

"Connector"

Field of the Invention

This invention relates to a panel connector, a panel incorporating such a connector and an assembly of such panels.

The invention has been devised in particular, though not necessarily solely, for sheet piling to facilitate interconnection of sheet piling elements to form a sheet piling assembly.

Background Art

A sheet pile's main function is to withstand sideways loading. Sheet piles are thus used to form retaining walls in various applications, including basement excavations, underground car parks, and cofferdams. Sheet piles may also be used in forming level roadways on embankments or for stabilising slope failures.

An advantage of sheet piles is that, owing to their relatively small cross sectional area, they may be driven into the ground either by means of a drop hammer or a vibratory hammer. Sheet piles, if adequate for a particular application, are often preferable to alternative forms of retaining wall which include contiguous bore piles, soldier bore piles with lagging and diaphragm walls. Use of sheet piles eliminates time consuming and costly site preparation work associated with the use of such alternatives and significantly reduces material costs.

Numerous difficulties may be encountered during manufacture and/or assembly of many existing types of sheet piling.

One such difficulty may arise during driving. Sheet piles are driven into the earth one by one, the sheet pile being driven being interconnected with an

adjacent sheet pile driven before it. The end of the pile being driven may encounter changes in earth hardness or inclusions such as rocks and pebbles, which can cause it to deflect, thereby subjecting the connection it forms with the adjacent sheet pile to complex loading. Such loading may be in directions the connection is not equipped to cope with. This problem in particular may be encountered where the sheet piles have been cold rolled because such sheet piles can be provided only with relatively simple shaped connectors able to permit substantially unidirectional loading. Loading of the connectors of sheet piles in a direction with which they are not equipped to cope, particularly during driving, can cause the connections to jam. Where the loading is sufficiently high, the connectors may fail, by unhooking and/or deformation, thus causing the sheet piles to become disconnected.

The stiffness of a sheet pile assembly is largely related to its cross sectional depth in the direction of loading. For heavy duty applications, an assembly of sheet piles must be sufficiently deep in cross section to have the requisite stiffness to withstand the high sideways loads. Where sheet piles in the assembly are identical, this requires either that they individually have sufficient cross sectional depth or that they be able to be arranged at various angles with respect to each other in an assembly whilst still being able to transfer shear between each other in service. Conventional cold rolled sheet piles, as a result of the directional loading constraints on their connectors, must therefore be provided with differing cross sectional configurations. The need for more than one type of cold rolled sheet pile thus creates manufacturing complexity. Also, the abovementioned risks of jamming and disconnection during driving remain.

Some tolerance to misalignment during driving can be achieved by separate hot rolling manufacture of more elaborate connections which also are able to cope at least with a degree of the associated complex loading discussed above.

WO 00/08263 (Horan et al.) discloses a metal sheet pile which comprises a cold formed wall section of sheet material to the longitudinally extending side edges of which are secured hot formed clutch sections. The hot formed clutch sections may be produced by hot rolling or extrusion and must be secured to the cold formed wall sections by welding, bolting, riveting or other means. The requirement that these clutch sections be separately hot rolled represents a significant drawback because of the very high production costs associated with hot rolling. Hot rolling requires complex and extremely expensive plants and infrastructure. It is therefore not economical to produce hot rolled items in small volumes.

Furthermore, the need to manufacture the clutches separately and then fix them to the sheet pile side walls introduces manufacturing complexity and further expense.

The preceding discussion of the background to the invention is intended only to facilitate an understanding of the present invention. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was part of the common general knowledge in Australia or elsewhere as at the priority date of the application.

Disclosure of the Invention

In accordance with one aspect of the present invention, there is provided a panel connector for interconnecting adjacent panels, wherein the panels have one or more flanges each having an edge, the connector comprising a portion of sheet material arranged to extend from the edge of the panel with a curved profile having an inner end adjacent the edge of the panel and an outer end, such that in transverse cross section, said curved profile includes:

a first portion extending from the inner end in a generally elliptical path; and

a second portion extending from the first portion to the outer end, the second portion curving inwardly from the generally elliptical path;

wherein the curved profile of the connector curves through at least 360 degrees, and the second portion defines an opening between the inner end and the outer end to receive a portion of a further connector on an adjacent panel of the same shape as said connector by longitudinally sliding the further connector within said connector.

