

[54] **PANEL CONNECTORS FOR REINFORCED CONCRETE DIAPHRAGM WALLS**

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[22] Filed: **July 24, 1972**

[21] Appl. No.: **274,789**

[30] **Foreign Application Priority Data**

July 29, 1971 Great Britain 35832/71

[52] U.S. Cl. **61/35**

[51] Int. Cl. **E02d 5/20**

[58] Field of Search 61/35, 39, 49, 53, 53.52, 61/53.5, 63; 52/742, 743, 744, 169

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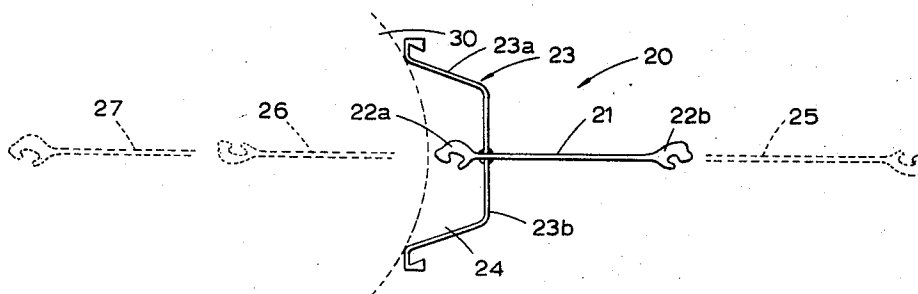
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[57]

ABSTRACT

The invention relates to methods and apparatus for forming reinforced diaphragm walling. According to the invention the wall is formed in stages by casting separately adjacent concrete panels and an excavated trench. Prior to pouring the concrete to form each panel stage, vertical steel pile elements are located in the trench and are inter-engaged to form a reinforcement supporting tension loading longitudinally of the trench. The piles each have at their vertical edges integral clutch means for inter-engagement with adjacent piles. According to the invention the clutch means of a pile element at one end of each panel stage is masked prior to pouring of the concrete whereby said pile element may subsequently have its masked clutch means inter-engaged with a pile element of a next succeeding panel stage. The invention further provides a cruciform shaped pile element for use as the end pile in forming each panel stage.

