

**Title****Anchoring of Retaining Walls****Background of Invention**

5 This invention relates to a method and apparatus for anchoring retaining walls and in particular, relates to a method of anchoring a sheet pile retaining wall or diaphragm wall.

**Description of the Prior Art**

10 Excavations usually require the use of retaining wall to prevent collapse of the excavated pit. The retaining wall is often described as a sheet pile retaining wall or diaphragm wall. There is a need to anchor the retaining wall to the earth that is behind the wall to prevent collapse of the wall into the excavation. One way  
15 of anchoring sheet pile retaining walls is to drill a hole through the wall into the earth behind the wall adjacent the position where the wall meets the earth on the forward side of the wall. The hole is usually inclined downwardly and is then excavated to provide a cylindrical passage  
20 behind the retaining wall. A bar or strands are then inserted into the hole and the hole is grouted. After a delay of between three and seven days, to allow the grout to set, a plate and nut may be attached to the bar which can then be tensioned to place the anchor into a  
25 stressed working condition. As excavation continues, the operation can be repeated at lower levels of the retaining wall.

The conventional method of anchoring retaining walls of this kind suffers from a number of problems that  
30 are associated with the difficulties of drilling the hole accurately, the difficulties in flushing or removing the material in the hole, the difficulties in ensuring that drilling of the hole does not disturb the surrounding soil, the problems of the hole collapsing during drilling, the need to grout the  
35 hole around the bars or strands, the delay in allowing the

grout to set and harden, the uncertainty of knowing whether the anchor is operating satisfactorily and the problems that are encountered in removing and replacing the anchor should it prove unsatisfactory. It is these problems with conventional methods of anchoring retaining walls that have brought about the present invention.

#### Summary of the Invention

According to the present invention there is provided a method of anchoring a sheet pile retaining wall or diaphragm wall characterised by the steps of:

placing a jacking boom against the forward face of the wall,

placing an elongate anchoring member on the jacking boom with one end adjacent an opening in the wall,

positioning a jacking means between a reaction surface and the other end of the anchoring member, and

operating the jacking means to push the anchoring member through the opening in the wall and into the earth on the other side of the wall.

According to the present invention there is further provided apparatus for anchoring a sheet pile retaining wall or diaphragm wall according to the method described above characterised by a jacking boom adapted to support an elongate anchoring member and jacking means, means to operate the jacking means whereby the retaining wall is used as a reaction member so that operation of the jacking means causes the anchoring member to be forced through an opening in the retaining wall into the earth behind the retaining wall.

#### Description of the Drawings

Embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a plan view of an excavation supported by a sheet pile retaining wall of rectangular

profile illustrating a jacking method for anchoring the retaining wall,

Figure 2 is a plan view of a jacking assembly shown in Figure 1,

5           Figure 3 is a side sectional view of the jacking assembly taken along the lines X-X in Figure 2,

Figure 4 is a sectional view taken along the lines Y-Y of Figure 3,

10           Figure 5 is a plan view illustrating another means of supporting a jacking boom of the assembly,

Figure 6 is a plan view showing an opposed jacking arrangement,

Figure 7 is a plan view showing a still further jacking arrangement, and

15           Figure 8 is a cross-sectional view taken along the lines X-X of Figure 7.

#### Description of the Preferred Embodiments

The method and apparatus for anchoring a sheet pile retaining wall or diaphragm wall essentially comprises  
20 a jacking boom 10 arranged to house a hydraulic jack 20 and a steel section 30 that is to be jacked into position through an opening 32 in the retaining wall 40. The hydraulic jack 20 is powered by a hydraulic power pack 21 which is a free standing unit which is coupled to the jack  
25 through suitable hydraulic hose attachments 22, 23. The boom 10 comprises a substantial elongate steel member of 'H' or 'I' cross-section with a plate 11 welded across one end. The plate 11 is apertured at four locations 12 and is adapted to fit onto four bolts 13, 14, 15, 16 that are  
30 welded or otherwise secured to the front face 41 of the retaining wall 40. The boom 10 is bolted onto the front face 41 of the retaining wall 40 to be supported in a cantilevered fashion therefrom. The opposite end 17 of the boom is also supported by a ground engaging support 18 that  
35 engages either side of the boom section to support the load of the boom 10 at that end. The boom also includes a

displaceable bearing plate 35 in the form of a rectangular steel plate that can be positioned across the boom as shown in Figures 1 and 2. The boom includes pairs of parallel spaced apart bearing blocks 36, 37, 38, 39 which are in the form of solid square steel bars that are welded onto the steel section of the boom. As shown in Figures 1 and 2, the bearing blocks 36, 37, 38, 39 are equally spaced along the length of the boom and the spacing of the blocks 36, 37, 38, 39 is such that the plate 35 can rest against the blocks and is prevented from longitudinal displacement in one direction along the length of the boom. As shown in Figure 3, the pairs of bearing blocks 36, 37, 38, 39 also act as guides guiding the passage of the steel section 30. The hydraulic jack 20 is positioned with its rear face 24 engaging the bearing plate 35 and its front face or piston 25 engaging the free end of the steel section 30 through the intermediary of a force transfer plate 26.

