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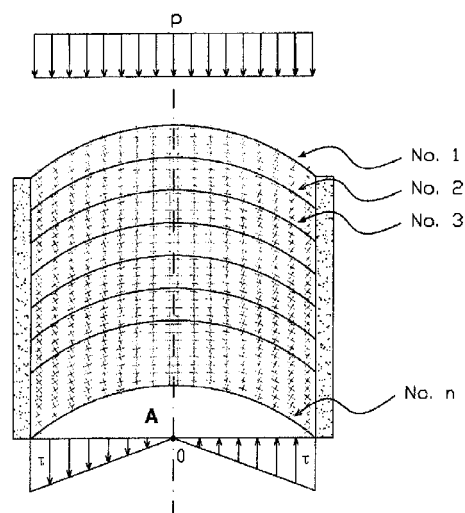
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(54) **REINFORCED SELF-SUPPORTED RETAINING WALL STRUCTURE MAKING USE OF THE ARCHING EFFECT AND A CONSTRUCTION METHOD OF EXCAVATIONS USING THE SAME**

(57) In a reinforced self-supported retaining wall structure using an arching effect, a soldier pile integrally formed with a soldier pile insertion portion in a vertical direction in a flange at one end of the soldier pile in which a lagging is inserted is installed at a width B to be perpendicular to the ground. A sheet panel protruding portion is inserted in and connected to the soldier pile insertion portion. A sheet panel protruding portion is serially inserted in a sheet panel insertion portion. A compression support plate protruding portion is inserted in and coupled to the sheet panel insertion portion. A relationship between a length L of a group of serial sheet panels and the width B between two groups of serial sheet panels is $0.5 \leq L/B \leq 3.0$ in a range of an internal friction angle of earth $\Phi = 10 \sim 34^\circ$ and a range of an adhesive power $C = 0.0 \sim 5.0 \text{ ton/m}^2$ so that a back earth pressure is not applied to the front lagging due to the arching effect.

FIG. 9



Description

TECHNICAL FIELD

[0001] The present invention relates to a reinforced self-supported retaining wall structure using an arching effect and a construction method of excavations using the same, and more particularly, to a reinforced self-supported retaining wall structure, which uses an arching effect, that supports a back earth pressure generated by vertical excavation.

BACKGROUND ART

[0002] A reinforced self-supported retaining wall structure, which uses an arching effect, that is installed in the rear of an excavation space does not interfere with an excavation work and helps an efficient excavation work. In particular, since a back earth pressure is not applied to a lagging inserted in a soldier pile due to an arching effect, a self-supported retaining wall structure may be formed and the self-weight of the self-supported retaining wall structure supports a back earth pressure, which is a new concept of a continuous sheet wall.

[0003] According to the present invention, since a reinforced self-supported retaining wall structure is installed in the rear of an excavation space, the reinforced self-supported retaining wall structure does not interfere with an excavation work. Accordingly, an excavation space is large so that an excavation work in a limited space such as a downtown area packed with tall buildings is made easy and efficient.

[0004] Since a connection portion of a sheet panel is firmly fixed by upper and lower fixing devices so as to produce a combined section, not only rigidity is improved, but also the structure of the upper and lower fixing devices is simplified so that assembly and disassembly thereof is made easy and also the sheet panel may be easily collected after construction is completed.

[0005] A conventional temporary earth retaining construction method to prevent collapse of excavated back earth during an excavation construction for an underground structure construction reinforces an insufficient support force of a soldier pile against an excavated back earth pressure. A typical construction method includes a strut construction method and a sheet-pile construction method.

A) Strut Construction Method

[0006] A strut construction method is a construction method to excavate the ground in a top-down method while reinforcing an insufficient horizontal support force of a soldier pile 10 against an excavated back earth pressure using a strut 20 (refer to FIG. 1).

[0007] An excavated back earth pressure is a horizontal force and the soldier pile is a vertical member. Supporting a horizontal force with only a vertical member and not a horizontal member is impossible in view of structural mechanics. The strut 20 functions as a horizontal member with respect to the soldier pile 10 that is a vertical member. The strut 20 is perpendicular to the soldier pile 10. The strut 20 is supported at two support points. The two support points of the strut 20 are the soldier piles 10 located at opposite positions. Since the strut 20 is installed between the opposite soldier piles 10, a strut in a latitudinal direction and a strut in a longitudinal direction are perpendicular to each other on the same plane.

[0008] The struts in the latitudinal and longitudinal directions are obstacles that decrease a work space for entering equipment for an excavation work and discharging soil to the outside. In particular, since tall buildings are around an excavation space in the downtown area, struts need to be piled more densely for structural safety.

[0009] Since the strut is a temporary structure, the installed struts are sequentially removed at the installation of a permanent structure after an excavation space is prepared. The construction of a permanent structure is performed by stages from the bottom toward the top in a bottom-up method.

[0010] Accordingly, the removal of struts is performed by stages. For example, assuming that the lowermost level of a permanent building is B1, struts installed on the level B1 are first removed to construct the level B1 of the permanent building. Even when the struts of the level B1 are removed, struts of upper levels B2, B3, B4, etc. as installed continue to support earth pressure. The struts removed from the level B1 need to be removed to the outside of the building and thus the struts in the latitudinal and longitudinal directions hinder the excavation work.

[0011] Also, concrete mortar and steel bars for construction of the level B1 need to be lowered to the level B1 through the struts of the levels B2, B3, B4, etc. The struts installed at an upper level may hinder the supply of materials so that work efficiency may be lowered. Such problems also affect the construction of the levels B2, B3, B4, etc.

[0012] Thus, the strut construction method is problematic because the struts installed within an excavation space facing the soldier pile which narrows a work space for an excavation work and a soil discharge work. Also, since the struts are temporary structures, the struts need to be removed by stages during construction of a permanent structure. Thus, the struts remaining above hinder the sequential construction of a permanent structure so that work efficiency may be lowered.

B) Sheet-Pile Construction Method

[0013] Korean Patent Publication No. 2008-45182, which is a related art, discloses "Structure of Sheet-Pile Wall Forming Body". Figure 3 of Korean Patent Publication No. 2008-45182 discloses an invention to address a problem of first and second interlocks 446 and 448 of U.S. Patent No. 6,715,964 B2, which are illustrated in FIG. 2. As illustrated in FIG. 2, a soil anchor 444 is coupled by the first interlock 446 of a first sheet 440 and the second interlock 448 of a second sheet 442. A soil failure plane is the maximum tension force line T_{max} -line to which an active earth pressure is applied. An acting force 450 is a tension force applied to a soil destruction plane. The soil anchor 444 resists the tension force.

[0014] Korean Patent Publication No. 2008-45182 points out that U.S. Patent No. 6,715,964 B2 has a problem in that a connection portion for coupling a sheet-pile wall sectioning portion to an anchorage receives a very high tension force due to an earth pressure of ground retaining from a surrounding area. To address this problem, the purpose of Korean Patent Publication No. 2008-45182 is to develop a forming body that may endure a very high tension force without disassembly of the connection portion where the first interlock 446 and the second interlock 448 are engaged with each other.

[0015] The purpose of Korean Patent Publication No. 2008-45182 is to configure a forming body that may endure a very high tension force without disassembly of the connection portion 16. The forming body is a core structure of the shape and structure of the connection portion 16.

[0016] FIG. 3 illustrates a sheet-pile wall sectioning portion 12, a first anchorage 14, a connection portion 16, an open cell 18, an open cell 22, a flat panel type combination body 22, a support wall 24, a welding portion 26, and a double-T carrier 28.

[0017] Korean Patent Publication No. 2008-45182 and U.S. Patent No. 6,715,964 B2 have the same fundamental concept of balance of an earth pressure and a force against the earth pressure.

[0018] FIG. 4 illustrates a fundamental concept of an earth retaining system using a sheet-pile. FIG. 4 is illustrated in U.S. Patent No. 6,715,964 B2 and also cited in the present invention. The fundamental concept of an earth retaining system is discussed below with reference to FIG. 4.

[0019] A reference numeral 200 denotes a unit cell structure of a typical sheet pile. The unit cell structure 200 has a U shape. A sheet pile of a U shape includes a curved portion 210 and a linear portion 220. The curved portion 210 is closed and the linear portion 220 is open. The unit cell structure 200 is vertically installed.

[0020] FIG. 4 is a plan view of the unit cell structure 200. The unit cell structure 200 is a structure to support a back earth pressure P transferred through earth filling the inside of the unit cell structure 200. A structure such as a road is built above the unit cell structure 200.

[0021] The back earth pressure P is based on a boundary condition of the unit cell structure 200 of a U shape. Referring to FIG. 8, the back earth pressure P is positioned at the back side. In FIG. 4, the back earth pressure P is applied to the curved portion 210 of the sheet pile.

[0022] In FIG. 4, the balance of forces is a concept that a frictional force F ($F=\mu N$) corresponds to the back earth pressure P . The back earth pressure P and the frictional force F having opposite application directions are balanced with each other. N denotes a vertical force acting on the linear portion 220 of the sheet pile. The fundamental concept of the related art of FIG. 4 may be summarized as follows: the back earth pressure P acting on the curved portion 210 of the unit cell structure 200 is balanced with the frictional force F .

DETAILED DESCRIPTION OF THE INVENTION

TECHNICAL PROBLEM

[0023] The present invention provides a reinforced self-supported retaining wall structure of a new concept which forms a lump of self-standing earth of a reinforced earth method using an arching effect generated due to a frictional force between earth particles and a sheet panel and resists an earth pressure applied to an excavation space by using the self-weight of the self-standing earth.

[0024] The present invention provides a reinforced self-supported retaining wall structure, which uses an arching effect, which is located at the back side of an excavation space so as not to be an obstacle to an excavation work so that a large excavation space may be used. Accordingly, an excavation work in a limited space in a downtown area where tall buildings are densely located may be easily and efficiently performed.

[0025] The present invention provides a reinforced self-supported retaining wall structure which may increase the rigidity of a connection portion of a group of serial sheet panels using upper and lower fixing devices by making the connection portion of the sheet panel be a combined section, and simultaneously facilitate the assembly and disassembly of the connection portion of the sheet panel due to a simple structure of the upper and lower fixing devices and thus make collection of installed sheet panels easy after construction is completed.

TECHNICAL SOLUTION

[0026] Since the present invention relates to a reinforced self-supported retaining wall structure using an arching effect, a general outline of an arching effect will be first described and then the arching effect in view of geotechnical engineering will be described.

A) General Outline of Arching Effect

[0027] A general outline of an arching effect will be described below with reference to FIGS. 5A and 5B.

[0028] When sand is contained in a box with an open upper cover plate and a hole of a diameter d formed in the bottom plate of the box is open, the sand is discharged downwardly through the hole of a diameter d (see FIG. 5A).

[0029] However, even when the hole of a diameter d is still open, the discharge of the sand discontinues. In a state of the sand being no longer discharged, it can be seen that the shape of the sand forms an arch shape of an arc.

[0030] When the hole of a diameter d is not open, the contained sand is supported by the bottom plate. When the hole of a diameter d is open, the contained sand is discharged due to a self-weight W of the sand to a degree and the discharge is stopped while the sand forms an arch shape of an arc.

[0031] A phenomenon that the sand is no longer discharged and is supported by the arch shape of an arc even when the self-weight W of the sand exists may be referred to as an arching effect. The arching effect is generated by the balance of a force to discharge the sand through the hole of a diameter d due to the self-weight W of the sand and a force to restrict the discharge of the sand due to a frictional force between the sand and four vertical surfaces of the box. The arching effect may be a state in which the force to discharge the sand through the hole of a diameter d is balanced with the frictional force generated as the sand closely contacts the four vertical surfaces.

[0032] Thus, the arching effect is generated only when the amount of the frictional force and the size of the diameter d are appropriately balanced. When the size of the diameter d is too greater than the amount of the frictional force, the sand is continuously discharged through the hole of a diameter d so that an arching effect may not be generated.

[0033] As the hole of a diameter d is open, the self-weight W of the sand is applied through the hole of a diameter d and thus the sand is discharged through the hole of a diameter d by the self-weight W . Nonetheless, the sand is not continuously discharged. While forming an arch shape of an arc as illustrated in FIG. 5B, the sand is no longer discharged and the discharge of the sand is stopped.

[0034] A mutual shear stress is generated between the sand to be discharged through the hole of a diameter d and sand particles restricting the sand to be discharged. The mutual shear stress supports the self-weight W of the sand in the arch shape of an arc. The arch shape of an arc is a state in which sand particles are rearranged by shear stress generated between the discharged sand and the sand particles restricting the discharged sand.

[0035] The arch shape characteristically forms an arc in an upward direction with respect to a direction in which the self-weight W of the sand is applied, as illustrated in FIG. 5B. The self-weight W of the sand is supported by the arch shape of an arc of FIG. 5B.