10 Claims, 5 Drawing Figures



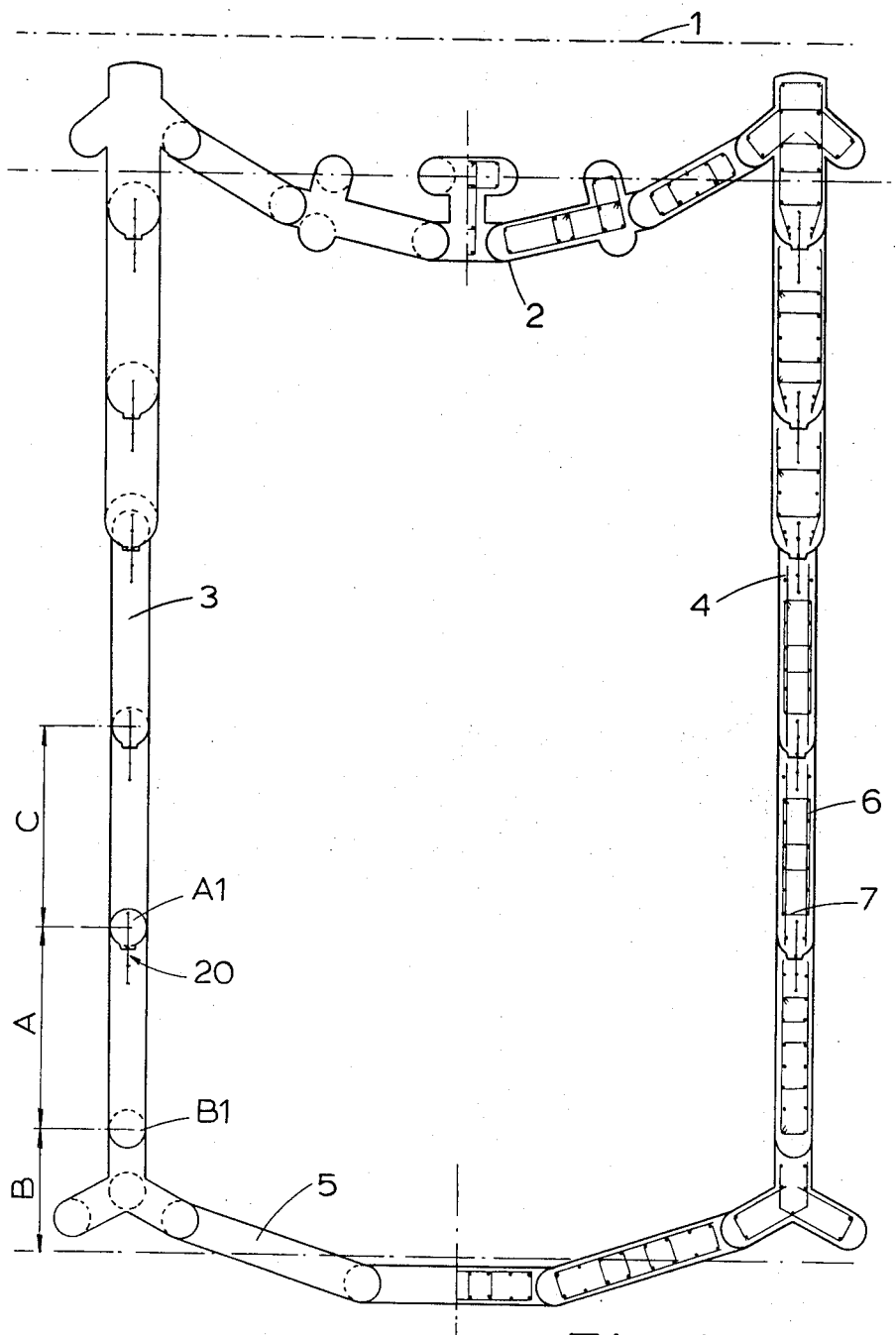


Fig. 1.

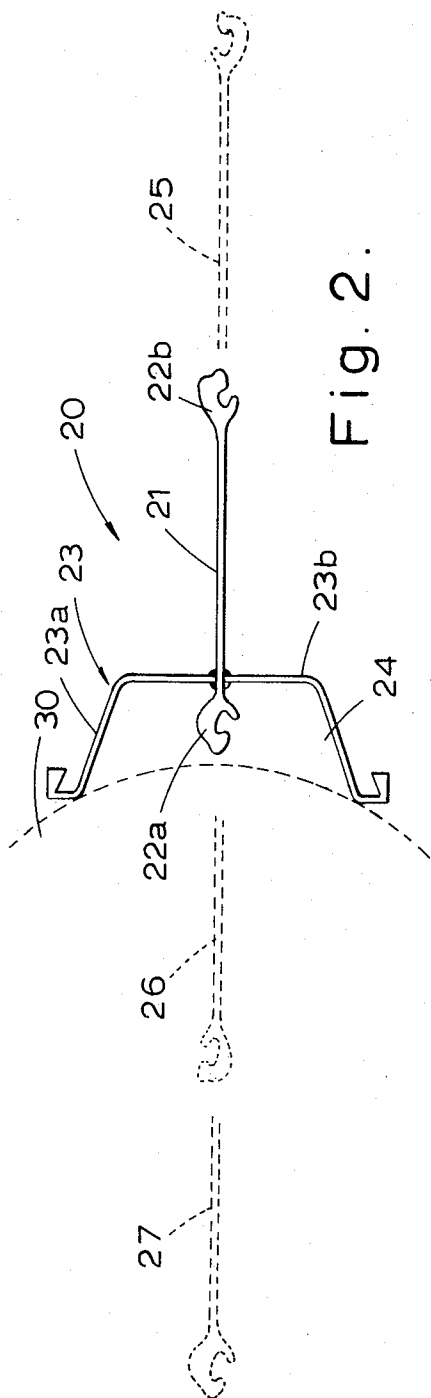


Fig. 2.