It is a feature of the invention that when a load is applied to a pair of interengaged connectors, portions of an inner face of one connector engage with opposed portions of an outer face of the other connector and vice versa to cause the connectors to bindingly lock against each other to prevent disconnection. The engagement of portions of the inner face of one connector with opposed portions of the outer face of the other connector under the tensile load causes deformation of the connectors to increase the degree of engagement between the opposed inner and outer faces which serves to further resist separation of the connectors.

When a torsional load is applied to the connection, portions of the opposed inner and outer faces of the connectors bind to interlock the connectors and thus to prevent disengagement.

The invention will be more fully understood in the light of the following description of one specific embodiment.

Brief Description of the Drawings

The description is made with reference to the accompanying drawings of which:

Figure 1A is a front perspective view of a sheet pile according to the embodiment;

Figure 1B is a first side perspective view of the sheet pile of Figure 1;

Figure 1C is a rear perspective view of the sheet pile of Figure 1;

Figure 1D is a second side perspective view of the sheet pile of Figure 1;

Figure 2A is an end view of the sheet pile of Figure 1 as seen from its first end;

Figure 2B is an end view of the sheet pile of Figure 1 as seen from its second end;

Figure 2C is a detail view of a connector provided on one flange of the sheet pile of Figure 1;

Figure 2D is a detail view of a connector provided on the other flange of the sheet pile of Figure 1;

Figure 3A is a plan view of an assembly of sheet piles according to the embodiment;

Figure 3B is a detailed view of one form of connection formed between a pair of adjacent sheet piles according to the embodiment;

Figure 3C is a detailed view of another form of connection between a pair of adjacent sheet piles according to the embodiment;

Figure 4 is a perspective view of the sheet pile assembly shown in Figure 3A;

Figure 5A is a schematic perspective view of an assembly of sheet piles as shown at figures 3 and 4 driven into a slope;

Figure 5B is a schematic perspective view of the sheet pile assembly of Figure 5A in service;

Figure 6 is a perspective view of the sheet pile assembly of Figures 5A and 5B showing the assembly engaging the earth into which it has been installed;

Figure 7A is a detail end view of the connection of Figure 3B when unloaded;

Figure 7B is a detail end view of the connection of Figure 3B with the connected sheet piles rotated with respect to each other into a first end position;

Figure 7C is a detail end view of the connection as shown in Figure 3B with the connected sheet piles rotated with respect to each other into a second end position;

Figure 7D is a detail end view of the connection as shown in Figure 3B when in tension;

Figure 7E is a detail end view of the connection as shown in Figure 3B when in compression;

Figure 8A is a detail end view of the connection as shown in Figure 3C when unloaded;

Figure 8B is a detail end view of the connection as shown in Figure 3C but with the connected sheet piles rotated with respect to each other to a first end position;

Figure 8C is a detail end view of the connection as shown in Figure 3C but with the connected sheet piles rotated with respect to each other into a second end position;

Figure 8D is a detail end view of the connection as shown in Figure 3C when in tension;

Figure 8E is a detail end view of the connection as shown in Figure 3C when in compression;

Figure 9A is an end view showing the possible end positions of sheet piles connected as shown at Figure 3B;

Figure 9B is an end view showing the possible extreme orientations of sheet piles connected as shown at Figure 3C;

Figure 10A is an end view of a closed assembly formed by three sheet piles according to the embodiment;

Figure 10B is an open assembly formed by three sheet piles according to the embodiment;

Figure 11A is an end view of the sheet pile according to the embodiment with ends of its flanges bent outwardly;

Figure 11B is an end view of an assembly of sheet piles of the type shown in Figure 11A;

Figure 12 is an end view of a closed assembly formed by six sheet piles with their flanges bent outwardly but to a lesser extent than as shown in Figure 11A (also showing the cross sectional configuration of the sheet piles in the assembly);

Figure 13 is an end view of a closed sheet pile assembly comprising five sheet piles having their flanges bent outwardly to a lesser extent than as shown in Figure 12 (also showing the cross sectional configuration of the sheet piles in the assembly).