B) Arching Effect in view of Geotechnical Engineering

[0036] An arching effect due to a continuous sheet wall is described in view of geotechnical engineering below with reference to FIG. 8. Although a safety problem of an earth structure is a 3 dimensional matter, the safety problem is typically interpreted in 2 dimensions. This is because a normal earth structure having a long width B and a long length L compared to an excavation height H may have almost a 2-dimensional boundary condition. Even when it is interpreted by 3 dimensions, an active earth pressure is remarkably reduced and a passive earth pressure is rather increased, compared to a 2-dimensional state due to an arching effect, so that a result of more safety is obtained rather than the 2-dimensional interpretation.

[0037] FIG. 8 is a 2-dimensional plan view of an earth retaining structure having the width B and the length L of FIG. 6. Since an earth pressure P indicates an earth pressure at the same excavation height H , the amount of the earth pressure P is the same. B denotes the width between sheet panels and L denotes the length of the continuously installed sheet panels.

[0038] A frictional force F equals μPO ($F = \mu PO$), where μ denotes a frictional coefficient and PO denotes an at-rest earth pressure. The application direction of PO is a vertical direction to the sheet panel. The frictional force F is generated by a back earth pressure p and a shear stress τ is distributed as illustrated in FIG. 22 or 9. The shear stress τ gradually decreases toward a center portion O .

[0039] Since the arch shape of an arc formed in FIG. 5B is a state in which sand particles are rearranged, the arch shape of an arc will be described in view of geotechnical engineering. When an earth stress-modification problem is handled as a 2-dimensional problem, if stress is applied to one element of earth, as illustrated in FIG. 23A, only normal stress σ_1 and σ_3 are applied to the element and planes, that is, a I-I plane and a III-III plane, that are two perpendicular

planes having shear stress of 0 exist. The normal stress σ_1 and σ_3 applied to the perpendicular planes, that is, the I-I plane and the III-III plane, are referred to as principal stress. The normal stress σ_1 is the maximum principal stress and the normal stress σ_3 is the minimum principal stress.

[0040] The shear stress τ is necessarily applied to a plane other than the principal stress plane, that is, the I-I plane and the III-III plane, in addition to the perpendicular stress σ , as illustrated in FIG. 23B. When the shear stress τ and the perpendicular stress σ on an a-a plane inclined counterclockwise by an angle α from the I-I plane is presented by a τ - α relationship, the shear stress τ and the perpendicular stress σ on an a-a plane is a point "a" of FIG. 23C. When the angle α varies from 0° to 180° , the trace of the point a may draw a Mohr's stress circle C having a diameter with both ends of a point I indicating the maximum principal stress σ_1 and a point III indicating the minimum principal stress σ_3 with respect to a point A on an axis σ .

[0041] A result of obtaining the perpendicular stress σ and the shear stress τ of the point a from the Mohr's stress circle C may be expressed as follows.

$$\sigma = 1/2(\sigma_1 + \sigma_3) + 1/2(\sigma_1 - \sigma_3)\cos 2\alpha \quad (A)$$

$$\tau = 1/2(\sigma_1 - \sigma_3)\sin 2\alpha \quad (B)$$

[0042] When $\alpha = 90^\circ$, $\tau = 0$ and $\sigma = \sigma_1$.

[0043] When an earth particle is rotated, the shear stress τ of the point "a" is 0 and the earth particle receives only the principal stress. The arch shape of an arc of FIG. 5B, formed by the rearrangement of sand particles, is in a state in which the shear stress τ is 0, that is, a state of receiving only the principal stress.

[0044] The arch shape of an arc generated by the operation of the back earth pressure p will be described below with reference to FIG. 9.

[0045] When the back earth pressure p is applied to the earth particles, the earth particles are rearranged with the principal stress direction rotated by the effect of the frictional force F .

[0046] When points having continuous principal stress directions are connected in a state in which the shear stress $\tau = 0$, that is, only the principal stress is applied, due to the rearrangement of sand particles, as illustrated in FIG. 5B, an arch shape line of an arc is formed. A lump of earth existing on the same arch shape line functions as an arch shape crossbeam supporting an earth pressure. The support of the weight W of sand disposed above in the arch shape of an arc in FIG. 5B is based on the above function of the arch shape.

[0047] In FIG. 9, a plurality of arch arcs No. 1, No. 2, No. 3, No. 4, ..., and No. n indicate arch shapes of an arc indicated at a constant interval. The arch arc No. 1 supports the highest back earth pressure p and a degree of the back earth pressure p decreases as the number increases. No back earth pressure is applied at the arch arc No. n . The back earth pressure p in an area A of the arch arc No. n is 0. Since the area A is a place where a lagging 30 is located, the back earth pressure p is not applied to the lagging 30.

[0048] Since the back earth pressure p is not applied to the area A of the lagging 30, the lagging 30 does not function as a structural member for supporting an earth pressure and functions as a protection member for simply preventing earth from flowing down.

[0049] In contrast, the curved portion 210 of the unit cell structure 200 according to the related art that corresponds to the lagging 30 is a structural member for supporting the back earth pressure p unlike the present invention. Thus, the curved portion 210 of the unit cell structure 200 and the lagging 30 of the present invention are totally different from each other in terms of structural mechanics.

[0050] The back earth pressure p decreases from the arch arc No. 1 to the arch arcs No. 2, No. 3, No. 4, ..., and No. n due to the arching effect. Since the back earth pressure p is necessarily 0 in the area A close to the lagging 30, earth within the sheet panels arranged parallel to one another forms a lump of earth and the lump of earth functions as a self-standing structure with respect to the back earth pressure p . FIG. 10 illustrates the self-standing structure due to the arching effect.

[0051] Referring to FIG. 10, the balance in force between the self-standing structure and the back earth pressure p is similar to reinforced earth. That is, the back earth pressure p is supported by the self-weight W of a lump of earth of the self-standing structure. The concept of the self-standing structure due to the arching effect is a new concept totally different from that of the unit cell structure 200 having a U shape of FIG. 4.

[0052] The structure of the reinforced self-supported retaining wall structure using an arching effect will be described below.

[0053] Referring to FIGS. 13 and 14, the present invention discloses a reinforced self-supported retaining wall structure

using an arching effect in which the soldier piles 10 integrally formed with a soldier pile insertion portion 14a in a vertical direction in a flange 12 at one end of the soldier pile 10 in which the lagging 30 is inserted are installed at a width B to be perpendicular to the ground, a sheet panel protruding portion 22a is inserted in and connected to the soldier pile insertion portion 14a, the sheet panel protruding portion 22a is continuously inserted in a sheet panel insertion portion 22a', a compression support plate protruding portion 46a is inserted in and coupled to the sheet panel insertion portion 22a', and the relationship between the length L of continuous sheet panels 20 and the width B between the sheet panels 20 is $0.5 \leq L/B \leq 3.0$ in a range of an internal friction angle of earth $\phi = 10 \sim 34^\circ$ and a range of an adhesive power $C = 0.0 \sim 5.0$ ton/m² so that a back earth pressure is not applied to the front lagging 30 due to the arching effect.

[0054] The relationship that $0.5 \leq L/B \leq 3.0$ is calculated by a Rankine earth pressure method with the internal friction angle Φ and the adhesive power C and a result thereof is shown in the graph of FIG. 24. When the L/B of $0.5 \leq L/B \leq 3.0$ exceeds 3.0, the length of the sheet panels 20 increases so that installation of the sheet panels 20 is uneconomical. When an installation place is downtown, a dispute related to a boundary may arise. Also, the collection of the sheet panels 20 is difficult. When the L/B does not reach 0.5, the rigidity of a member such as the sheet panel 20 is reduced so that a member force may be insufficient.

[0055] Referring to FIG. 24, as the amount of the L/B in a range that $0.5 \leq L/B \leq 3.0$ decreases, construction is economical. To this end, the range that $0.5 \leq L/B \leq 3.0$ may be divided into a range that $0.5 \leq L/B \leq 1.5$ and a range that $1.5 \leq L/B \leq 3.0$.

[0056] When the range is $0.5 \leq L/B \leq 1.5$, the internal friction angle Φ of earth is within a range that $\Phi = 14 \sim 22^\circ$ and the adhesive power C is $C = 0.0 \sim 5.0$ ton/m². When the range is $1.5 \leq L/B \leq 3.0$, the internal friction angle Φ of earth is that $\Phi = 10 \sim 14^\circ$ and the adhesive power C is within a range that $C = 0.0 \sim 5.0$ ton/m².

[0057] The sheet panel insertion portion 22a' is formed at one end of the sheet panel 20 and the sheet panel protruding portion 22a is formed at the other end thereof. In another embodiment, an S-shaped bent portion 22b is formed at one end of the sheet panel 20 and a reversed S-shaped bent portion 22b' is formed at the other end thereof.

[0058] Since the sheet panel 20 is connected between the soldier pile 10 and a compression support plate 40, the shape of connection portions of the soldier pile 10 and the compression support plate 40 may vary according to the shape of the connection portion of the sheet panel 20. For example, when the sheet panel protruding portion 22a is connected to the soldier pile 10 and the sheet panel insertion portion 22a' is connected to the compression support plate 40, the shape of the connection portion of the soldier pile 10 should be the soldier pile insertion portion 14a and the shape of the connection portion of the compression support plate 40 should be the compression support protruding portion 46a. In contrast, the shape of the connection portion of the soldier pile 10 should be a soldier pile protruding portion 14a' and the shape of the connection portion of the compression support plate 40 should be a compression support plate insertion portion 46a'.

[0059] Since the soldier pile protruding portion 14a' and the compression support plate insertion portion 46a' may vary according to the shape of the connection portion of the sheet panel 20, the illustration of the soldier pile protruding portion 14a' and the compression support plate insertion portion 46a' is omitted in the drawing, and the soldier pile insertion portion 14a and the compression support plate protruding portion 46a, which are located at the same positions, are used instead.

[0060] Also, when the S-shaped bent portion 22b of the sheet panel 20 is connected to the soldier pile 10 and the reversed S-shaped bent portion 22b' of the sheet panel 20 is connected to the compression support plate 40, the shape of the connection portion of the soldier pile 10 should be the reversed S-shaped bent portion 14b' and the shape of the connection portion of the compression support plate 40 should be the S-shaped bent portion 40b.

[0061] In contrast, the shape of the connection portion of the soldier pile 10 should be the S-shaped bent portion 14b and the shape of the connection portion of the compression support plate 40 should be the reversed S-shaped bent portion 46b'.

[0062] Since the reversed S-shaped bent portion 14b' varies according to the shape of the connection portion of the sheet panel 20, the reversed S-shaped bent portion 14b' is omitted from the drawing, and the S-shaped bent portion 14b, which is located at the same position, is used instead.

[0063] As such, since the connection shape of the soldier pile 10 and the compression support plate 40 varies according to the left and right connection shapes of the sheet panel 20, the connection shape of the sheet panel protruding portion 22a and the sheet panel insertion portion 22a' will be described as an example of the connection shape, for convenience of explanation.

[0064] The connection shape of the soldier pile 10 is the soldier pile insertion portion 14a or the soldier pile protruding portion 14a', or the S-shaped bent portion 14b or the reversed S-shaped bent portion 14b'. The connection shape of the compression support plate 40 is the compression support plate protruding portion 46a or the compression support plate insertion portion 46a', or the S-shaped bent portion 46b or the reversed S-shaped bent portion 46b'. Since the S-shaped bent portion 46b or the reversed S-shaped bent portion 46b' are selected according to the left and right connection shapes of the sheet panel 20, the illustration of the reversed S-shaped bent portion 46b' is omitted from the drawing, and the S-shaped bent portion 14b, which is located at the same position, is used instead.

[0065] To increase the rigidity and a second moment of area I of the sheet panel 20, the sheet panel connection portion

22 is firmly fixed by upper and lower fixing devices 50a and 50b.

[0066] While the connection portion 22 of the sheet panel 20 is firmly fixed by the upper and lower fixing devices 50a and 50b, the upper fixing device 50a is fixed by a coupling bolt 56a passing through the sheet panel 20, an attachment pad 52a, and a coupling plate 54a when the attachment pad 52a and the coupling plate 54a are sequentially located at both sides of the connection portion 22 of the sheet panel 20. The lower fixing device 50b includes a first cut portion 52b and a second cut portion 56b. An upward inclined surface 524b and a hook step 526b are formed at the first cut portion 52b and a rotation plate 54b and a spring 59b are formed at the second cut portion 56b. An upper end inclined surface 542b is formed on an upper end of the rotation plate 54b that rotates around a hinge shaft 58b. A lower end rotation groove 546b is formed in a lower end of the rotation plate 54b and a vertical insertion groove 544b is formed in a vertical surface thereof. The spring 59b inserted in a spring insertion groove 548b is connected and fixed to a spring mounting device 562b.

[0067] The rotation plate 54b formed in the second cut portion 56b rotates around the hinge shaft 58b installed at an axis point 582b by an elastic force of the spring 59b so that the upper end inclined surface 542b of the rotation plate 54b is caught by the hook step 526b of the first cut portion 52b.

[0068] The lower end rotation groove 546b of the rotation plate 54b is formed to be deep enough for the rotation plate 54b to smoothly rotate without being caught by the lower end portion of the sheet panel 20.