Fig. 3.

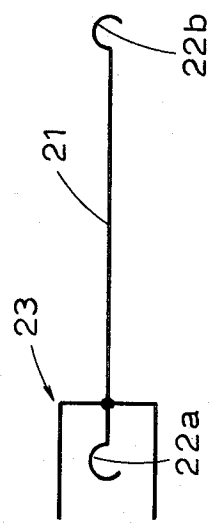


Fig. 4.

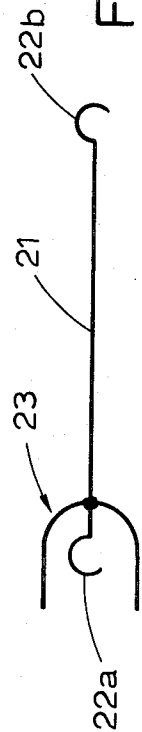


Fig. 5.

PANEL CONNECTORS FOR REINFORCED CONCRETE DIAPHRAGM WALLS

This invention relates to a method of forming a structural connection between adjacent panels of reinforced concrete diaphragm walling formed by the bentonite slurry displacement system of construction.

In the construction of retaining or containment structures it is known to employ large cellular constructions with the cell walls being formed of concrete reinforced by steel sheet vertical piles. In the case of very deep retaining walls it is known for such cells to be formed of diaphragm walls of steel pile reinforced concrete cast in excavated trenches.

In some cases, such cells are formed in part by two parallel walls extending transversely and at right angles from the wall directly bounding the deep excavation and these parallel walls may be stressed in compression by superimposed vertical loads and in tension and shear due to the ground pressures of the material contained and retained by the cell.

The present invention relates particularly to these cell walls and their method of construction, although it may be applied equally to other walls of reinforced concrete formed in deep trenches, by means of the bentonite slurry displacement system which are subjected to similar forces.

Such walls may be of say 0.40 to 1.150 metres in thickness and up to say 45.0 metres in depth, while the completed wall may have a length of 20 metres or more, made up of individual panels, the lengths of which are determined by the excavating equipment.

The usual method of forming this type of construction is to form panels of the wall in stages. Thus a section of trench will be excavated say, 4 metres in length and to the required width and depth using a grab or other suitable equipment, with the bentonite slurry process being employed to retain the stability of the soils forming the sides of the trench. Following this a temporary stop end will be inserted by placing vertically a steel tube at one end of the excavated trench, for its full depth. Following pouring of concrete around a prefabricated cage of steel reinforcement placed in the trench, the stop end tube will be withdrawn as the concrete commences to set. After the concrete has attained sufficient strength, excavation of the next section of trench is begun and the process repeated.

On removal of each stop end, the concrete adjacent the stop end conforms to the latter's shape which is circular and the concrete placed into the adjacent length of trench flows into the concave cavity so that, in the result, the junction somewhat resembles a knuckle joint. However, when using conventional stop ends in this manner there is no structural connection across the joints between adjacent wall panels.

According to the present invention, it is proposed that in a method of constructing a diaphragm wall panel as above described, after the placing of the stop end in the excavated trench section, and prior to placing the concrete into the section, there is included the step of lowering into the trench adjacent the stop end tube a steel panel connector of general cruciform section fabricated from steel sheet piling elements. This comprises a first section of steel straight web pile extending generally longitudinally of the trench, and having at its opposite vertical edges an integral clutch for engaging further piles which may be generally aligned

with it; this first straight web pile is intersected by and welded to a second generally transverse steel element which is of general U-shaped steel pile section with its upright edges defining a concave trough inside which one of the clutches of the first straight web pile is located. The panel connector is so placed that the trough edges of the U-shaped pile are in contact with the stop end tube.