Figure 14 is an end view of a closed sheet pile assembly comprising four sheet piles having their flanges bent outwardly to a lesser extent than as

shown in Figure 13 (also showing the cross sectional configuration of the sheet piles in the assembly).

Detailed Description of the Specific Embodiment

The panel according to the specific embodiment is a sheet pile 1, generally shown at Figures 1A to 1D, and in particular a thin walled sheet pile. The sheet pile 1 according to the embodiment is formed of a resiliently flexible material and, in particular, cold rolled from metal plate such as mild steel plate.

The sheet pile 1 according to the embodiment comprises a main body in the form of a channel section. The main body 2 (shown at Figures 2A and 2B) comprises a web 3 and opposed flanges 5 and 7 extending from the web to edges 6 and 8 respectively. The flanges 5 and 7 diverge from the web 3 to give the main body 2 a generally W-shaped configuration and thus to afford the sheet pile 1 increased transverse stiffness.

The edges 6 and 8 of the main body 2 according to the embodiment are substantially parallel.

In this embodiment, a middle portion of the web 3 is offset from the general plane of the web in the direction of the main body 2 to form a corrugation 4. The purpose of the corrugation 4 is to increase further the transverse stiffness of the sheet pile 1.

It is preferable that the transverse cross sectional configuration of the main body 2 be symmetrical. This is to give the main body 2 a centre of mass which is substantially coincident with its centre of shear, thereby to minimise torsional loading on the sheet pile 1 when in service.

Connectors 9 and 11 are located at the edges 6 and 8 of the flanges 5 and 7 respectively. Preferably the connectors 9 and 11 are formed integrally with the main body 2 as is the case with this embodiment.

The connectors 9 and 11, shown in detail at Figures 2C and 2D respectively, are of corresponding form, each having a curved profile.

The connector 9 has an inner end 10 located at the edge 6 of the main body 2. The connector 9 also has an outer end 14. The curved profile of the connector 9 defines a partially enclosed space 18 which is non-circular. In particular, the partially enclosed space 18 is generally elliptical. An opening 22 is defined between the inner and outer ends of the connector 9. The connector 9 has an inner face 19 and an outer face 21.

Correspondingly, the connector 11 is provided with an inner end 12 located at the edge 8 of the main body 2. The connector 11 has an outer end 16. The curved profile of the connector 11 also defines a partially enclosed space 20 which is generally elliptical. An opening 24 is defined between the inner and outer ends of the connector 11. The connector 11 also has inner and faces 25 and 27 respectively.

The connector 9 is also provided with a neck 17. The curvature of the neck 17 is opposite in sense to that of the curved profile 13 such that portions of the connector 9 are disposed to either side of a plane passing through the flange 5.

Correspondingly, the connector 11 is provided with a neck 23. The curvature of the neck 23 is opposite in sense to that of the curved profile 15, again such that portions of the connector 11 are disposed to either side of a plane passing through the flange 7.

As will become further apparent, the effect of the disposal of portions of the connectors 9 and 11 to either side of the edges 6 and 8 respectively is to

reduce the cantilevering effect about the edges 6 and 8 when the respective connectors 9 and 11 are loaded in a transverse plane in operation.

The curved profile 13 of the connector 9 includes a first portion and a second portion. The first portion extends from the inner end 10 of the connector 9 and follows a generally elliptical path, as can be seen in Figures 2c and 2d. The first portion extends from the neck 17 along the generally elliptical path until at least a point where the path is directed back towards and parallel to the plane of the flange 5. The second portion extends from the first portion to the outer end 14. The second portion curves inwardly from the generally elliptical path to define the opening 22. The curved profile 13 curves through at least 360 degrees. Further, a central axis of the elliptical path parallel to the plane of the flange 5 but is offset in the direction that the next 23. As can be seen in the embodiment shown in the Figures, said central axis parallel to the plane of the flange 5 is the major axis of the elliptical path.

