is a top figurative view of the component members of the excavation method illustrated in Figure 1; and
- FIGURES 3a to 3j are a series of side sectional views depicting the various stages of
- 25 excavating an underground region consisting of two underground levels similar to that illustrated in Figure 1.

In the following description, like reference characters designate like or corresponding parts throughout the several views of the drawings.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to Figure 1, there is shown a top perspective view of a building or construction site 200 incorporating the excavation method 100 according to a

5 preferred embodiment of the present invention. Excavation method 100 includes a peripheral diaphragm or retaining wall 110 which in this case is formed as a secant pile wall or alternatively a plurality of contiguous bored piles. Retaining wall 110 thus forms a continuous retaining structure around construction site 200 that defines the outer extent of the underground region 210 to be excavated below ground level.

10 As would be apparent to those skilled in the art, peripheral retaining wall 110 must be supported as excavation occurs otherwise wall 110 will collapse inwardly. Surrounding retaining wall 110 is a barrier 116 which divides the construction site 200 from the surrounding area 260.

15 Excavation method 100 further includes forming a support structure that incorporates a plate member 120 cast from reinforced concrete and extending from the interior of retaining wall 110 to an inner ring member or section 130 supported by a plurality of inner piles 140. Inner ring section 130 also forms an aperture that allows access to the underground region 210 which has already been partially excavated in

20 this figure. To facilitate the removal of earth in the excavation process, a platform 220 is constructed over the underground region 210 to support cranes 230 and other excavation equipment 240. Plate member 120 is also supported by a plurality of outer piles 145 (as shown in Figure 3a) due to the longer spans between the retaining wall 110 and the inner ring section 130.

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As the underground region 210 being excavated in this preferred embodiment will eventually consist of two underground levels, a second plate member 125 and corresponding inner ring section 135 are constructed below the top level plate member 120. This lower level also functions to support retaining wall 110 at a lower

30 depth and employs inner piles 140 and outer piles 145 also as a means for vertical

support. In this preferred embodiment, the inner ring section 130 is able to support a central aperture of approximately 79 metres in diameter.

Top level plate member 120 also includes a number of apertures or openings 160, 161 for the vertical support members (not shown here) which will support the ground level permanent structure that will be built above plate member 120. Vertical support members will be erected on the first underground level. The substantially square shaped openings 160 correspond to the location of the support columns, whilst the rectangular or elongate openings 161 correspond in location to walled structures such as lift core walls that will extend between the different permanent levels or alternatively function as general access openings in plate member 120 to facilitate the construction of the permanent levels. Similarly, second plate member 125 will also include openings for corresponding vertical support members that will support the first underground level. The process for constructing both the permanent works (i.e. the permanent levels) and the temporary works (i.e. the plate members 120, 125) is described below in further detail with respect to Figures 3a to 3j.

Referring now to Figure 2, there is shown a figurative top view of the support structure for the retaining wall 110 according to a preferred embodiment of the present invention. Depicted are the various forces that occur as a result of the excavation process. Shown in solid arrows are the forces exerted by the retaining wall 110 on plate member 120 due to the effect of excavating the region interior to retaining wall 110. In this preferred embodiment, plate member 120 is in continuous and complete contact with retaining wall 110. These forces are directed inwardly and are counterbalanced by forces as indicated by arrows which originate from inner ring section 130 which in this preferred embodiment is constructed of reinforced concrete and has a horizontal width of 1.20 metres and a vertical depth of 0.60 metres.

Inner ring section 130, due to its ring like structure, functions to resist the compressive loads generated by the forces that radiate inwardly from retaining wall 110. As would be clear to those skilled in the art, the inner ring section 130 is not required to be of a strictly circular shape but may be modified as required to balance the compressive loads arising from retaining wall 110. In this preferred embodiment, further bracing plate members 150 have been incorporated interior to inner ring section 130. Bracing plate members 150 function to ensure that the inner ring section 130 remains in compression and not in tension.

- 10 The shape required for inner ring section 130 may be determined by calculating the distribution of forces across plate member 120. This distribution will depend principally on the boundary shape of the retaining wall 110 and the extent and configuration of plate member 120 as these will potentially be the origin of any asymmetries in the distribution of forces which may require compensation in the shape of inner ring section 130. In one embodiment, the shape of inner ring section 130 may be determined by modelling the force distribution along plate member 120 and surrounding inner ring section 130 using computational finite element analysis techniques. As would be apparent to those skilled in the art, generally the most suitable shape for inner ring section 130 will be circular with the size varying according to the strength of the inner ring section 130 required.