One or more further single straight webbed piles are preferably lowered into the trench in interlocking engagement with the clutch on the first straight web pile on the side of the panel connector remote from the stop end, these further piles having their webs extending generally longitudinally of the trench. Concrete is then placed into the trench to encase these further piles and the major part of the cruciform sectioned panel connector, but leaving the space between the stop end tube and the trough of the cruciform panel connector unfilled.

A bottom plate may be provided to prevent concrete entering the trough from below.

The stop end tube is subsequently withdrawn leaving the straight web pile clutch located in the trough exposed. When the next panel of wall trench section has been excavated the exposed straight web pile clutch may be connected to further straight web piling extending longitudinally of the trench in such next section, and when this further piling has been encased in concrete, the piles connected to the first web of the cruciform section constitute a structural connection across the joint between the adjoining diaphragm wall panels.

Preferably the cruciform pile element is fabricated from conventional and readily available piles. For example, the first web may be an Appleby Frodingham straight web pile and the second transverse web may be a Larssen pile cut longitudinally of its web, with the resultant sections being fillet welded at right angles to opposite sides of the web of the Appleby Frodingham straight web pile adjacent the clutch at one edge of the web of the latter.

The invention will be further described purely by way of example with reference to the accompanying drawings.

In the drawings:

FIG. 1 is a diagrammatic plan view of a cellular structure incorporating a series of interlocking reinforced concrete diaphragm wall panels alongside a deeply excavated shipping berth, while,

FIG. 2 is a plan view to larger scale illustrating the steel joint spanning successive wall panels as provided for in an exemplary embodiment of the present invention.

FIGS. 3, 4 and 5 are diagrammatic plan views of further forms of connector means for use in joining adjacent edges of the panels together.

Referring first to FIG. 1, 1 represents a wharf frontage line of a shipping berth which has been dredged to a depth of say, 30 metres or more below the finished top level of the wharf.

2 generally represents an arched retaining wall alongside the wharf front, the wall 2 being of reinforced concrete cast in an excavated trench of a depth exceeding that of the depth of the wharf front.

The arched retaining wall 2 forms part of the whole cellular structure comprising parallel transverse walls 3 and 4 and a rear arched wall 5. The parallel walls 3 and

4 extend generally at right angles from the wharf front and may be stressed in shear and/or tension due to ground pressures of the soils within and behind the cell. It will be understood that the wharf front 1 is bordered by a large number of cells, one of which is shown by FIG. 1.

The walls of the cell may be of say 0.4 to 1.15 metres in thickness and up to say, 45 metres in depth. As shown in the particular illustration (FIG. 1) the side walls 3 and 4 increase in thickness as they approach the retaining wall 2, but this feature is peculiar to the particular design which forms an illustration of the device. These transverse walls have a length of the order of 20 metres. The wall 4 on the right of FIG. 1 is shown in completed condition and here steel reinforcement for the concrete is indicated generally at 6 and 7. The construction of this wall will be described in detail with reference to the wall 4 on the left of FIG. 1 and with reference also to FIG. 2.

The method of construction is to form the separate panels of the wall in stages. Thus in FIG. 1, panel A of trench of some 4 metres in length and to the required width and depth is excavated, it being assumed that the previous panel indicated at B has already been completed and that a stop-end tube B1 used in the completion of the previous panel has been removed.

After excavating the trench panel A a stop-end A1 comprising a circular steel tube is placed into the end of the trench section whilst bentonite slurry is placed in the remainder of the trench as excavation proceeds to retain the stability of the soils forming the sides of the trench.

According to previously known procedures the next steps would be to place steel reinforcement cages in the trench and then to place concrete to encase the reinforcement up to the stop end A1. The stop end tube would then be withdrawn as the concrete commences to set and follow hardening of the concrete the next panel C of the trench would be excavated and filled with reinforced concrete by a similar process. This would leave a concrete to concrete joint resembling a knuckle joint between the concrete panels A and C and there would be no structural steel connection spanning this joint.