The curved profile 15 of the connector 11 is the same shape as the curved profile 13 of the connector 9.

As mentioned previously, the connectors 9 and 11 are formed integrally with the main body 2, the inner ends 10 and 12 thus being coincident with edges 6 and 8 respectively. In an alternative embodiment, the connectors 9 and 11 may be formed separately from the main body 2 and attached at edges 6 and 8 by conventional fixing means.

As shown at Figures 2A and 2B, the opening 22 of connector 9 is located facing the main body 2 while the opening 24 of the other connector 11 faces away from the main body 2, the connectors 9 and 11 thus extending from edges 6 and 8 respectively of the main body 2 in the same rotational directions (shown as clockwise in Figures 2C and 2D). This allows the sheet pile 1 to be connected with a like sheet pile in two alternative ways, as will be described later.

In an alternative embodiment, where the sheet pile is intended to be connected to only one other sheet pile, a connector may be provided at only one of the edges 6 and 8.

As shown at Figures 2A and 2B, the connectors 9 and 11 in the case of this embodiment are small relative to the main body 2 so as to upset as little as possible the symmetry of the sheet pile 1, thus ensuring the centre of mass of the sheet pile 1 is close to the centre of shear of the sheet pile 1.

Each of the connectors 9 and 11 is interconnectable with the connector of a like sheet pile to form a connection adjoining the sheet piles wherein portions of the inner face of one connector are adapted to engage with opposed portions of the outer faces of the other connector and vice versa under load to cause the interconnected connectors to bindingly lock against each other to prevent disconnection of the sheet piles.

The curved profiles 13 and 15 of the connectors 9 and 11 respectively are such that the sheet pile 1 may be formed in its entirety and as a single piece from a single sheet of material through a cold forming procedure such as cold rolling. This is because the thickness of the sheet pile is uniform throughout. This is most advantageous because it allows for the connectors 9 and 11 to be integral with the main body 2 of the sheet pile 11 as is the case for this embodiment, thus eliminating the need for separate manufacture of the connectors 9 and 11 as well as the need to bolt, weld, rivet, or otherwise connect the connectors 9 and 11 to the flanges 5 and 7 respectively.

Shown in plan at Figure 3A, is an example assembly 30 of sheet piles of the type shown in the preceding figures. Each of partially enclosed spaces 18 and 20 of connectors 11 and 13 respectively is configured and dimensioned to longitudinally receive another connector of corresponding form.

Each of the sheet piles 1 in the assembly 30 is connected to an adjacent sheet pile 1 by either a type-A connection 31 as shown in Figure 3B or a type-B connection 33 as shown in Figure 3C. The assembly 30, to be utilised for typical sheet piling applications, would be assembled by driving each component sheet pile 1 into the ground one after another. This is achieved by interconnecting the connector of an inserted pile, at its upper end, with the connector of the next pile to be inserted, at its lower end, to form a connection in the direction of which the next sheet pile is driven into the ground.

The connection must be able to tolerate complicated and heavy loading encountered by the sheet pile 1 during driving. Such loading is complicated for numerous reasons. In particular, where the end of a sheet pile encounters a change in the hardness of the earth through which it is being driven (such as at a boundary between sand and clay or due to an inclusion such as a rock), the effect may be to deform the driven sheet pile in a way which causes torsion, tension, compression, or particular combinations of such loads, at the type-A connection 31 or type-B connection 33. As will be shown later, each of connections 31 and 33 is able to withstand considerable tensile and compressive loads as well as to allow the interconnected piles to rotate with respect to each other about a longitudinal axis of the interengaged connectors in response to a load which would otherwise subject the connection 31 or 33 to a torsional stress.

The type-A connection 31 as shown in Figure 3B is characterised by interconnection of like connectors; that is, by interconnection of connector 9 on one sheet pile and connector 9 on the other sheet pile or alternatively interconnection of connector 11 on one sheet pile and connector 11 on the other sheet pile (the latter being as shown in Figure 3B). It can be seen in the type-A connection as shown in Figure 3B that the flanges 7 of the connected sheet piles are approximately 180° apart.

