

PATENT SPECIFICATION

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(54) CONSTRUCTION OF DIAPHRAGM WALLS

(71) We, COMAR REG. TRUST, a Liechtenstein body corporate, of Vaduz, Principality of Liechtenstein, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method of *in situ* construction of diaphragm walls and in particular to the formation of joints between successively cast sections of such walls.

Diaphragm walls are concrete walls cast in trenches in the soil and commonly constructed in sections or panels each extending over a limited length of the wall. Initially it is usual to excavate a vertical trench of a width corresponding to that of the wall, of a length of the order of 3 to 6 m and of the full depth of the wall by means of a clamshell or other suitable trenching equipment. Concrete is cast into the trench to form a first section of the wall. The sides of the trench form part of the mould for casting the concrete but at the ends of the trench temporary steel shutters are inserted to the full depth of the trench to create smooth concrete surfaces against which the next section of the wall will be cast.

The main functions of the diaphragm walls are as follows:

(a) as a retaining wall when the earth is removed from one side of the wall, for example when building underground structures such as basements and underground car parks. In this case a diaphragm wall is formed all round the site and the soil inside the wall is removed to the designed depth to enable the structure to be built inside. Another application is in the construction of tunnels for subways or underpasses. In this case two diaphragm walls are installed at the sides of the proposed tunnel, a roof slab is cast across the top of the tunnel between the diaphragm walls, and the soil is removed from under the roof slab.

(b) cutting off underground water when

there is a difference of water level between the two sides of the wall. The typical case is in foundations of dikes and dams to cut off water seepage in pervious strata of soil.

(c) as both retaining wall and water cut off in the case of a soil retaining wall when the excavation on one side of the wall is at a level lower than the water table level at the other side of the wall.

(d) for foundations when building or other structures are founded on diaphragm wall elements.

In order to accomplish the functions for which the structure has been designed, particularly those of earth support and water interception, the vertical joints between the wall sections must fulfil the following requirements:

1) to guarantee an effective key connection capable of withstanding the horizontal shear force which might be acting on the joint as a consequence of different load conditions on the two wall sections and

2) to be watertight.

Accordingly, special attention must be given to the shutters for the concrete.

A known shutter for forming the vertical joint between adjacent wall sections is a circular, tube-like member called a "stop end pipe" having a diameter equal to the width of the trench which has been excavated. Such tube-like member is placed vertically at the location of the end of the wall section to be cast prior to casting of the concrete. Once the casting is completed and the concrete sufficiently hardened, the pipe is withdrawn, leaving a part-circular concavity at the end surfaces of the concrete wall section. When constructing the next adjoining section, concrete will be cast against this surface, thus forming the joint.

In early applications of diaphragm walls, when the wall thickness was rather small, the circular pipe was considered the most appropriate form of shutter because of its capability of withstanding the pressure of the concrete, which in the case of deep

further pin is provided for lug 32 and slot 34, which however is not shown in the drawing.

Each element comprises further holes or openings 40 for receipt of pins or hooks of a pulling-out machine known as such and thus not shown.

The bodies 18 and 19 are hollow steel bodies. They comprise mainly two shaped thick steel plates, of which one steel plate forms the rear main side surface 20 and half of each the secondary side surfaces 26, 27 up to the longitudinal line 41. The other steel plate forms the front surface 21 integrally with the wedge 23 and the second half of the secondary side surfaces 26, 27. These two plates are welded together along a welding seam 41. The body is completed by welding further flat steel plates to the first-mentioned two steel plates, such that the top 29 and the bottom 30, the projecting lugs 31 and 32 and also the slots 33 and 34 are obtained.

The openings or through-holes are drilled at a suitable step during manufacture of the plates or bodies.

In Figs. 7 and 8, which are sections similar to Figs. 1 and 2 respectively, there is shown the casting of the concrete 9 into the trench 1 filled with bentonite slurry 6, using two steel shutters 42 and 43 consisting of a number of coupled shuttering elements of the type shown in Fig. 6.

Referring now to Fig. 5, it has been mentioned earlier that in order to construct the trench section 1 use is made of a clam-shell grab or other trenching equipment, that the steel shutter is then placed and finally the concrete is cast into the trench 1, displacing the bentonite slurry 6 upwards.

In order to obtain now one wall element 9 having a specific final length 43 it is obvious that a much longer length 44 of the trench must be excavated when using a circular steel shutter according to the prior art compared with the reduced length 45 of a trench which is required when using shutters of Figs. 6 to 8.

Fig. 9 shows in horizontal section the joint between two adjacent cast wall sections formed in accordance with the invention. It is obvious, in comparison with the joint shown in Fig. 4, that an effective key capable of transmitting large lateral loads is obtained. Furthermore, the length of the path through the joint from side to side of the wall is almost twice the length obtainable by means of the prior art, such that an effective sealing off of ground water seepage is obtained.

In Fig. 10 there is shown the end section of a wall element 9 after the steel mould has been retrieved and before the excess concrete 46 has been removed. There exists here a sharply defined line 47 up to which the excess concrete will be removed thus

leaving at every joint a well defined form of the face of the wall segment 9.

The triangular shape of the projection 23 and therewith obtained joint as shown in Fig. 9 corresponds to the maximum shear resistance obtainable, taking the quality and the homogeneity of the concrete cast under bentonite slurry into consideration.