[0069] The lower fixing device 50b is installed at the connection portion of two adjacent sheet panels 20 and the two adjacent sheet panels 20 are coupled by the first cut portion 52b and the second cut portion 56b. The first cut portion 52b is formed in one sheet panel 20 and the second cut portion 56b is formed in the other sheet panel 20. The two adjacent sheet panels 20 are fixed and coupled to each other by the operation of the rotation plate 54b.

[0070] When the upper and lower portions of the connection portion of the sheet panel 20 are firmly fixed by the upper and lower fixing devices 50a and 50b, the two adjacent sheet panels 20 become one combined section and rigidity is improved with the second moment of area I.

[0071] Next, the relationship of the length L of the continuous sheet panel 20 and the width B between the two sheet panels 20 generating an arching effect is described as follows.

[0072] Assuming a back earth pressure per unit area applied to the width B between the sheet panels 20 is p, a sum P of the earth pressures can be expressed as $P=p \times B$.

$$P=p \times B \quad (1)$$

[0073] That is, the sum P of earth pressures p of the expression (1) is applied to a lump of earth between the continuous sheet panels 20. When the self-weight of the lump of earth is W, the self-weight W resists the sum P of earth pressures p.

$$P=r \times H \times Ka - 2 \times C \times \sqrt{Ka} \quad (2)$$

or

$$P=B(r \times H \times Ka - 2 \times C \times \sqrt{Ka}) \quad (2')$$

[0074] The sum P of earth pressures p of the expression (2) forms a function relationship of the adhesive power C and the internal friction angle Φ . Here, Ka denotes a Rankine active earth pressure coefficient $Ka=\tan^2(45^\circ-(\Phi/2))$, Φ denotes the internal friction angle, r denotes the unit weight of earth, H denotes the depth of excavation, and C denotes an adhesive power.

[0075] Assuming that a frictional force between the continuous sheet panel 20 and the lump of earth contacting the continuous sheet panel 20 is F, the friction force F is as follows.

$$F=2 \times L(PO \times \mu \times C')=2 \times L(r \times H \times KO \times \mu + C') \quad (3)$$

[0076] L denotes the length of the continuous sheet panel 20, PO denotes the at-rest earth pressure, μ denotes a

frictional coefficient, and C' is a frictional adhesive power.

[0077] Assuming the earth pressure applied to an earth wall is P_t , the relationship of the back earth pressure P and the frictional force F is as follows.

$$P_t = P - F \quad (4)$$

[0078] In Equation 4, since an earth pressure is not applied to the area A of FIG. 24 due to the arching effect, the P_t becomes 0 ($P_t=0$).

$$P - F = 0 \quad (5)$$

[0079] In Equation 5, when F is equal to or greater than P ($F \geq P$), a lump of earth existing in a space defined by the width B and the length L of the continuous sheet panel 20 may stand by itself due to the arching effect, maintaining the self-weight W .

$$F \geq P \quad (6)$$

[0080] When Equations 3 and 2' are substituted into Equation 6, a result of the substitution is as follows.

$$\begin{aligned} 2 \times L(r \times H \times K_o \times \mu + C') &\geq B(r \times H \times K_a - 2 \times C \times \sqrt{K_a}) \\ L/B &\geq (r \times H \times K_a - 2 \times C \times \sqrt{K_a}) / [2 \times (r \times H \times K_o \times \mu + C')] \end{aligned} \quad (7)$$

[0081] In Expression 7, it may be seen that L/B is a function of the internal friction angle Φ and the adhesive power C .

[0082] Next, when the excavation depth H is 10 m, a lower limit of L/B according to a change in the internal friction angle Φ and the adhesive power C is obtained by Expression 7.

[Conditions]

[0083] Excavation Depth $H=10$ (m), Unit Weight of Lump of Earth $r=1.7$ (t/m³), Frictional Coefficient $\mu=[\tan(2/3 \Phi)]$, Rankine Active Earth Pressure Coefficient $K_a=\tan^2(45^\circ-\Phi/2)$, Rankine Active Earth Pressure Coefficient $K_p=\tan^2(45^\circ+\Phi/2)$, Adhesive Power C (ton/m²), Frictional Adhesive Power $C'=[2/3C]$ (ton/m²), and At-rest Earth Pressure K_o .

[0084] A result of calculation of the L/B by Expression 7 using the above conditions and the ranges of the internal friction angle $\Phi=10\sim34^\circ$, and the adhesive power $C=0.0\sim5.0$ (ton/m²), which are variables, is shown in the graph of FIG. 24. The following results may be obtained from FIG. 24.

1) The maximum value and the minimum value of L/B are expressed between boundaries of the adhesive powers $C=0$ and $C=5.0$ (ton/M²).

2) When the L/B exceeds 3 in the ranges of internal friction angle $\Phi=10\sim34^\circ$ and the adhesive power $C=0.0\sim5.0$ (ton/m²), it may be seen that the back earth pressure is not applied to the lagging due to the arching effect.

3) However, when the L/B exceeds 3, the length of the continuous sheet panel needs to be long, which is uneconomical. Also, when the L/B is smaller than 0.5, the rigidity of the sheet panel decreases so that a member force may be insufficient. Thus, in the present invention, the range of L/B is limited to be $0.5 \leq L/B \leq 3.0$.

4) That is, when the relationship of the length L of the continuous sheet panel 20 and the width B between the two sheet panels 20 is $0.5 \leq L/B \leq 3.0$ in the ranges of internal friction angle $\Phi=10\sim34^\circ$ and the adhesive power $C=0.0\sim5.0$ (ton/m²), it may be seen that the back earth pressure is not applied to the front lagging due to the arching effect.

5) When the relationship of the length L of the continuous sheet panel 20 and the width B between the two sheet panels 20 is $0.5 \leq L/B \leq 1.5$ in the ranges of internal friction angle $\Phi=14\sim22^\circ$ and the adhesive power $C=0.0\sim5.0$ (ton/m²), it may be seen that the back earth pressure is not applied to the front lagging due to the arching effect.

6) That is, when the relationship of the length L of the continuous sheet panel 20 and the width B between the two adjacent sheet panels 20 is $1.5 \leq L/B \leq 3.0$ in the ranges of internal friction angle $\Phi = 10 \sim 14^\circ$ and the adhesive power $C = 0.0 \sim 5.0$ (ton/m²), it may be seen that the back earth pressure is not applied to the front lagging due to the arching effect.

[0085] Even when the L/B satisfies the range of $0.5 \leq L/B \leq 3.0$, since a marginal space from a boundary of adjacent territory is insufficient or buildings may not be built continuously in the downtown area, there is a limit in construction so that the length of a continuous sheet panel may not satisfy the above-described range. As a solution to address the above limit in construction, the insufficient length of the continuous sheet panel is compensated for by a passive earth pressure due to an embedded depth H_b of FIG. 21. The embedded depth H_b is a minimum 1.0 m to improve safety of a wall member and to maintain a freezing depth.

ADVANTAGEOUS EFFECTS

[0086] According to the present invention, a lump of self-standing earth of a reinforced earth type in which a back earth pressure is not applied to a lagging by using an arching effect between earth particles and a sheet panel. Accordingly, the back earth pressure applied to an excavation space may be resisted by the self-weight of the lump of self-standing earth. Thus, construction may be efficient and economical, compared to a conventional sheet pile.

[0087] Since the reinforced self-supported retaining wall structure using an arching effect is located at the back side of an excavation space, the structure does not interfere with an excavation work so that use of a large excavation space may be possible. Accordingly, an excavation work in a small space in a downtown area where tall buildings are densely arranged is made easy and efficient.

[0088] Since the connection portion of the sheet panel becomes a combined section by the upper and lower fixing devices, not only rigidity is improved but also the structures of the upper and lower fixing devices are simplified. Accordingly, the assembly and disassembly of the sheet panel connection portion is made easy and the collection of the installed sheet panels after the completion of the construction is made easy, so that construction and collection of sheet panels is efficient and economical.

DESCRIPTION OF THE DRAWINGS

[0089]

FIG. 1 is a front view illustrating a top-down type underground excavation according to a conventional strut construction method.

FIG. 2 is a view illustrating a state of a connection portion of a sheet pile according to a conventional sheet pile method.

FIG. 3 is a plan view illustrating a connection portion of a sheet pile according to a conventional sheet pile method.

FIG. 4 is a basic concept view illustrating the relationship between a frictional force and a back earth pressure according to the sheet pile method of FIGS. 2 and 3.

FIGS. 5A and 5B are views illustrating an arch state due to an arching effect after a predetermined amount of sand filling a box is discharged through a small hole formed in a lower plate of the box.

FIG. 6 is a perspective view illustrating a state in which the inside formed by the sheet panels continuously connected between the soldier piles is filled with earth.

FIG. 7 is a perspective view illustrating a state in which the earth has been removed from the state of FIG. 6.

FIG. 8 is a plan view illustrating a state in which a force balancing with the back earth pressure of FIG. 6 is operated.

FIG. 9 is a view illustrating a shear stress distribution illustrated in the plan view of FIG. 8 with respect to the back earth pressure, an arching effect according thereto, and a state in which the back earth pressure is not applied to the area A.

FIG. 10 is a perspective view illustrating a relationship between the back earth pressure and a lump of earth W formed by the arching effect.

FIG. 11 illustrates balanced forces of the relationship of FIG. 10 indicated on a 2-dimensional plane.

FIG. 12 is a cross-sectional view illustrating a shear stress distribution when a lump of earth is not formed.

FIG. 13 is a perspective view illustrating the shapes of a connection portion of a sheet panel and a soldier pile according to an embodiment of the present invention.

FIG. 14 is a perspective view illustrating a state in which an upper fixing device is installed at the connection portion of the sheet panel of the present invention.

FIG. 15 is a perspective view illustrating the shapes of a connection portion of a sheet panel and a soldier pile according to another embodiment of the present invention.

FIG. 16 is a perspective view illustrating a state in which an upper fixing device is installed at the connection portion

of FIG. 15.

FIG. 17 is a perspective view illustrating the shapes of a connection portion of a sheet panel and a soldier pile according to another embodiment of the present invention.

FIG. 18 is an exploded perspective view illustrating a lower fixing device that is installed at the connection portion of the sheet panel of the present invention.

FIGS. 19 and 20 respectively illustrate a state in which a lower fixing device of the present invention is being installed and a state after the lower fixing device is installed.

FIG. 21 is a cross-sectional view illustrating a state in which the soldier pile and the sheet panel of the present invention are installed deeper than a designed ground by an embedded portion H_b so as to receive a passive earth pressure.

FIG. 22 illustrates a distribution of shear stress τ due to a frictional force F .

FIGS. 23A, 23B, and 23C illustrate a relationship of stress and deformation of earth.

FIG. 24 is a graph showing a result of L/B obtained with variables of the internal friction angle Φ and the adhesive power C .

MODE OF THE INVENTION

[0090] A construction method of excavations using a reinforced self-supported retaining wall structure according to the present invention will be described in detail with reference to the accompanying drawings. The construction method of excavations using a reinforced self-supported retaining wall structure according to the present invention comprises:

(a) Piling the soldier pile 10 into the ground of a boundary surface to be excavated to have a width B and a vertical depth H that is a designed ground;

(b) Inserting the sheet panel protruding portion 22a into the soldier pile insertion portion 14a formed at the flange 12 of the soldier pile 10 to be connected to each other, continuously inserting the sheet panel protruding portion 22a into the sheet panel insertion portion 22a', and inserting the compression support plate protruding portion 46a into the sheet panel insertion portion 22a' to be connected to each other, under the condition that a relationship between the length L of the continuous sheet panel 20 and the width B between the sheet panels 20 is $0.5 \leq L/B \leq 3.0$ in a range of the internal friction angle of earth $\Phi = 10 \sim 34^\circ$ and a range of the adhesive power $C = 0.0 \sim 5.0 \text{ ton/m}^2$;

(c) Gradually performing underground excavation from the ground to a predetermined depth h_1 and then inserting the lagging 30 from the top end of the soldier pile 10;

(d) When the excavation to the predetermined depth h_1 is completed, performing further excavation to a predetermined depth h_2 and then inserting the lagging 30 from the top end of the soldier pile 10;

(e) Completing the underground excavation by repeating the operations (c) and (d).

[0091] In the operation (b), a relationship between the length L of the continuous sheet panel 20 and the width B between the sheet panels 20 may be $0.5 \leq L/B \leq 1.5$ in a range of the internal friction angle of earth $\Phi = 14 \sim 22^\circ$ and a range of the adhesive power $C = 0.0 \sim 5.0 \text{ ton/m}^2$. Also, in the operation (b), a relationship between the length L of the continuous sheet panel 20 and the width B between the sheet panels 20 may be $1.5 \leq L/B \leq 3.0$ in a range of the internal friction angle of earth $\Phi = 10 \sim 14^\circ$ and a range of the adhesive power $C = 0.0 \sim 5.0 \text{ ton/m}^2$.