The type-B connection 33 is characterised by interconnection of opposite connectors. This is illustrated at Figure 3C where the interconnection is between connector 11 on one sheet pile connector 9 on the connecting sheet pile. It can be seen that the flange 7 is approximately 142° in a clockwise direction from flange 5.

It should be noted that the connections 31 and 33, as shown at Figures 3B and 3C respectively, reflect the arrangement of the connectors above ground. Below ground level, earth will typically occupy the area between the connectors and may become compressed between opposed inner and outer faces of the connectors in a loaded situation. However, the requisite load transfer between the connectors in the connections 31 and 33 may still be achieved in such conditions.

The detail of the connections 31 and 33 will be discussed further later, and with reference to Figures 7A to 7D and 8A to 8E.

A perspective view of the assembly 30 depicted in Figure 3A is shown in Figure 4. The length of the sheet piles is typically 12 to 15 metres for heavy duty retaining wall applications. However, in general, the sheet pile may vary in length from 2 metres to 20 metres. The thickness of the sheet pile may vary from 3 millimetres to 20 millimetres, though typically will fall within the range of 6 to 12 millimetres for thick-walled sheet piles and 4 to 6 millimetres for thin-walled sheet piles such as that according to this embodiment.

Figure 5A provides a schematic perspective view of the assembly 30 as formed by driving the sheet pile members one by one into the side of a slope 40. Figure 5B depicts the assembly 30 then supporting a backfill 41, thus acting as a retaining wall. The assembly 30 may be capped with pile capping 43 to create useful area above the sheet piles such as is known in the art.

As will be described below, the connections 31 and 33 are able to allow the interconnected piles to rotate with respect to each other about a longitudinal axis of the interengaged connectors. This feature provides for an ability to create sheet pile assemblies having various cross sectional configurations and high section moduli, as well as providing interconnected adjacent sheet piles with an improved capacity to tolerate angular misalignment during driving without jamming or disconnecting.

A further detail view of the type-A connection 31 is shown at Figure 7A. It can be seen that the connection 31 is able to allow the respective inner faces 25 of each of the connectors 11 to move more closely together along an axis generally transverse to the plane defined by the flanges 7, and thus able to permit limited relative transverse movement between the connectors 11.

It can also be seen in Figure 7A that, if the inner faces 25 are moved slightly more closely together, in the manner described above, the connectors 11 will no longer be in physical contact and the connection 31 thus becomes able to permit relative transverse movement between the connectors 11 along a plurality of axes transverse to the longitudinal axis of the edges 8.

The ability of the connection 31 to permit limited relative transverse movement between the connectors 11 may assist in tolerating translational misalignment in a generally transverse plane during driving and thus also can help to prevent jamming of one connector with the other connector in the type-A connection 31 as well as possible damage to the type-A connection 31 which might otherwise result therefrom.

As shown at Figure 7B the sheet pile on the right of the type-A connection 31 may be rotated, relative to the sheet pile on the left of the type-A connection 31, through a maximum of approximately 41° in an anticlockwise direction, about a longitudinal axis of the interengaged connectors, from the position it occupies as shown at Figure 7A.

As shown at Figure 7C, the sheet pile on the right of the type-A connection 31 may be rotated, relative to the sheet pile on the left of the type-A connection 31, through a maximum of approximately 24° in a clockwise direction, about a longitudinal axis of the interengaged connectors, from the position it occupies as shown at Figure 7A.

Under the action of a torsional load, further relative rotation of the sheet piles beyond the maximum angular orientations shown in Figures 7B and 7C is precluded because the generally elliptical shape of the curved profiles 15 result in portions of the opposed faces of the connectors binding to interlock the connectors. This binding action also helps prevent disengagement.