According to the invention, however, before concrete is poured into panel A a cruciform panel connector is placed into the trench in abutment with the stop end A1. This cruciform panel connector is generally represented at 20 in FIG. 1.

One embodiment of such cruciform panel connector is shown by way of example in FIG. 2. This comprises a straight web-tension pile for example a standard Appleby Frodingham straight web pile 21 having at its opposite ends clutches 22a and 22b, by which it may be connected to further identical Appleby Frodingham straight web piles in such manner that webs of the connected piles are substantially aligned. This Appleby Frodingham pile forms a first web of the cruciform panel connector and is disposed generally longitudinally of the excavated trench.

A second or transverse web generally designated 23 is formed by a trough shaped steel pile, for example a Larssen pile as shown, which is cut in two longitudinally down its web and the resultant sections 23a and 23b are then fillet welded at right angles on opposite sides of the web of the Appleby Frodingham straight

web pile 21 adjacent the clutch at one of its edges, in this case the clutch 22a.

The sections 23a and 23b constitute a general U-section forming a concave trough inside which a clutch 22a of the Appleby Frodingham straight web pile is located.

The cruciform panel connector 20 is placed into the excavated trench section so that the flanges of the second transverse steel element 23 abut against the stop end tube indicated at 30 in FIG. 2.

Preferably according to the invention, a further straight webbed pile as indicated at 25 in FIG. 2 is placed into the trench and interlocked with the clutch 22b of the straight web pile 21.

Still further straight web piles may, if desired, be connected to the straight web pile 25 if the design of the wall so warrants. Such piles may have holes cut in them or structural attachments added to increase their embodiment in the concrete.

The construction otherwise proceeds in conventional manner with steel reinforcement being placed in the trench panel under construction and concrete is placed by means of a tremie pipe to encase the steel reinforcement and to displace the bentonite slurry.

The placed concrete encases also the straight web piles 21 and 25 and lies against the arms 23a and 23b of the cruciform panel connector 20, but concrete is at this stage prevented from entering into the trough bounded by the arms 23a and 23b in which the clutch 22a is located. Preferably concrete is prevented from entering the bottom by a steel plate 24 shaped to suit the side of the stop end tube and welded in position across the lower end of the Larssen trough section.

As the concrete commences to set the stop end tube 30 is withdrawn leaving the clutch 22a exposed. Then when the next succeeding trench panel C has been excavated, further straight web pile elements 26 and 27 may be connected to the clutch 22a and it will be appreciated that when the succeeding panel C has been filled with reinforced concrete the straight web piles 27, 26, 21 and 25 will form a structural connection spanning the joint between the concrete in panels C and A in FIG. 1 and will strengthen the interfaces between these separately formed wall panels.

The connector 20 need not be formed of piles having the particular cross sectional shapes shown in FIG. 2. For example the connector may be shaped as illustrated in one of FIGS. 3, 4 or 5.

In these drawings 21 represents the straight webbed pile element adapted to extend longitudinally of the trench and 22a and 22b are the clutches at its opposite vertical edges.

The transverse web 23 may be H-shaped as shown in FIG. 3, of rectangular U-shape as shown in FIG. 4 or of curved U-shape as shown in FIG. 5 but in each case the clutch 22a is located in a trough defined by the transverse web and the arms of the latter are sufficiently extended to abut with a stop-end 30 in such manner as to prevent concrete from entering the trough. The stop-end 30 may be a cylindrical tube or a tube of other section or even a straight webbed pile element located transversely of the trench.

By the present invention improved reinforced concrete retaining structures are achieved, wherein the diaphragm walls are connected structurally by panel connectors which have the properties of transmitting ten-

side and vertical shear forces between adjacent panels.