The steel section 30 that is to be jacked through the opening 32 in the retaining wall 40 into the earth structure can be of a variety of cross-sections but is preferably of circular cross-section in the form of a hollow steel tube. The opening 32 is formed by cutting the steel sheet pile that constitutes the retaining wall prior to the jacking operation. In the case of a diaphragm wall the opening 32 may be formed by drilling or other suitable means. The steel section 30 or anchoring member is preferably in the form of a hollow tube. However, it is envisaged that other sections such as a channel section, I section or H section may also be used as the anchoring member that is jacked into position behind the retaining wall.

The force transfer plate 26 once engaged by the piston 25 of the hydraulic jack 20 engages the end of the steel section 30 which in turn engages the earth behind the retaining wall 40. The resistance of the earth causes the jack 20 to press up against the bearing plate 35 and in the embodiment shown in Figures 1 and 2, the rear face of the

boom 10 acts as a reaction through its association with the bolts 13, 14, 15, 16 on the front face 31 of the retaining wall 40. Thus, as the hydraulic force from the power pack 21 is increased, the piston 25 forces the steel section 30 into the earth forming a plug of compressed earth within the first part of the hollow tube. When the hydraulic piston 25 has completed its stroke, it is then returned to the retracted position at which time the bearing plate 35 is positioned further along the length of the boom against a pair of bearing blocks 37, 38, or 39 adjacent the end 24 of the jack 25. The jack 25 can thus be moved up as the section 30 is inserted into the retaining wall 40. This operation is repeated until the steel section 30 is inserted virtually into the opening 32 in the retaining wall 40. At this stage the nuts can be undone from the bolts 13, 14, 15, 16 on the front face 31 and the boom 10 can be removed for use to install the next steel section.

Although not shown in the drawings it is understood that once the steel section 30 or anchoring member is jacked into position a large bolt (not shown) is welded to the end of the section with the threaded shank facing forwardly. A channel section member is welded above and below the bolt and an apertured bearing plate is positioned on the bolt against the channel section members. A nut is then placed on the end of the bolt and tensioned to secure the anchoring member to the front face 31 of the retaining wall.

The hydraulic power pack 21 is selected to provide hydraulic pressure of up to 10,000 lbs f/in<sup>2</sup> and is capable of operating a 100 Ton hydraulic cylinder at satisfactory speed measured by the length of stroke per minute. The power pack includes control valves which control flow of hydraulic fluid and consequently the operating pressures.

In this embodiment, it is the action of the bolts 13, 14, 15, 16 and the end plate 35 of the boom 10 that effectively give the reaction allowing the jack to

effectively press the steel section 30 into the earth behind the wall 30. Consequently, it is the retaining wall through its bolted association with the boom that provides the reaction member that effects the jacking force. In the  
5 embodiment of Figures 1 to 4 the thrust of the jack 25 is exerted on the jacking boom 10 producing a pushing force onto the bolts 13, 14, 15, 16 which in turn transfer the force to the sheet pile retaining wall 40. During the  
10 jacking process the sheet pile wall 40 is subjected to bending under the pushing action of the jacking boom 10. The force which counters this pushing force comes from the stiffness of the sheet pile section or the diaphragm wall itself and the passive resistance of the earth behind the wall.

15 However, in other embodiments, a different form of reaction may be used and examples of these embodiments are shown in Figures 5, 6, 7 and 8. In Figure 5, the boom extends across opposed retaining walls 40 and 50 so that the end 34 of the boom 10 acts as the reaction member  
20 through its abutting contact with the opposing wall 50. In this case, there is no need to bolt the boom 10 to the forward face 31 of the front wall 40. It is simply supported in a horizontal or slightly inclined manner with the reaction force always being provided by the opposite  
25 retaining wall 50.

In the embodiment shown in Figure 6, a pair of jacks 25a and 25b are located in a coaligned manner with the boom 10 with the hydraulic jacks being mounted opposed to one another but backing on against the reaction plate 35  
30 between the ends of the jacks 25a and 25b. In this case, the boom 10 extends across the gap between opposed retaining walls 40 and 50. It is the abutment of the two jacks 25a and 25b that causes the reaction force and there is no need for the boom 10 to be secured to the front face  
35 of either retaining wall 40 or 50.