A detail view of the type-A connection 31 in tension is shown at Figure 7D. Portions of the inner face of one connector engage with opposed portions of the outer face of the other connector and vice versa under load to cause the connectors to bind and thus to lock against each other to prevent disconnection. A detail view of the type-A connection 31 in compression is shown at Figure 7E. Portions of the inner face of one connector engage with opposed portions of the outer face of the other connector and vice versa under load to cause the connectors to bind and thus to lock against each other to prevent disconnection.

As described previously, the central axis of the elliptical path of each of the connectors 9 and 11 parallel to the flanges 7 is offset in the direction of the neck 23. In the configuration shown in Figures 7d and 7e, the central axis of the elliptical paths of each of the connectors 11 are therefore generally aligned and located between the planes defined by the flanges 7. This has the effect that when under compression as shown in Figure 7e, the connectors 9 and 11 tend to rotate inwardly and bind together, rather than rotate outwardly and open up, which would cause disengagement of the connectors 11.

Further, during this compression, due to the curved profile extending through 360 degrees, the second portion of the connector 11 is forced into engagement with the inner face of the other connector 11 adjacent the point where the outer face of the other connector 11 engages with the inner face of the connector 11 adjacent the neck 23. The same type of engagement occurs at the second portion of the connector 11 resulting in the connectors 11 engaging and binding at more than two points (in this case at four points). This engagement allows significant force to be transferred across the connectors 9 and 11 in this type of engagement. As can be seen in Figures 3a, the orientation of the connection of this type is generally transverse to the plane of the sheet pile assembly, requiring it to be sufficiently resistant to such forces.

A further detail view of the type-B connection 33 is shown at Figure 8A. There is little or no relative transverse movement possible between the connectors 11 though this is merely a consequence of the angular orientation of the interconnecting sheet piles in the example assembly shown in Figure 3A. If the sheet piles are rotated relative to each other so as to bring the general planes of interconnected flanges 5 and 7 more closely into alignment, the respective inner faces 19 and 25 become able to move more closely together along an axis generally transverse to the flanges 5 and 7, and thus able to permit limited relative transverse movement between the connectors 9 and 11 respectively. If the inner faces 19 and 25 are then moved slightly more closely together, in the manner just described, the connectors 9 and 11 will no longer be in physical contact and the connection 33 thus becomes able to permit relative transverse movement between the connectors 9 and 11 along a plurality of axes transverse to the edges 6 and 8.

The ability of the connection 33 to permit limited relative transverse movement between the connectors 9 and 11 may assist in tolerating translational misalignment in a generally transverse plane during driving and thus also can help to prevent jamming of one connector with the other connector in the type-

B connection 33 as well as possible damage to the type-B connection 33 which might otherwise result therefrom.

As shown at Figure 8B the sheet pile on the right of the type-B connection 33 may be rotated, relative to the sheet pile on the left of the type-B connection 33, through a maximum of approximately 4° in an anticlockwise direction, about a longitudinal axis of the interengaged connectors, from the position it occupies as shown at Figure 8A.

As shown at Figure 8C, the sheet pile on the right of the type-B connection 33 may be rotated, relative to the sheet pile on the left of the type-B connection 33, through a maximum of approximately 61° in a clockwise direction, about a longitudinal axis of the interengaged connectors, from the position it occupies as shown at Figure 8A.

Under the action of a torsional load, further relative rotation of the sheet piles beyond the maximum angular orientations shown in Figures 8B and 8C is precluded due to the generally elliptical shape of the curved profile causing portions of the opposed faces of the connectors to bind to interlock the connectors. This binding action also helps prevent disengagement.

A detail view of the type-B connection 33 in tension is shown at Figure 8D. Portions of the inner faces of one connector engage with opposed portions of the outer faces of the other connector and vice versa under load to cause the connectors to bind and thus to lock against each other to prevent disconnection in a manner similar to that described for the type-A connection 31. A detail view of the type-B connection 33 in compression is shown at Figure 8E. Portions of the inner faces of one connector engage with opposed portions of the outer faces of the other connector and vice versa under load to cause the connectors to bind and thus to lock against each other to prevent disconnection in a manner similar to that described for the type-A connection 31. Figure 9A shows the orientations of the sheet piles about type-A

connection 31, as depicted Figures 7A, 7B and 7C, superimposed. Correspondingly, Figure 9B shows the orientations of the sheet piles about type-B connection 33, as depicted Figures 8A, 8B and 8C, superimposed.