[0092] In a downtown area where a marginal space from a boundary of adjacent territory is insufficient or buildings exist one after another, there is a limit in construction so that the length of a continuous sheet panel may not satisfy the above-described range. In this case, as illustrated in FIG. 21, it is preferable to receive a passive earth pressure by installing the embedded portion H_b of the soldier pile 10 and the sheet panel 20 to be deeper than the vertical depth H that is the designed ground. This is to improve safety in relation to the movement and falling down of the reinforced self-supported retaining wall structure. When an appropriate L/B is not satisfied, an earth pressure is applied to the front lagging 30 so that the width B and the length L may be determined by structural calculation.

[0093] In the operation (b), the upper fixing device 50a is coupled and fixed to the upper end of the connection portion of the sheet panel 20 by using the coupling bolt 56a passing through the sheet panel 20, the attachment pad 52a, and the coupling plate 54a when the attachment pad 52a and the coupling plate 54a are sequentially located at both sides of the sheet panel 20. The lower fixing device 50b includes the rotation plate 54b formed in the second cut portion 56b that rotates around the hinge shaft 58b by an elastic force of the spring 59b so that the upper end inclined surface 542b of the rotation plate 54b is caught by the hook step 526b of the first cut portion 52b. The rotation plate 54b includes the upper end inclined surface 542b formed on the upper end of the rotation plate 54b, the lower end rotation groove 546b formed in the lower end thereof, and the vertical insertion groove 544b formed in the vertical surface thereof.

[0094] The installation and removal of the upper and lower fixing devices 50a and 50b are described below.

[0095] The sheet panel 20 is continuously assembled by inserting the sheet panel protruding portion 22a into the soldier pile insertion portion 14a installed on the ground (or the reversed S-shaped bent portion 22b' of the sheet panel

20 into the S-shaped bent portion 14b of the soldier pile 10), and then the compression support plate protruding portion 46a is inserted into the sheet panel insertion portion 22a'.

[0096] The lower fixing device 50b is structurally installed by installing the sheet panel 20 having the second cut portion 56b formed therein after installing the sheet panel 20 having the first cut portion 52b formed therein. The removal of the installed sheet panel 20 has the same order as above. That is, after the sheet panel 20 having the first cut portion 52b is first removed, the sheet panel 20 having the second cut portion 56b is removed. If the order is reversed, neither the installation nor the removal is possible.

[0097] The assembly and disassembly of the lower fixing device 50b is described as follows.

[0098] First, in the assembly of the lower fixing device 50b, when the sheet panel protruding portion 22a of the sheet panel 20 having the second cut portion 56b is inserted into the sheet panel insertion portion 22a' of the sheet panel 20 having the first cut portion 52b that is installed underground, the rotation plate 54b rotating around the hinge shaft 58b is vertically guided by the sheet panel insertion portion 22a' having a vertical shape so as to be in a vertical state (see FIG. 15).

[0099] The hinge shaft 58b is inserted into the shaft point 582b. When the rotation plate 54b maintaining the vertical state meets the first cut portion 52b, as illustrated in FIG. 16, the rotation plate 54b is rotated toward the first cut portion 52b by the elastic force of the spring 59b fixed to the spring mounting device 562b so that the upper end inclined surface 542b of the rotation plate 54b is caught by the hook step 526b of the first cut portion 52b. The vertical insertion groove 544b of the rotation plate 54b inserted in the second cut portion 56b of the sheet panel 20 and the lower end rotation groove 546b inserted in the lower end portion of the second cut portion 56b are respectively released from the second cut portion 52b and the lower end portion of the second cut portion 56b, together with the rotation of the rotation plate 54b.

[0100] In particular, since the rotation plate 54b is rotated around the hinge shaft 58b, the lower end rotation groove 546b of the rotation plate 54b is formed to have a depth such that the rotation thereof is not hindered by the second cut portion 56b of the sheet panel 20. As such, the lower fixing device 50b is firmly fixed in a state that the upper end inclined surface 542b of the rotation plate 54b is caught by the hook step 526b of the first cut portion 52b.

[0101] The spring 59b is inserted into the spring insertion groove 548b of the rotation plate 54b and fixed to the spring mounting device 562b.

[0102] In the disassembly of the lower fixing device 50b, when the upper end inclined surface 542b of the rotation plate 54b is caught by the hook step 526b of the first cut portion 52b, if the sheet panel 20 having the first cut portion 52b is first pulled up for disassembly, the rotation plate 54b is guided to be vertical by the sheet panel insertion portion 22a' having a vertical shape so as to be in a vertical state. While the sheet panel 20 having the first cut portion 52b is pulled up, the rotation plate 54b maintains a vertical state and the vertical insertion groove 544b and the lower end rotation groove 546b of the rotation plate 54b are inserted again into the second cut portion 56b of the sheet panel 20. Accordingly, while the sheet panel 20 having the first cut portion 52b is pulled up, the rotation plate 54b hardly interferes with the sheet panel 20 having the first cut portion 52b so that the disassembly of the sheet panel 20 having the first cut portion 52b is made easy. Since the lower fixing device 50b has a simple structure that is easy to be assembled or disassembled, the assembly and disassembly work is efficient and rigidity of the serial sheet panels 20 is improved.

[0103] While this invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

Claims

1. A reinforced self-supported retaining wall structure using an arching effect, wherein a soldier pile integrally formed with a soldier pile insertion portion in a vertical direction in a flange at one end of the soldier pile in which a lagging is inserted is installed at a width B to be perpendicular to the ground, a sheet panel protruding portion is inserted in and connected to the soldier pile insertion portion, a sheet panel protruding portion is serially inserted in a sheet panel insertion portion, a compression support plate protruding portion is inserted in and coupled to the sheet panel insertion portion, and a relationship between a length L of a group of serial sheet panels and the width B between two groups of serial sheet panels is $0.5 \leq L/B \leq 3.0$ in a range of an internal friction angle of earth $\Phi = 10 \sim 34^\circ$ and a range of an adhesive power $C = 0.0 \sim 5.0$ ton/m² so that a back earth pressure is not applied to the front lagging due to the arching effect.
2. The reinforced self-supported retaining wall structure using an arching effect of claim 1, wherein the relationship of the length L of the continuous sheet panel and the width B between the two groups of sheet panels is $0.5 \leq L/B \leq 1.5$ in the ranges of internal friction angle $\Phi = 14 \sim 22^\circ$ and the adhesive power $C = 0.0 \sim 5.0$ ton/m².
3. The reinforced self-supported retaining wall structure using an arching effect of claim 1, wherein the relationship of

the length L of the continuous sheet panel and the width B between the two groups of sheet panels is $1.5 \leq L/B \leq 3.0$ in the ranges of internal friction angle $\Phi=10\sim 14^\circ$ and the adhesive power $C=0.0\sim 5.0 \text{ ton/m}^2$.

4. The reinforced self-supported retaining wall structure using an arching effect of either claim 1 or 2, wherein a connection portion of the soldier pile comprises a soldier pile insertion portion or a soldier pile protruding portion, and a connection portion of the sheet panel coupled to the connection portion of the soldier pile comprises a sheet panel protruding portion or a sheet panel insertion portion.

5. The reinforced self-supported retaining wall structure using an arching effect of either claim 1 or 2, wherein a compression support plate comprises a vertical portion and a horizontal portion and a connection portion of the compression support plate comprises a compression support plate protruding portion or a compression support plate insertion portion that is integrally formed with the vertical portion.

6. The reinforced self-supported retaining wall structure using an arching effect of either claim 1 or 2, wherein the connection portion of the sheet panel is firmly fixed by using upper and lower fixing devices, wherein the upper fixing device is fixed by a coupling bolt passing through the sheet panel, an attachment pad, and a coupling plate when the attachment pad and the coupling plate are sequentially located at both sides of the connection portion of the sheet panel, the lower fixing device comprises a first cut portion and a second cut portion, an upward inclined surface and a hook step are formed at the first cut portion, and a rotation plate and a spring are formed at the second cut portion, an upper end inclined surface is formed on an upper end of the rotation plate that rotates around a hinge shaft, a lower end rotation groove is formed on a lower end of the rotation plate and a vertical insertion groove is formed on a vertical surface thereof, and the spring inserted in the spring insertion groove is connected and fixed to a spring mounting device.

7. A construction method of excavations using a reinforced self-supported retaining wall structure, the method comprising:

(a) piling a soldier pile into the ground of a boundary surface to be excavated to have a width B and a vertical depth H that is a depth of a designed ground;

(b) inserting a sheet panel protruding portion into a soldier pile insertion portion formed at a flange of the soldier pile to be connected to each other, continuously inserting the sheet panel protruding portion into a sheet panel insertion portion, and inserting a compression support plate protruding portion into the sheet panel insertion portion to be connected to each other, under the condition that a relationship between a length L of a continuous sheet panel and a width B between the sheet panels is $0.5 \leq L/B \leq 3.0$ in a range of an internal friction angle of earth $\Phi=10\sim 34^\circ$ and a range of an adhesive power $C=0.0\sim 5.0 \text{ ton/m}^2$;

(c) gradually performing underground excavation from the ground to a predetermined depth and then inserting a lagging from the top end of the soldier pile;

(d) when the excavation to the predetermined depth is completed, performing further excavation to a predetermined depth h_2 and then inserting the lagging from the top end of the soldier pile; and

(e) completing the underground excavation by repeating the operations (c) and (d).

8. The method of claim 7, wherein, in the operation (b), a relationship between the length L of the continuous sheet panel and the width B between the sheet panels is $0.5 \leq L/B \leq 1.5$ in a range of the internal friction angle of earth $\Phi=14\sim 22^\circ$ and a range of the adhesive power $C=0.0\sim 5.0 \text{ ton/m}^2$.

9. The method of claim 7, wherein, in the operation (b), a relationship between the length L of the continuous sheet panel and the width B between the sheet panels is $1.5 \leq L/B \leq 3.0$ in a range of the internal friction angle of earth $\Phi=10\sim 14^\circ$ and a range of the adhesive power $C=0.0\sim 5.0 \text{ ton/m}^2$.

10. The method of either claim 7 or 8, wherein, in the operation (b), an upper fixing device is fixed by a coupling bolt passing through the sheet panel, an attachment pad, and a coupling plate when the attachment pad and the coupling plate are sequentially located at both sides of the connection portion of the sheet panel, a lower fixing device comprises a first cut portion and a second cut portion, an upward inclined surface and a hook step are formed at the first cut portion, and a rotation plate and a spring are formed at the second cut portion, an upper end inclined surface is formed on an upper end of the rotation plate that rotates around a hinge shaft, a lower end rotation groove is formed in a lower end of the rotation plate and a vertical insertion groove is formed in a vertical surface thereof, and the spring inserted in the spring insertion groove is connected and fixed to a spring mounting device.