In the embodiment shown in Figures 7 and 8, partial excavation takes place within the excavated area

between the retaining walls 40 and 50. By positioning a load distributing bearing plate 60 of substantially large cross-section against the edge of the upper level 51, the boom 10 may be positioned horizontally to be supported about suitable tresses in the lower level 54 with the rear of the boom 10, and in consequence the hydraulic jack 25, abutting the bearing plate 60. The reaction force is then distributed through the bearing plate 60 and the hydraulic jack 25 can be operated to drive the steel section 30 into the earth behind the wall 40. In this embodiment, there is also no need for the boom 10 to be attached to the front face of the retaining wall 40.

It is understood that the boom and jack are usually positioned horizontally, however, it is possible for the boom to work on an incline to the horizontal meaning that the steel section 30 can be driven into the earth behind the retaining wall at an incline to the horizontal.

The method and apparatus described above has the advantage over conventional methods in that there is no need to drill a hole and flush/remove the soil prior to location of the anchoring member. The drilling and flushing of a hole causes a number of problems such as loosening of the soil peripheral to the hole thus adversely affecting the soil properties. The method of the subject application that operates by forcing or jacking in a shaft or steel section has the effect of compressing the soil. The compression of the soil surrounding the shaft improves a number of characteristics of the soil and enhances the strength and integrity of the retaining wall. In situations where the soil is prone to collapse, the drilling technique is very difficult to carry out due to the unstable nature of the soil. This is not a problem with the method described above. Another advantage of the anchoring technique described above is that once the

section has been positioned behind the retaining wall, the characteristic of the anchor is known unlike the more conventional anchor where there is the unknown quantity of the quality of the soil that has been drilled and there is a delay whilst the grouting associated with the steel member of the anchor sets. The conventional methods suffer from the problem that a number of anchors may be positioned before it is realised that they have failed to reach the desired characteristics. When some anchors fail the prescribed tests, it is often too late to put in replacement anchors and thus the correction of these faults is very time consuming and consequently costly.

A very important advantage that flows from the method of the subject application concerns the use of much cheaper machinery. It is envisaged that the method of the subject application is much cheaper than the conventional method. The cost effectiveness of the method relates not only to the simplicity in operation but the high success rate of the anchors in comparison with the many problems that flow from the conventional methods.



Claims

1. A method of anchoring a sheet pile retaining wall or diaphragm wall characterised by the steps of:  
placing a jacking boom (10) against the forward  
5 face (31) of the wall (40),  
placing an elongate anchoring member (30) on the jacking boom (10) with one end adjacent an opening (32) in the wall (40),  
positioning a jacking means (25) between a  
10 reaction surface and the other end of the anchoring member (30), and  
operating the jacking means (25) to push the anchoring member (30) through the opening (32) in the wall (40) and into the earth on the other side of the wall (40).
- 15 2. The method of claim 1 characterised by placing the anchoring member (30) in tension against the retaining wall (40) after the anchoring member (30) has been jacked into position.
- 20 3. The method according to either claim 1 or claim 2 characterised by attaching the boom (10) to the forward face (31) of the wall (40) and causing the jacking means (25) to engage the opposite end of the boom (10) as the reaction surface.
- 25 4. The method according to either claim 1 or claim 2 characterised by placing the boom (10) between two opposed retaining walls (40, 50) with the rearward end of the boom engaging one retaining wall (50) which acts as the reaction surface and operating the jacking means (25) to push the anchoring member (30) through the opening (31) in the  
30 opposite retaining wall (40).
5. The method according to claim 4 characterised by forming openings (31) in both retaining walls (40, 50), placing an anchoring member (30) adjacent each opening



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(31), positioning jacking means (25<sub>a</sub> and 25<sub>b</sub>) back to back against the anchoring members 30 and operating the jacking means (25<sub>a</sub> and 25<sub>b</sub>) to push both anchoring members (30) into the openings (31) and into the earth behind the retaining walls (40, 50).

6. The method according to either claim 1 or 2 wherein the retaining wall borders a tiered excavation, the method being characterised by positioning the boom (10) between one wall (40) and the edge of the upper tier (51), positioning a force distributing plate (60) between the boom (10) and the edge of the tier (51) whereby the reaction surface is the force distributing plate (60).

7. Apparatus for anchoring a sheet pile retaining wall or diaphragm wall according to the method of any one of claims 1 to 6 characterised by a jacking boom (10) adapted to support an elongate anchoring member (30) and jacking means (25), means to operate the jacking means (25) whereby the retaining wall is used as a reaction member so that operation of the jacking means (25) causes the anchoring member (30) to be forced through an opening (31) in the retaining wall (40) into the earth behind the retaining wall (40).



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