It is a feature of the connectors 9 and 11 that opposing faces of the interconnecting connectors are able to bind and thus to lock against each other in response to a tensile or compressive load applied to either connection 31 or 33, with the connected sheet piles adopting any orientation between and including the extreme orientations thereby to prevent disconnection. The connections 31 and 33 are thus able to transfer shear thereacross, in both compression and tension, in a wide variety of assemblies, the assembly 30 shown at Figure 3A, being only one example of many. Owing to this ability, the connections 31 and 33 may be subjected to complex loading without failing. Assemblies with relatively deep cross sectional configurations therefore have high associated section moduli and are thus able to be used in heavy duty retaining wall applications.

As best illustrated at Figures 7D, 7E and 8D, it is a further feature of each of connectors 9 and 11 that, for particular orientations of the sheet piles within the ranges illustrated in Figures 9A and 9B, engagement of portions of the inner faces thereof with opposed portions of the outer faces of the other connector and vice versa occurs at both sides of the general plane of each flange adjacent the connection. This is a consequence of the provision of the necks 17 and 23 which causes the curved profiles 13 and 15 respectively to be almost centred about the general planes of the respective flanges 5 and 7 with which they are associated. With this configuration, the bending moments, about each neck, caused by such engagement can be in opposite rotational directions and the resultant cantilever effect about the respective necks may thus be small.

As mentioned above, the ability of the connections 31 and 33 to permit relative rotation of the interconnected sheet piles about a longitudinal axis of

the interengaged connectors allows for the formation of sheet pile assemblies having variable cross sectional configurations wherein adjacent sheet piles are positioned at various angles. An example of such an assembly is the assembly 30 shown at Figure 3A. In particular, it is possible to create sheet pile assemblies with deep cross sectional configurations and therefore high section moduli. The variability of the cross sectional configuration of an assembly is further increased as a result of the ability for sheet piles to be connected to form either of the two alternative types of connection, type-A or type-B.

An advantage owing to both the ability of the sheet pile 1 to be assembled in two different ways, i.e. connected by either type-A or type-B connections, and the ability of each of those types of connection to permit relative rotation of the interconnected sheet piles about a longitudinal axis of the interengaged connectors, is that significant variability in the cross sectional configuration of an assembly can be achieved using identical sheet piles of the type having the configuration of the sheet pile described. This advantage in particular simplifies the manufacturing process.

In addition to the assembly 30 shown at Figure 3A, which has a large section modulus whilst comprising connections 31 and 33 having an ability to transfer shear thereacross, closed assemblies such as the assembly 45, shown at Figure 10A, formed by three sheet piles 1 interconnected by connection types 33 are also possible. Such closed assemblies may be used in more specialised applications, such as cofferdams and caissons wells.

Whilst the sheet piles 1 may be arranged at varying angles to form assemblies having deep cross sectional configurations, they may also be arranged in assemblies having shallower cross sectional configurations, such as for example the assembly 47 shown in Figure 10B. The assembly 47 may be desirable in an application where the section modulus need not be as high and space able to be occupied by the depth of the cross sectional

configuration of the assembly is limited. An example of such an application is basement excavation where such space constraints are common.

Figure 6 depicts the sheet pile assembly 30 engaging the earth into which it has been installed. The interconnected sheet piles 1 are arranged to form cavities 51 extending parallel with the connections 31 and 33 (also shown at Figure 3a). The assembly 30 also comprises mouths 52 extending parallel with the cavities 51 and providing access thereto. The mouths 52 are narrower than the respective cavities 51.

The cavities thus entrap and engage respective columns of earth 53 thereby deriving transverse reinforcement therefrom and affording the assembly a large integral mass. The installed assembly 30 is thus able to act as both a composite conventional mass gravity retaining wall and also as a flexural sheet pile wall.