I claim:

1. A method of constructing a steel pile reinforced concrete diaphragm wall of the kind in which the wall is formed in stages by casting separately, using the bentonite slurry displacement process, adjacent concrete panels in an excavated trench, characterized in that prior to pouring the concrete to form a panel stage, vertical steel pile elements are located in the trench and are interengaged with one another to form a reinforcement adapted to support load in tension in the direction along the trench, the piles each having at their vertical edges clutch means for interengagement with adjacent piles, and including the step of masking the clutch means of a pile element at one end of each panel stage prior to pouring of the concrete, so as to prevent said masked clutch means from becoming embedded in the concrete poured to form that panel stage, and wherein the said end pile element at one end of each panel is cruciform in plan view having a main longitudinal web with clutch means at each of its vertical edges, and with a transverse web of trough shape with the said masked clutch means located between the arms of the trough shaped transverse web, and wherein the cruciform shaped end pile element is placed in the excavated trench with the arms of its trough shaped transverse web in abutment with a stop-end element occupying the full width of the trench and separating that section of trench from a neighboring section.
2. A method of constructing a steel pile reinforced diaphragm wall panel comprising the steps of
 - a. cutting a trench of the required length, depth and width;
 - b. stabilizing the trench walls with bentonite slurry;
 - c. closing off a length of the excavated trench with a stop-end lowered into the trench and extending across its full width;
 - d. lowering into the trench adjacent the stop-end a steel panel connector of general cruciform section in plan;
 - e. said connector extending over substantially the full depth of the trench and having a main sheet steel web extending longitudinally of the trench in the central region of the trench;
 - f. the main longitudinal web, having at its opposite vertical edges integral clutch means for engaging sheet pile elements which may be aligned with it;
 - g. the main longitudinal web member being intersected by a second transverse, sheet-steel web element which is of general trough form in plan view with the edges of the arms of the transverse web being placed in abutment with the stop-end and wherein the clutch at one vertical edge of the main longitudinal web is located in the trough between the arms of the transverse web;
 - h. lowering at least one further straight web sheet pile

element into the trench on the side of the cruciform connector remote from the stop end and engaging clutch means of the further pile element with the clutch means of the cruciform member remote from the stop end;

- i. and pouring concrete into the trench to embed said interconnected pile elements and a major part of the cruciform element, leaving the clutch means between the trough arms unembedded;
- j. following at least partial setting of said concrete, removing the stop end, and engaging a pile element with the clutch disposed in the trough, then
- k. repeating the process to form an adjacent panel, the resultant adjacent panels having interconnected sheet pile webs extending longitudinally of the trench across the joints between said adjacent panels.

3. A method according to the preceding claim 2, wherein the cruciform member has at its lower end and closing the bottom of the trough defined by the transverse sheet metal element, means for preventing ingress of concrete into the lower end of the space defined by the trough.

4. A method according to claim 2, including the step of arranging a structure of reinforcing elements in the trench prior to pouring concrete into the trench.

5. A connecting element for use in the bentonite slurry displacement process of construction of sheet pile reinforced concrete diaphragm walls wherein the wall is formed in stages by casting adjacent panels separately in an excavated trench, comprising a steel member of general cruciform section fabricated from steel sheet piling elements and including a first straight web section having at each of its opposite lateral edges an integral clutch for engaging corresponding clutches of further straight web pile elements which may be arranged alongside, this first straight web section being intersected and welded to a second generally transverse web section, the lateral arms of the second transverse web section defining a trough between which is located one of the clutches of the first straight web section.

6. A connecting element according to claim 5, wherein the first straight web section comprises a standard straight web pile.

7. A connecting element according to claim 5, wherein the second transverse web section comprises a standard trough sectioned pile, split longitudinally into two halves which are welded respectively on opposite sides of the straight web of the first section.

8. A connection element according to claim 6, wherein the straight web pile is an Appleby Frodingham pile.

9. A connection element according to claim 7, wherein the trough sectioned pile is a Larssen pile.

10. A connection element according to claim 5, wherein the trough sectioned pile consists of a pile of H-section.

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