FIG. 1

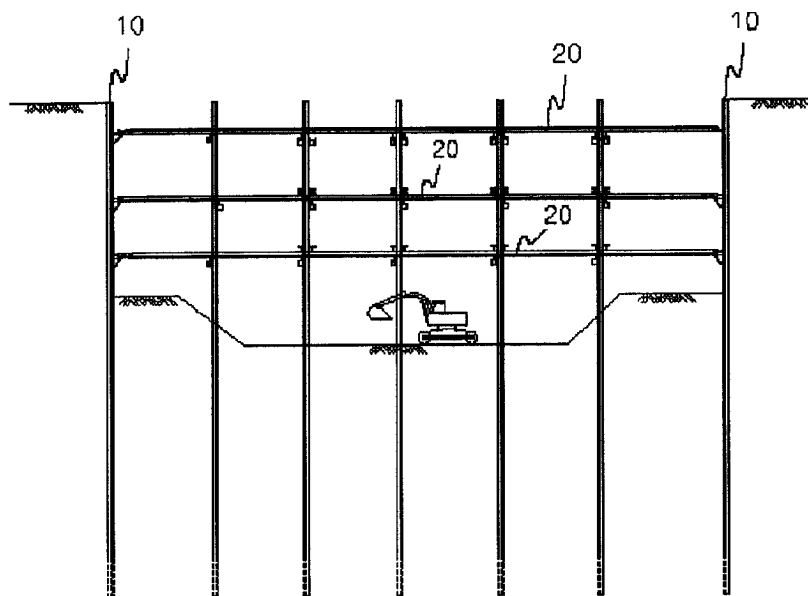


FIG. 2

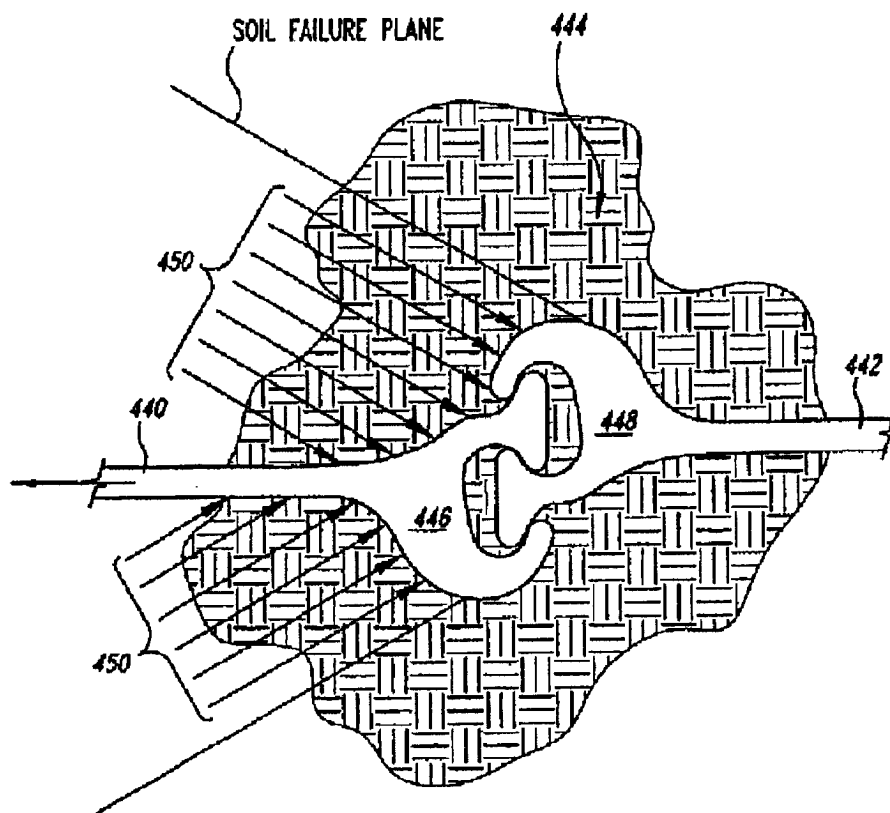


FIG. 3

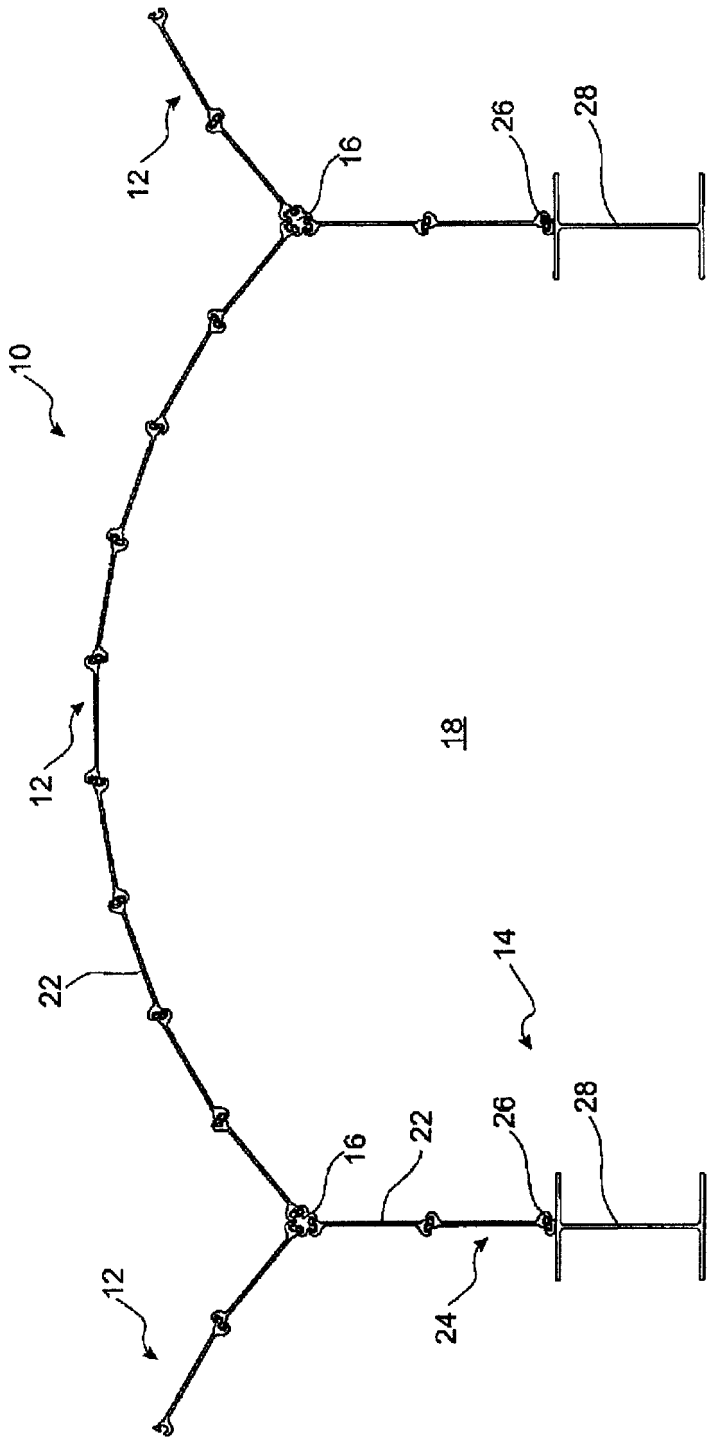


FIG. 4

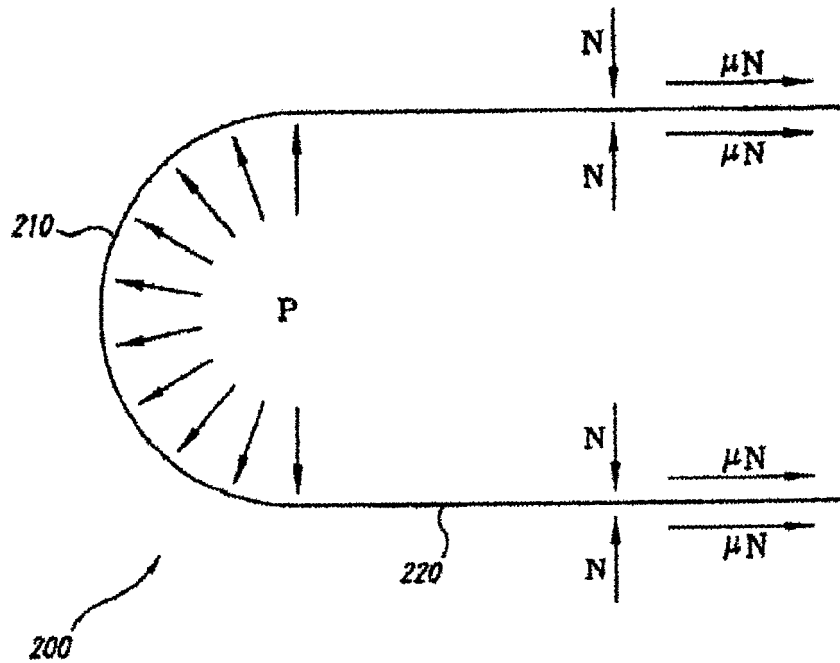


FIG. 5A

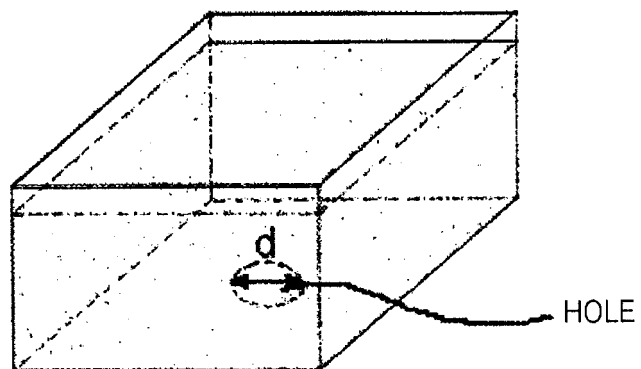


FIG. 5B

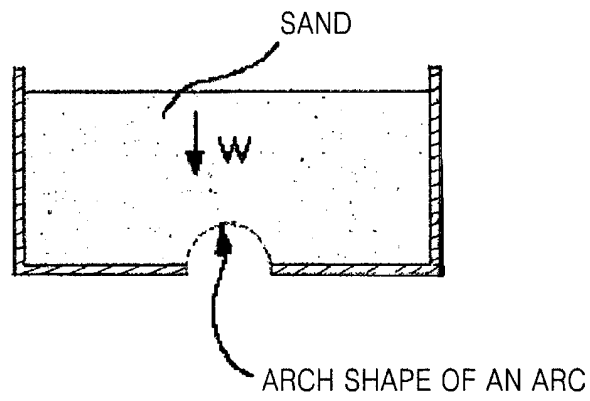


FIG. 6

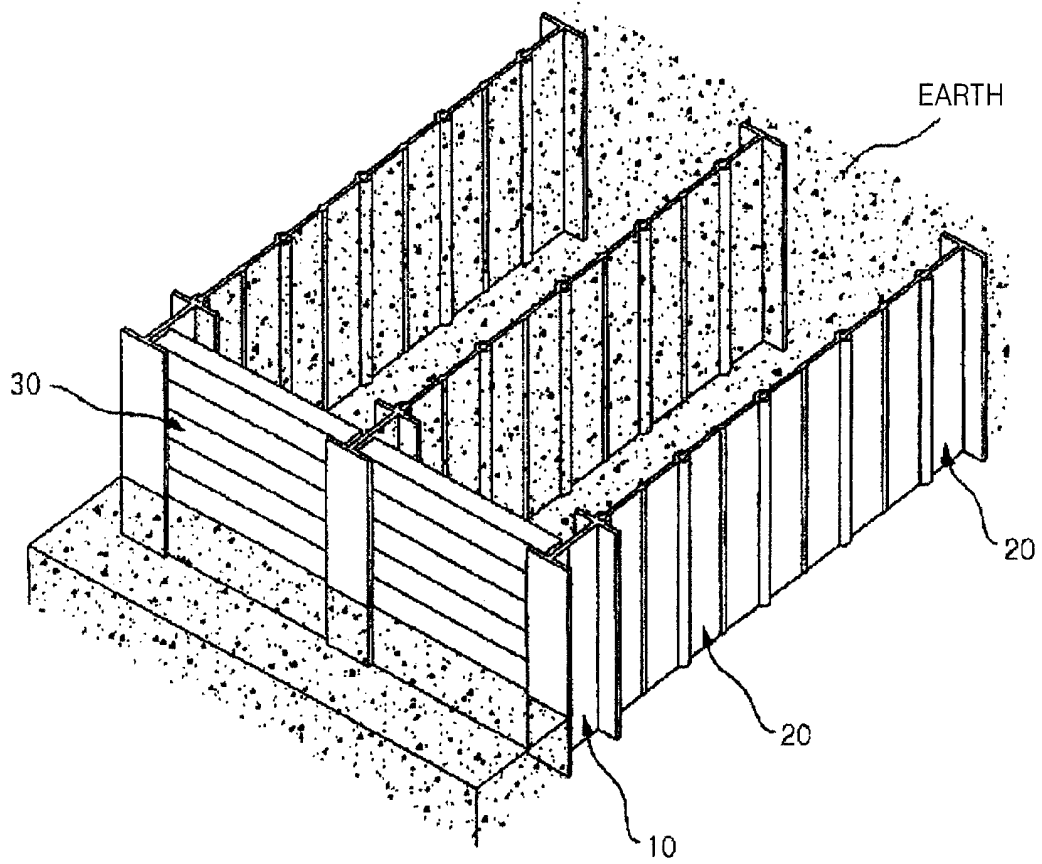


FIG. 7