As shown in Fig. 11 the width of the base 49 of the triangular projection is about half the thickness of the wall and such a joint is suitable for medium loads. When smaller lateral forces are expected the length of the base 49 can be reduced, as shown in Fig. 12. For larger lateral forces the base 49 can be as shown in Fig. 13. The shear resistance of the joint is increased by means of adequate steel reinforcements shown in Fig. 13 installed in the wall elements, whereby the contour of the joint allows placing of the steel bars extending into the joint itself whereby such bars can overlap at the joints, relative to the longitudinal extension of the walls.

The thickness of each shuttering element is very small in comparison with the circular pipe diameter. That is to say the dimension of the shutter element in the longitudinal direction of the wall is less than the width of the trench. Nevertheless the new shutter will, due to its particular form, have a sufficient rigidity to keep the deflection of the shutter due to concrete pressures within acceptable limits. The rigidity of the form, resulting from the said particular shape, is comparable with the rigidity of the circular pipe.

After pulling out of the mould when one wall section is sufficiently hard (see Fig. 10), there exists at the face of the wall element 9 a void space 48 of such dimensions as to be an efficient guide for the clamshell grab during excavation of the adjacent wall element and to improve the progress of the excavation. Moreover, due to the particular shape of the face, an efficient guide for the clamshell grab is provided.

Figs. 14A and 14B show the end portion of the wall element 55 in the two cases of a vertical joint formed according to the prior art and according to the invention, in each case with an abnormal quantity of concrete surrounding the shutter space due to soil cavitation in the vicinity of the joint.

In the case of the prior art (Fig. 14A) during excavation of the next element 56, the excess concrete may break, for example, along the lines 53 and 54. This will give rise to a deviation of the wall element 56 during its excavation from the theoretical axis 57 to the position 58.

In the case of the invention (Fig. 14B), during the excavation of the adjacent panel

56, the excess concrete will break off course along lines 51 or 52, starting at the corners of the shutter space, in both cases allowing the construction of the adjacent panel 56 in its exact position.

In Fig. 15A is shown the cross-section of a shutter element which is normally adopted for use in the method of the invention in the case of a wall thickness exceeding 1.00 m. In this case two triangular projections are adopted.

In Fig. 15B is shown a detail of the internal reinforcing plates (60) which provide the shutter element with the rigidity that is required to withstand the pressure of the concrete.

WHAT WE CLAIM IS:—

1. A method of *in situ* construction of diaphragm walls in which a trench is excavated in sections and concrete is cast into each section before the next section is excavated, at least one end of each trench section containing a shutter to form a recess in the end of the cast wall section, the adjacent wall section being cast into the recess in order to form a joint between the wall sections after withdrawal of the shutter, characterized in that the shutter is formed by at least one metal shuttering member in the form of a prism of generally rectangular section with a projection on one face to form the recess in the end of the wall section, the projection being spaced from the sides of the trench and the shuttering member having an overall dimension in the direction of the length of the wall which is less than its width in the direction between the sides of the trench.

2. A method as claimed in claim 1 in which the projection is triangular as seen in plan.

3. A method as claimed in claim 1 or 2 in which the or each shuttering member has two similar projections on the same face arranged symmetrically on opposite sides of the central plane parallel to the sides of the trench.

4. A method as claimed in any of claims 1

to 3 in which the or each shuttering member is a hollow steel body.

5. A method as claimed in any of the preceding claims in which each shutter is composed of a plurality of identical shuttering members stacked one on top of the other and coupled together in such a way that the shutter can be raised as a unit by lifting the top shuttering member.

6. A method as claimed in claim 5 in which each of the shuttering members has at least one lug extending upward from its top surface and a slot in its bottom surface to engage over the lug of the shuttering member below it in the stack.

7. A method as claimed in claim 6 in which each shuttering member has two lugs extending upward from its top surface and two corresponding slots in its bottom surface.

8. A method as claimed in claim 7 in which the two lugs lie in a plane parallel to the two larger faces of the shuttering member and are disposed near the opposite faces of the shuttering member which abut the walls of the trench.

9. A method as claimed in claim 6, 7 or 8 in which the shuttering members are coupled by pins extending through apertures in the lugs and in the structure on each side of the slot.

10. A method as claimed in any of claims 5 to 9 in which each shuttering member has through holes extending between its larger faces to receive pins of a lifting mechanism to raise the shutter from the trench.

11. A method as claimed in claim 5 in which each shuttering member has a form substantially as described with reference to Fig. 6 of the accompanying drawings.

12. A method of *in situ* construction of diaphragm walls substantially as described with reference to Figs. 6 to 9 of the accompanying drawings.

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In Fig. 15A is shown the cross-section of a shutter element which is normally adopted for use in the method of the invention in the case of a wall thickness exceeding 1.00 m. In this case two triangular projections are adopted.

In Fig. 15B is shown a detail of the internal reinforcing plates (60) which provide the shutter element with the rigidity that is required to withstand the pressure of the concrete.

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1. A method of *in situ* construction of diaphragm walls in which a trench is excavated in sections and concrete is cast into each section before the next section is excavated, at least one end of each trench section containing a shutter to form a recess in the end of the cast wall section, the adjacent wall section being cast into the recess in order to form a joint between the wall sections after withdrawal of the shutter, characterized in that the shutter is formed by at least one metal shuttering member in the form of a prism of generally rectangular section with a projection on one face to form the recess in the end of the wall section, the projection being spaced from the sides of the trench and the shuttering member having an overall dimension in the direction of the length of the wall which is less than its width in the direction between the sides of the trench.

2. A method as claimed in claim 1 in which the projection is triangular as seen in plan.

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5. A method as claimed in any of the preceding claims in which each shutter is composed of a plurality of identical shuttering members stacked one on top of the other and coupled together in such a way that the shutter can be raised as a unit by lifting the top shuttering member.

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