Referring now to Figures 3a to 3j, there are shown a series of side sectional views depicting the various stages of excavating an underground region according to a preferred embodiment of the present invention. Each of the side sectional views is symmetrical about the centre and hence only the components of the excavation method on the left hand side of each figure have been enumerated. Furthermore, for clarity the central portion of construction site 200 is not shown in each of the figures. In Figure 3a, retaining wall 110 is constructed to form a continuous outer boundary of the underground region 210 to be excavated. Ground level is indicated at 250. In this preferred embodiment, where a two storey underground region is to be

excavated, retaining wall 110 has a total height of 9.0 metres with an underground portion extending up to 40 metres underground.

Displaced interior to retaining wall 110 is a set of outer piles 145. Outer piles 145 are provided for longer spans between retaining wall 110 and inner ring section 130. A set of inner piles 140, displaced inwardly from the outer piles 145 are arranged in a ring like configuration. As shown in Figure 3b, the next step in the excavation method is the construction of a horizontal plate member 120 formed of reinforced concrete and cast in situ to extend from retaining wall 110 to an inner ring section 130 supported by the corresponding ring of inner piles 140. This inner ring section 130 forms an inner boundary 131 to plate member 120 thereby defining a central aperture above the underground region 210 to be excavated. Plate member 120 is also supported by outer piles 145.

Referring now to Figure 3c, there is shown the next stage in the excavation method in which excavation commences and a first portion of the underground region 210 is excavated having a depth of 6.4 metres. Plate member 120 is supported at mounting points 121 by outer piles 145 and inner piles 140. The inwardly radiating force originating from retaining wall 110 is transferred to inner ring section 130 which due to its ring like structure will balance the compressive load, in the process supporting retaining wall 110 from collapsing inwardly into underground region 210.

Whilst in this preferred embodiment, inner ring section 130 is formed from reinforced concrete and to some extent forms a discrete force bearing member from plate member 120, it would be appreciated by those skilled in the art that the inner surface of plate member 120 may be simply terminated in a ring like configuration which in of itself will function to resist compressive forces originating from retaining wall 110 and subsequently transferred by plate member 120. In another embodiment, where plate member 120 is not required to extend over a large distance, plate

member 120 and inner ring section 130 will be essentially self supporting without the need for supporting piles or other support means.

Referring now to Figure 3d, there is shown a second plate member 125 and a
 5 corresponding inner ring section 135 which is constructed at the new lower ground level 250 formed after the initial excavation as depicted in Figure 3c. Second plate member 125 and corresponding inner ring section 135 and aperture defining inner boundary 136 are constructed in an identical manner to that of the top level plate member 120 and its corresponding inner ring section 130 and further functions to
 10 support retaining wall 110. As shown in Figure 3e, the next stage is the further excavation of a second portion of the underground region 210 below the level of second level plate member 125 to the depth at which point a horizontal floor is constructed spanning the base of the subterranean region 210 defined by retaining wall 110 and forming a lower underground level 300 as shown in Figure 3f. It should
 15 be noted that the stage of excavation depicted in Figure 3e corresponds with that shown in Figure 1.

Following construction of the lower underground level 300, a series of vertical columns 311 is erected to support the upper underground level 310. Where
 20 necessary, columns 311 will extend through the pre-formed openings 165 located in second level plate member 125. Referring now to Figure 3g, there is shown the construction of the upper underground level 310 as supported by columns 311. Similar to the lower underground level 300, the upper underground level 310 covers the region interior to retaining wall 110.

25 At this stage, as shown in Figure 3h the second plate member 125 and corresponding inner ring section 135 may be removed as indicated by the dashed outlines. A further series of vertical columns 321 are also erected which again will, where necessary, extend through corresponding openings 160 located in plate member 120. As shown
 30 in Figure 3i, following the removal of the second plate member 135 and the erection

of vertical columns 321, ground floor level 320 can be constructed. In this preferred embodiment, the ground floor level 320 is a small height above the actual ground level. The final stage in the excavation system is the removal of first plate member 120, corresponding inner ring section 130, outer piles 145 and inner piles 140 (as shown in Figure 3)).