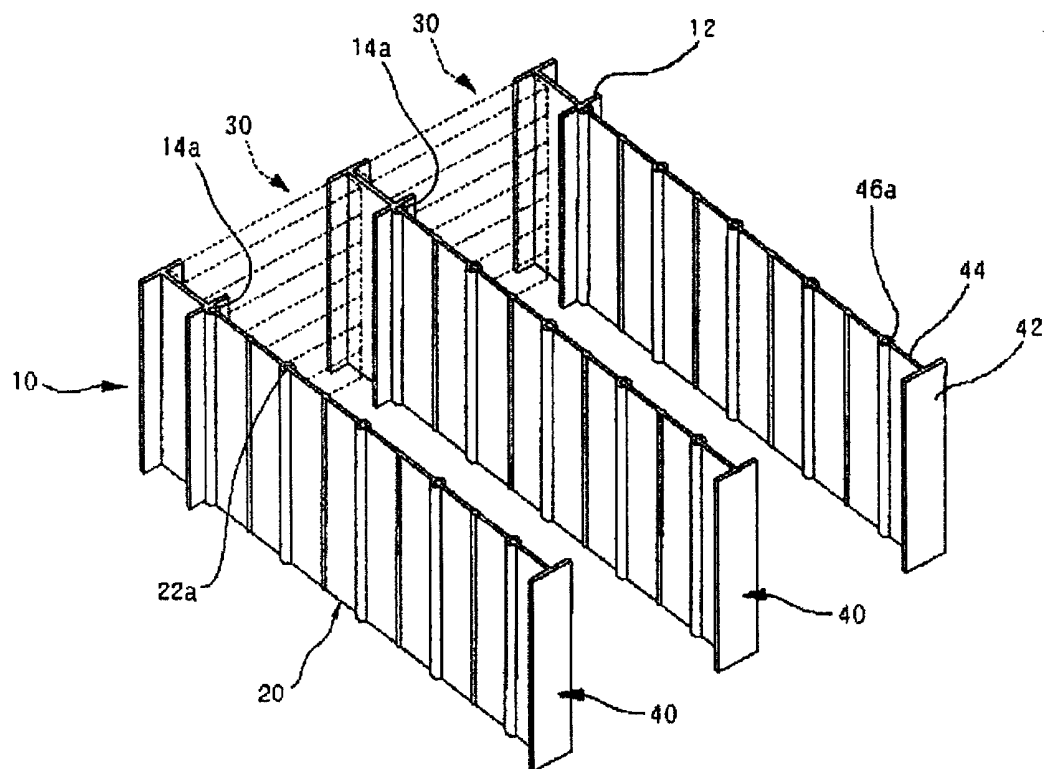


FIG. 8

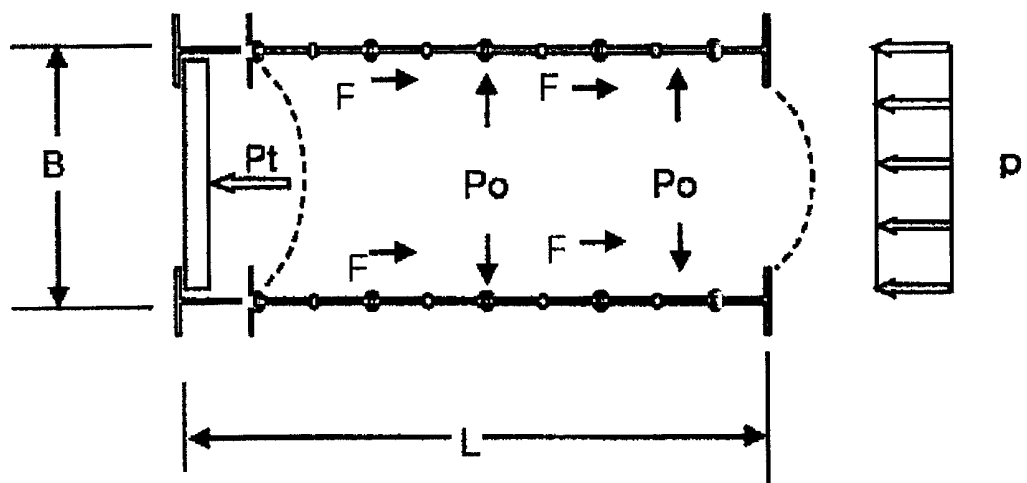


FIG. 9

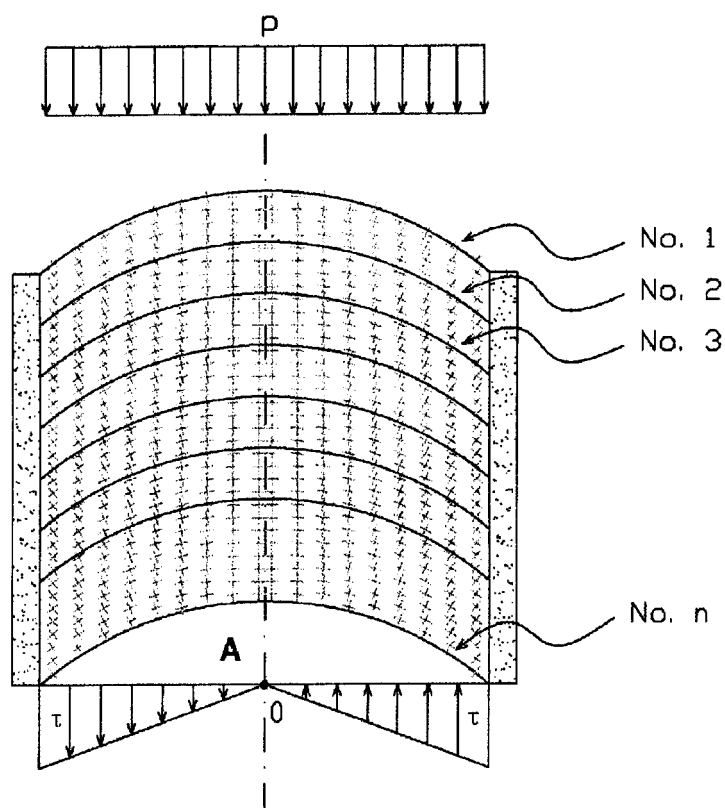


FIG. 10

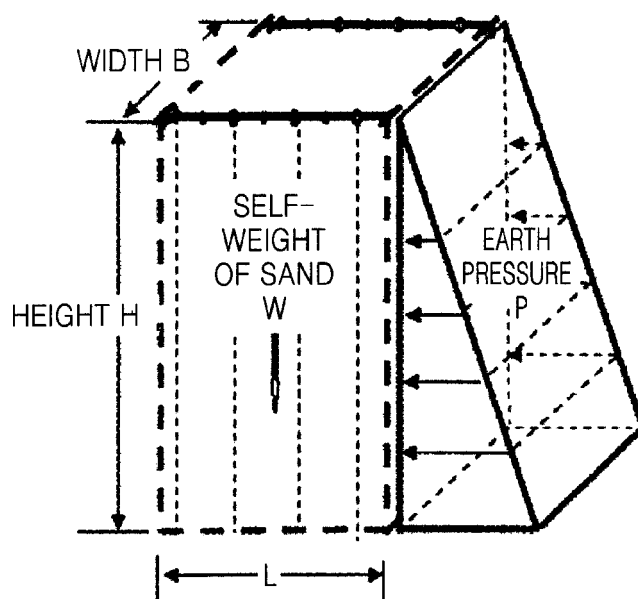


FIG. 11

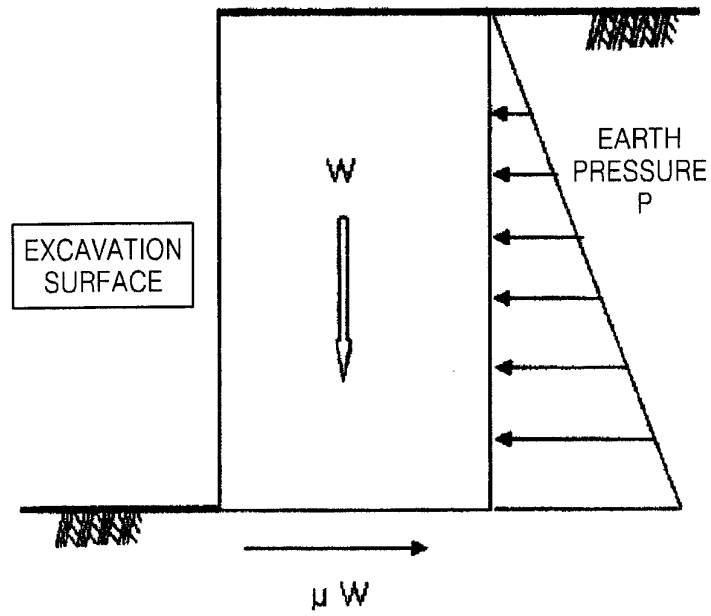


FIG. 12

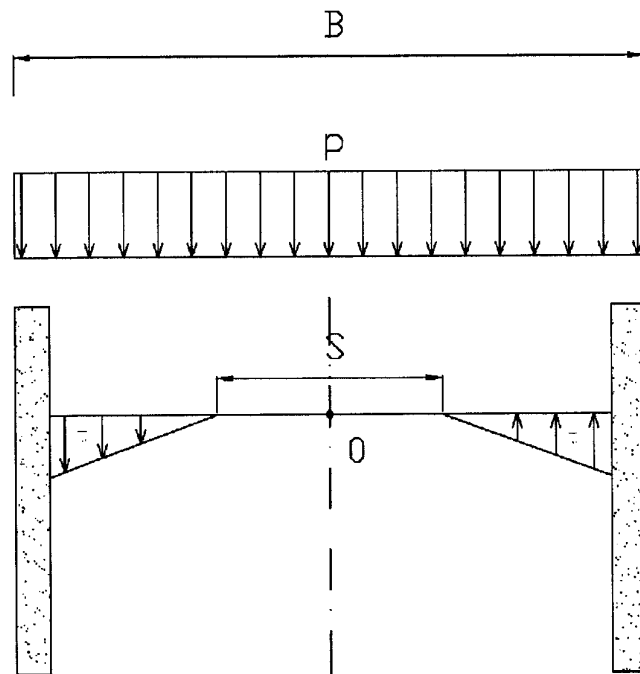


FIG. 13

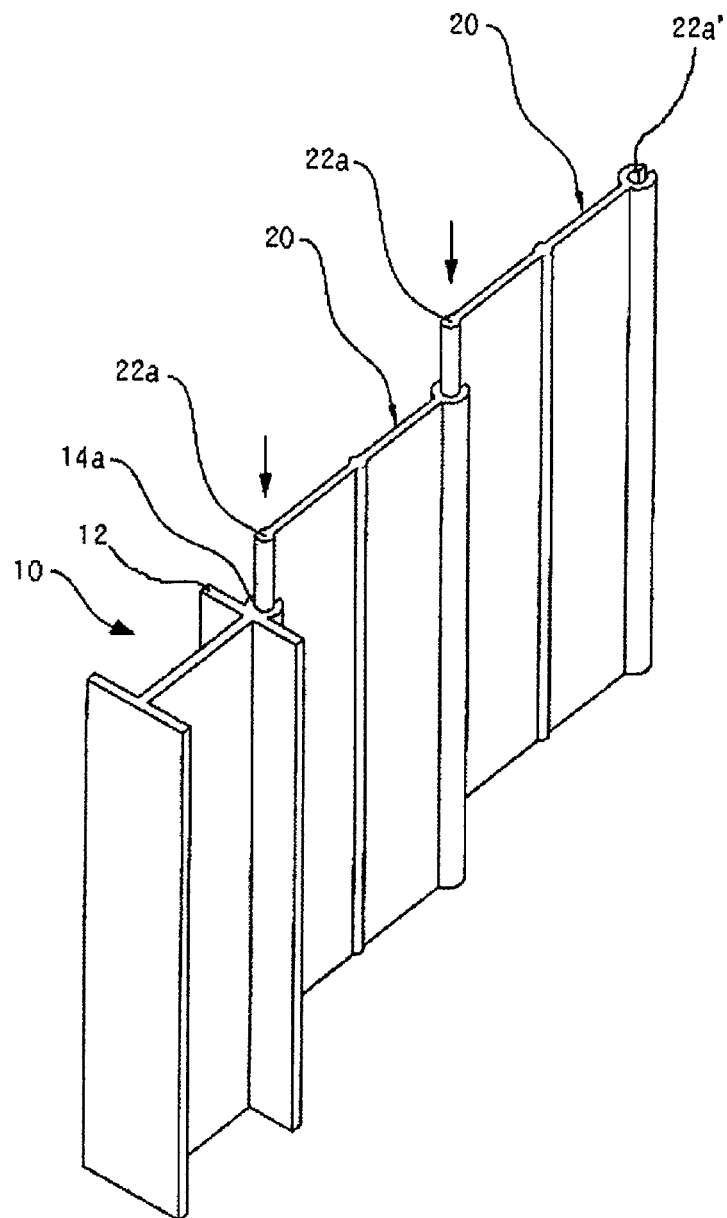


FIG. 14

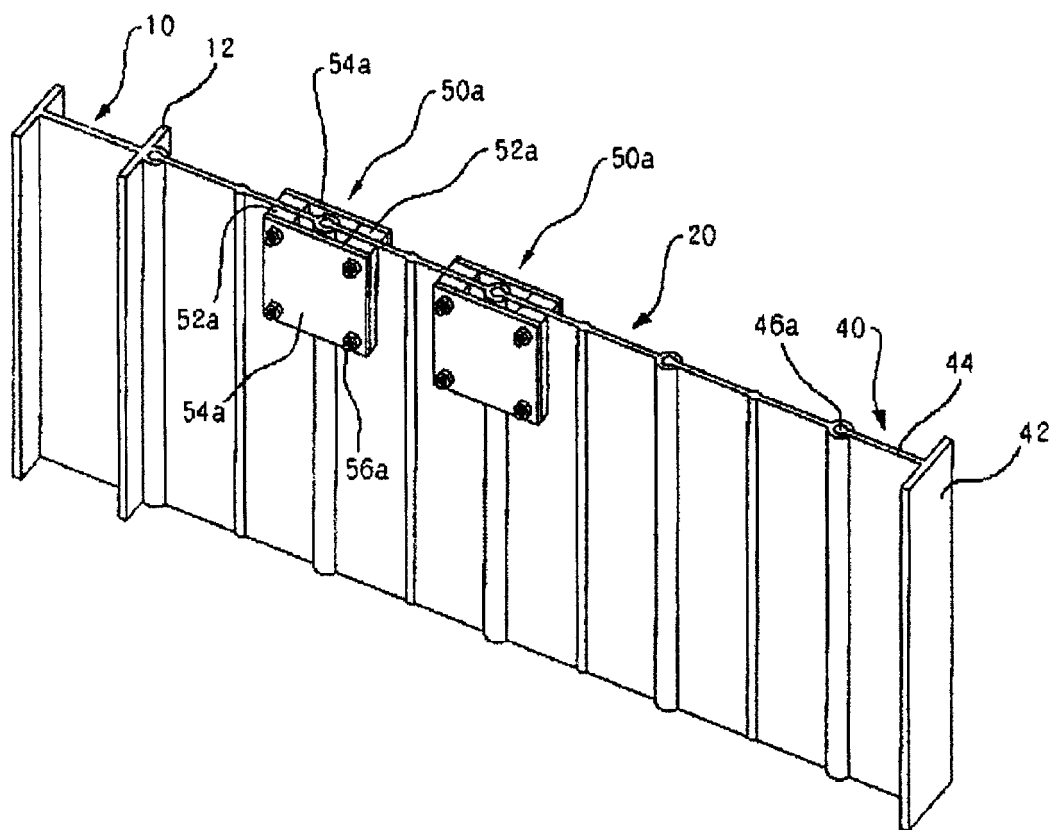