A further feature of an assembly of sheet piles according to the embodiment is that when a flexural bending load is applied to either of the type-A and type-B connections 31 and 33, the connection locks preventing the piles from relative longitudinal displacement. The connection is thus able to transmit both transverse and longitudinal shear forces when in service with little or no relative slippage of the connectors therein. As a result, the assembly behaves as a single piece with a consequently high section modulus.

A further feature of the sheet pile 1 according to the preferred embodiment is an ability of the flanges 5 and 7 to be bent outwardly from the main body 2, as shown at Figure 11A. As will be described below, the bending may be carried out to varying degrees.

An open assembly formed of sheet piles having the configuration shown in Figure 11A and connected by type-B connections 33 is shown at Figure 11B. Figures 12, 13 and 14 show closed assemblies, enclosing a progressively

reducing cross sectional area, formed from six, five and four identical sheet piles respectively. In each of these figures, the cross sectional configuration of the sheet piles is also shown separately from the closed assembly which they form. It can be seen that the flanges of the sheet piles 1', 1'' and 1''' shown in Figures 12, 13 and 14 respectively are outwardly bent to a progressively lesser extent.

It should be understood that engagement between portions of radial faces as referred to herein may comprise direct or indirect engagement. Indirect engagement may occur, for example, where there is a layer of soil or other debris trapped between the engaging portions.

Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

It should be appreciated that the scope of the present invention need not be limited to the particular scope of the embodiments described above.

Claims

The claims defining the invention are as follows:

1. A panel connector for interconnecting adjacent panels, wherein the panels have one or more flanges each having an edge, the connector comprising a portion of sheet material arranged to extend from the edge of the panel with a curved profile having an inner end adjacent the edge of the panel and an outer end, such that in transverse cross section, said curved profile includes:

a first portion extending from the inner end in a generally elliptical path;
and

a second portion extending from the first portion to the outer end, the second portion curving inwardly from the generally elliptical path;

wherein the curved profile of the connector curves through at least 360 degrees, and the second portion defines an opening between the inner end and the outer end to receive a portion of a further connector on an adjacent panel of the same shape as said connector by longitudinally sliding the further connector within said connector.
2. A panel connector in accordance with claim 1, wherein there is provided a neck extending from the edge of the panel to the first portion, the neck being curved in an opposite direction to the generally elliptical path such that portions of the connector are located on either side of a plane defined by the flange.
3. A panel connector in accordance with claim 1 or 2, wherein the curved profile extends through around 360 degrees.

4. A panel connector in accordance with any one of claims 1 to 3, wherein the first portion of the curved profile extends along the generally elliptical path at least to a point where the path is directed towards and is parallel to the flange.
5. A panel connector in accordance with any one of claims 2 to 4, wherein a central axis of the generally elliptical path parallel to the plane of the flange is offset from the plane of the flange in the direction of the neck.
6. A panel connector in accordance with Claim 5, wherein said central axis is the major axis of the elliptical path.
7. A panel connector in accordance with any one of claims 1 to 5, wherein the shape of the curved profile is such that two interconnected connectors having the respective flanges thereof generally parallel are able to move relative to each other to a limited extent in a direction perpendicular to the plane of the flanges such that an inner face of one connector disengages from an outer face of the other connector and an outer face of the other connector disengages from an inner face of the connector, thereby allowing limited relative movement of the interconnected connectors along a plurality of axes perpendicular to the edges of the panels.
8. A panel connector substantially as hereinbefore described with reference to the accompanying drawings.
9. A panel having a connector according to any one of claims 1 to 8 along at least one edge.
10. A panel according to claim 9, wherein the panel includes two flanges, each flange having a connector as claimed in any one of claims 1 to 7 along a respective edge.

11. A panel according to claim 10, wherein the panel includes a web portion, the two flanges extending from opposed ends of the web portion in a direction angled to the plane of the web portion.
12. A panel according to claim 11, wherein the web portion includes a corrugation such that the panel has a generally W-shaped cross-section.
13. A panel in accordance with any one of claims 9 to 12, wherein the connectors are formed integrally with the panel.
14. A panel substantially as hereinbefore described with reference to the accompanying drawings.