Although in this preferred embodiment the location of the two sets of vertical columns 311, 321 are substantially aligned for both upper underground level 310 and ground floor level 320, it would be apparent to those skilled in the art that these arrangements may be customised for each level provided that corresponding openings 165, 160 are provided in the associated plate members 125, 120 for the vertical columns to extend through.

A brief consideration of the above described embodiment will indicate that the invention provides a number of significant advantages over prior art excavation methods. The primary advantage is that the present invention provides excellent access to the underground region that is to be excavated and the subsequent construction of underground levels in those cases where a retaining wall cannot be directly anchored to the surrounding ground. The use of a ring like aperture to provide the support structure for the retaining wall gives ready access to the areas to be excavated via the aperture.

Another important advantage of the present invention is that the plate members and inner ring sections are cast in situ making this process more convenient, efficient and cost effective than prior art methods that involve the construction of a framework to support the retaining wall. Although in this preferred embodiment, the support structure is removed once the underground region has been completed, equally the present invention could be adapted to form part of the finished underground structure.

The ring like structure also has the advantage of providing an improved support to the wall when compared to the installation of a framework consisting of temporary vertical and horizontal steel or concrete struts. Furthermore, as in the case of the preferred embodiment described here, the support structure according to the present
5 invention may be repeated at subsequent lower levels at greater and greater depths.

Although a preferred embodiment of the method and apparatus of the present invention has been described in the foregoing detailed description, it will be understood that the invention is not limited to the embodiment disclosed, but is
10 capable of numerous rearrangements, modifications and substitutions without departing from the scope of the invention as set forth and defined by the following claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS

1. A support structure for a retaining wall, said retaining wall forming an outer boundary for an underground region to be excavated, said support structure extending inwardly from said retaining wall and over said underground region to be excavated, said support structure further including an aperture to allow access to said underground region, wherein said aperture is adapted to resist compressive loads exerted by said retaining wall on said support structure thereby supporting said retaining wall during excavation of said underground region.
2. The support structure of claim 1, wherein said support structure includes a plate member extending inwardly from said retaining wall and wherein said plate member terminates in an inner boundary thereby forming said aperture.
3. The support structure of claim 2, wherein said inner boundary of said plate member has a substantially ring like configuration.
4. The support structure of claim 2 or 3, wherein said inner boundary of said plate member is adapted to increase its compressive load bearing capacity.
5. The support structure of any one of claims 2 to 4, wherein said plate member includes support means located interior to said retaining wall for vertically supporting said plate member.
6. The support structure of claim 5, wherein said support means includes a plurality of piles driven into said underground region.
7. The support structure of claim 6, wherein said plurality of piles are arranged to support said inner boundary of said plate member.
8. The support structure of any one of claims 2 to 7, wherein said plate member includes at least one opening for a corresponding substantially vertical member to

extend through said plate member, said vertical member employed in the construction of permanent works associated with said underground region.

9. The support structure of claim 8, wherein said substantially vertical member is a support column for a permanent level constructed above said plate member.

10. A method for excavating an underground region, said method including the steps of :

constructing a retaining wall forming an outer boundary for said underground region to be excavated;

forming a first support structure for supporting said retaining wall, said first support structure extending inwardly from said retaining wall and over said underground region to be excavated, said first support structure further including an aperture to allow access to said underground region, wherein said aperture is adapted to resist compressive loads exerted by said retaining wall on said support structure; and

excavating a first portion of said underground region.

11. The method of claim 10, wherein said first support structure includes a plate member extending inwardly from said retaining wall and wherein said plate member terminates in an inner boundary thereby forming said aperture.

12. The method of claim 11, wherein said inner boundary of said plate member has a substantially ring like configuration.

13. The method of claim 11 or 12, wherein said inner boundary of said plate member is adapted to increase its compressive load bearing capacity.

14. The method of any one of claims 11 to 13, wherein said plate member includes support means located interior to said retaining wall for vertically supporting said plate member.

15. The method of claim 14, wherein said support means includes a plurality of piles driven into said underground region.
16. The method of claim 15, wherein said plurality of piles are arranged to support said inner boundary of said plate member.
17. The method of any of claims 10 to 16, wherein said method further includes forming a second support structure below said first support structure for further supporting said retaining wall, wherein said second support structure is substantially configured as said first support structure and extends over a second portion of said underground region below said excavated first portion; and excavating said second portion of said underground region.