FIG. 15

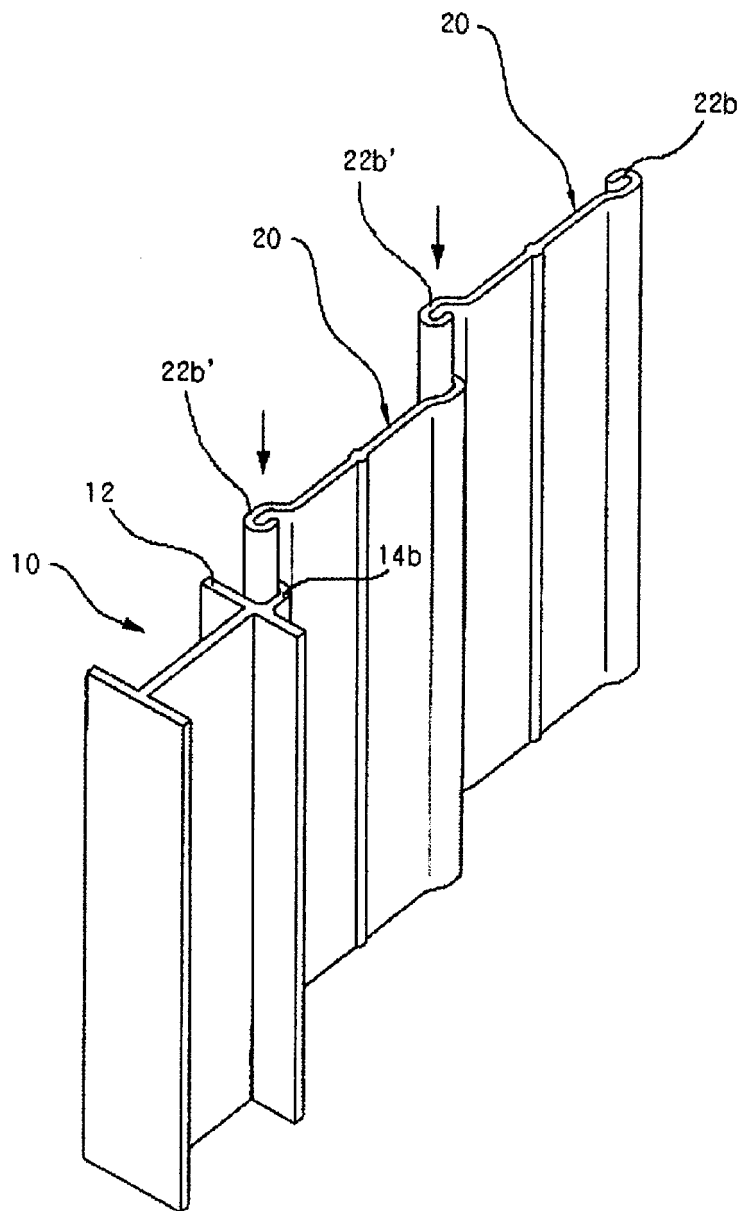


FIG. 16

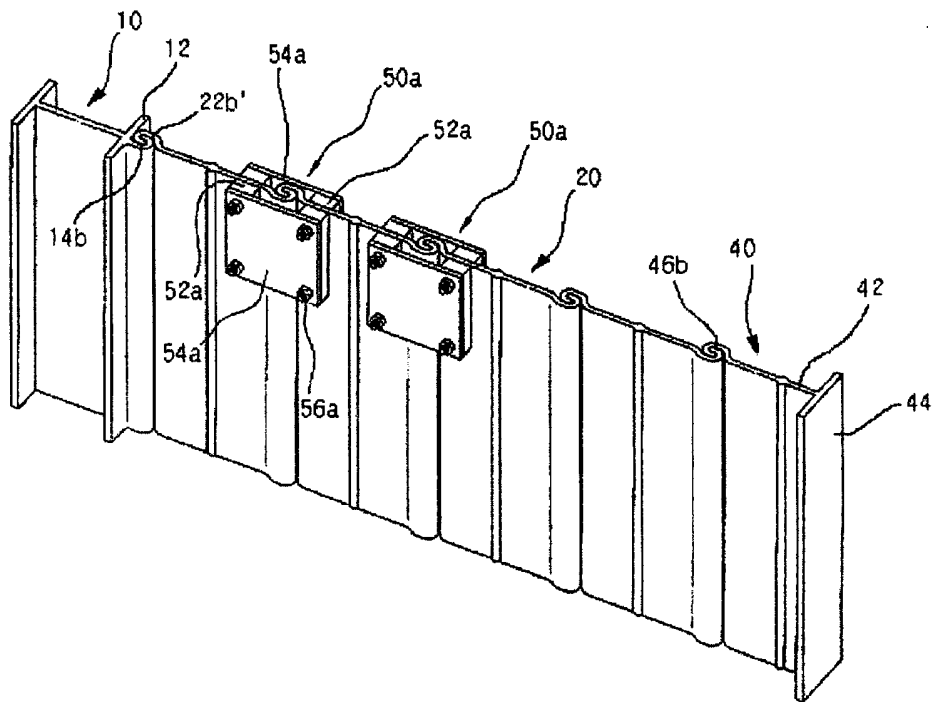


FIG. 17

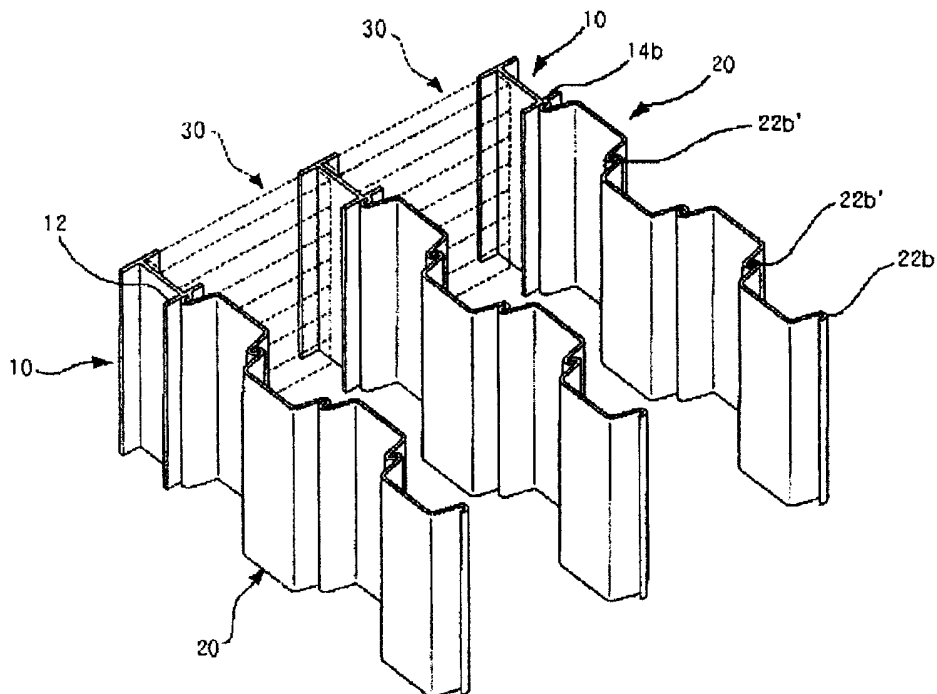


FIG. 18

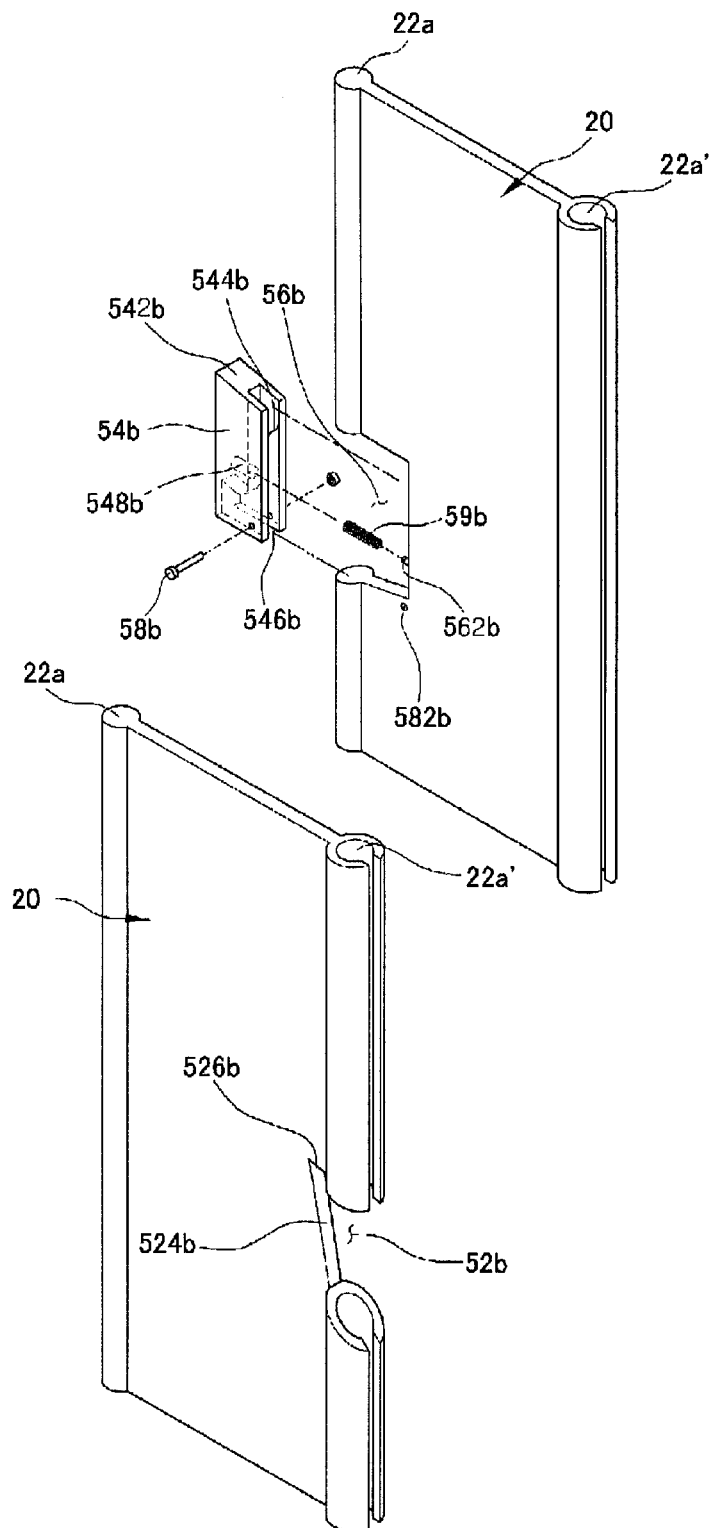


FIG. 19

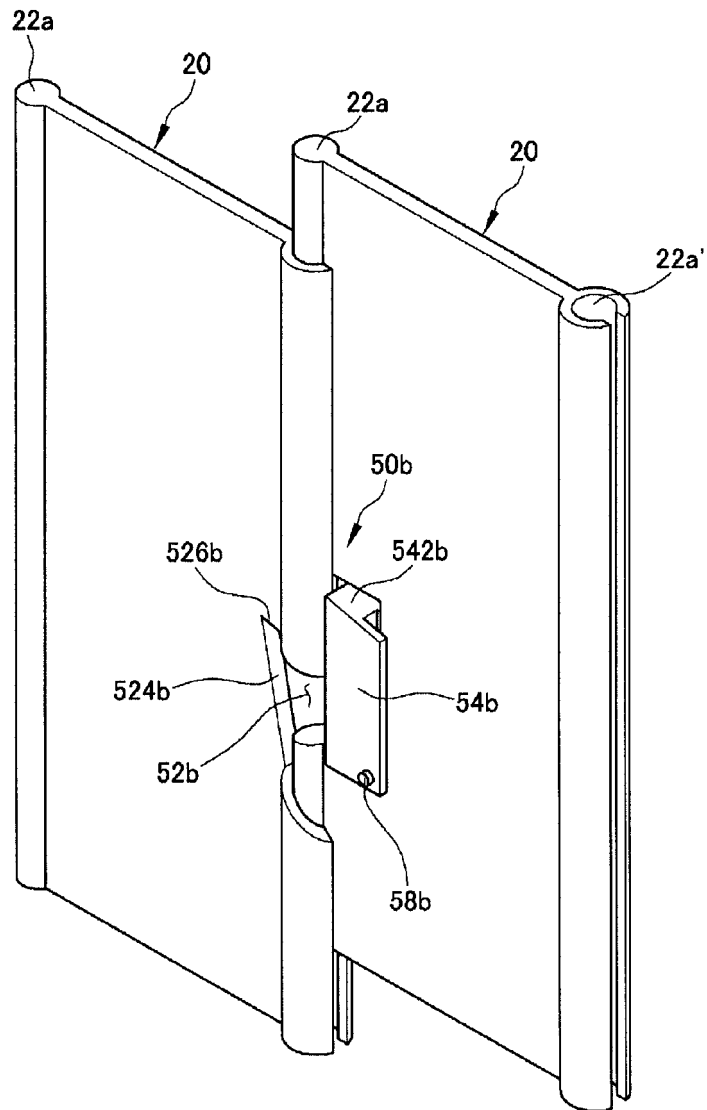


FIG. 20

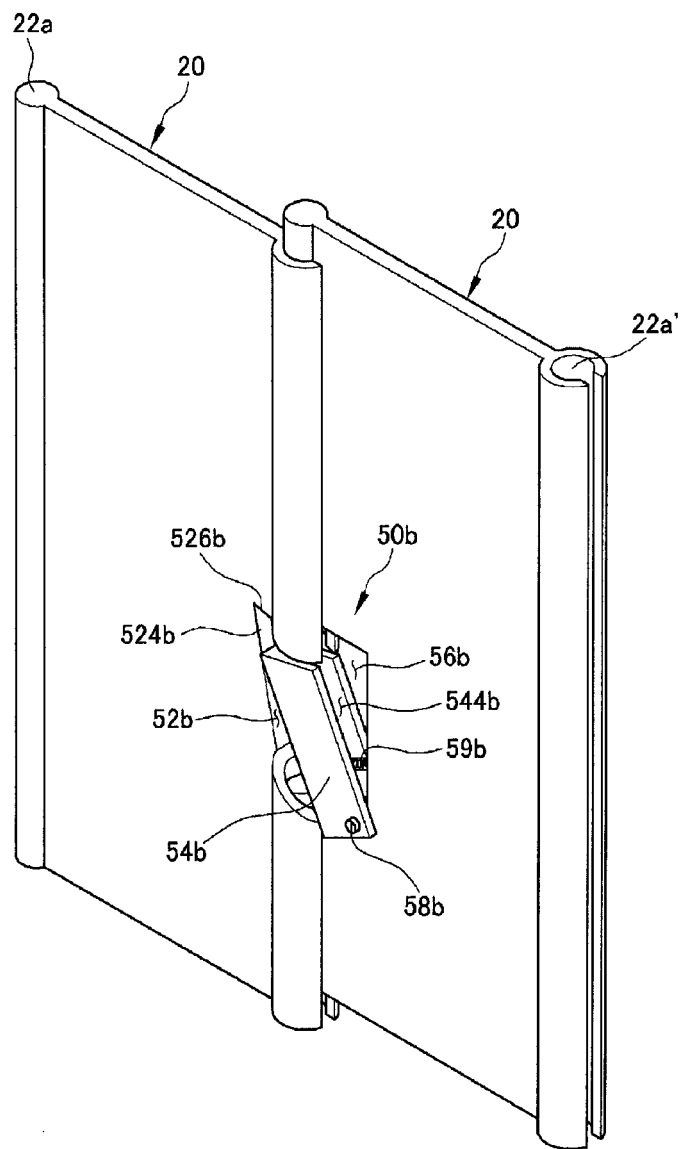


FIG. 21

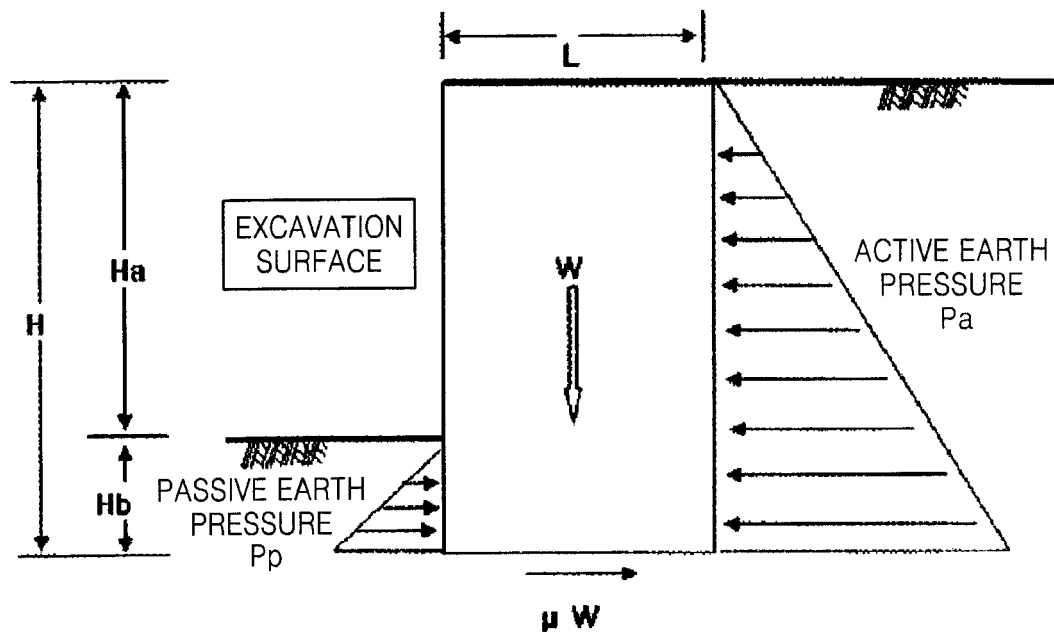


FIG. 22

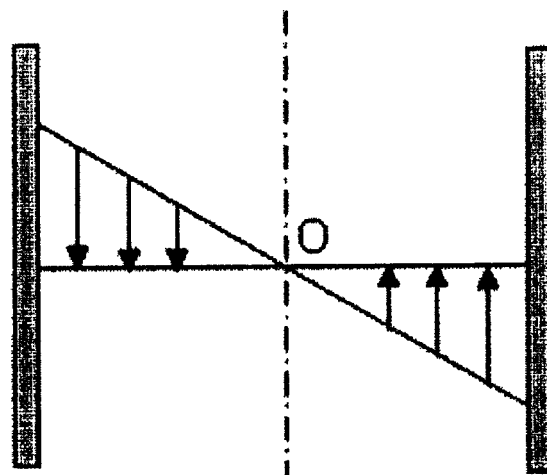


FIG. 23A

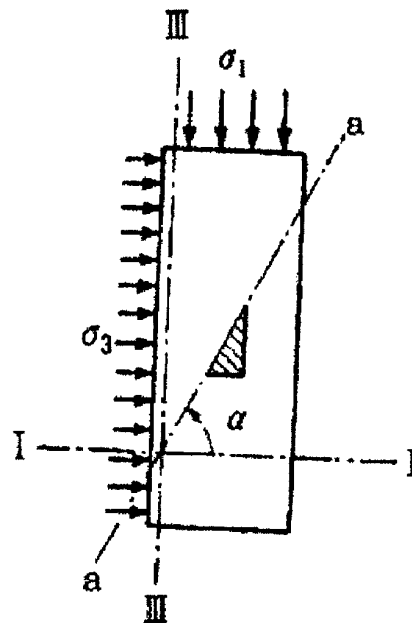


FIG. 23B

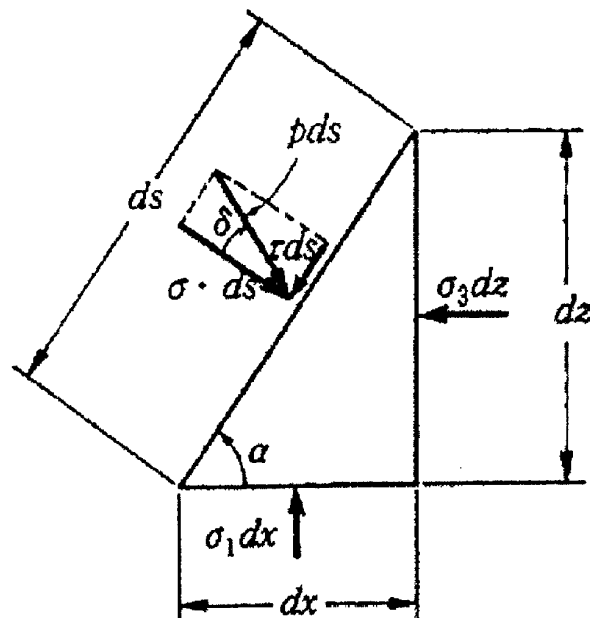


FIG. 23C

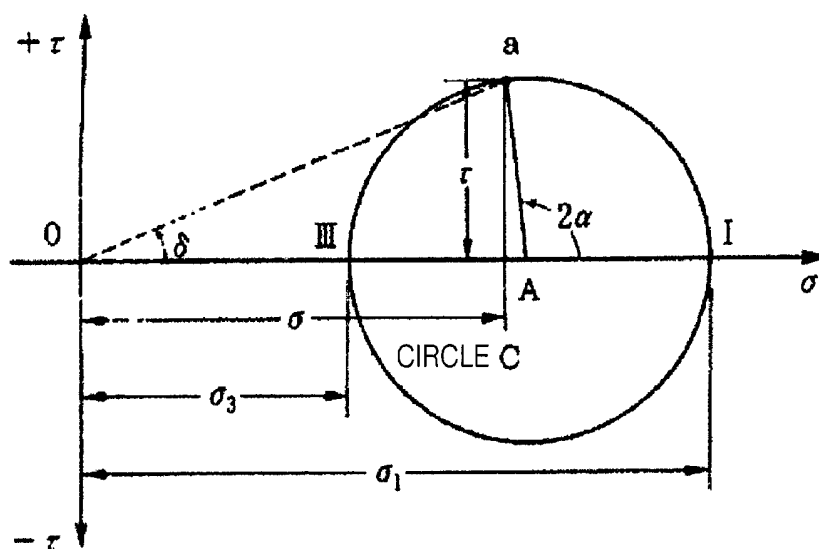
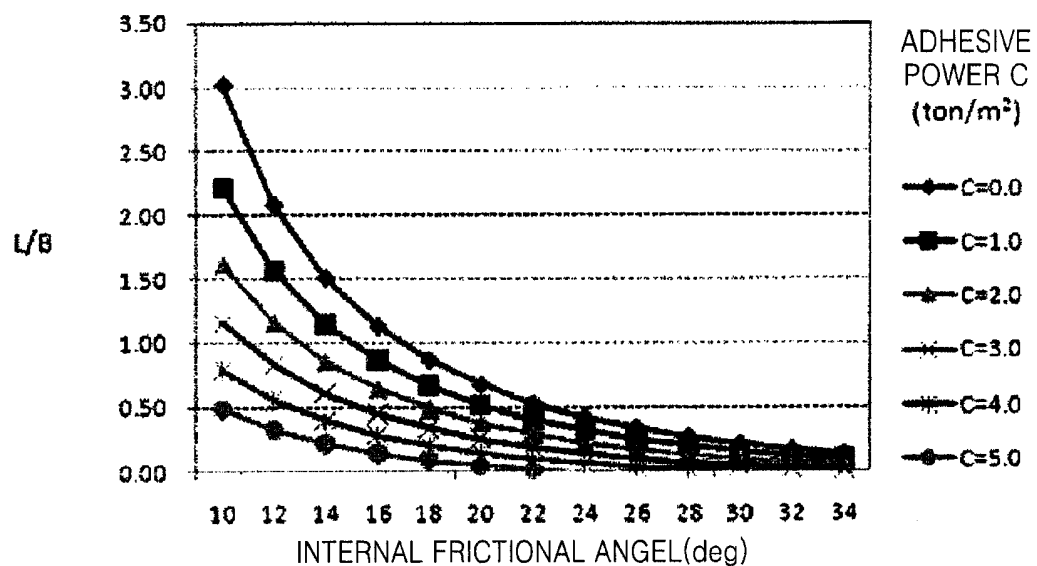


FIG. 24



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- KR 200845182 [0013] [0014] [0015] [0017]
- US 6715964 B2 [0013] [0014] [0017] [0018]