United States Patent [19]

Peterson

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[54] **MACHINE AND METHOD FOR EXCAVATING TRENCHES AND FOR CONSTRUCTING WALLS IN TRENCHES**

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[73] Assignee: **Rapidex, Inc.**, Gloucester, Mass.

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[21] Appl. No.: **409,726**

[52] **U.S. Cl.** **61/35**; 61/63; 37/86

[51] **Int. Cl.** **E02d 5/20**; E02f 5/06

[58] **Field of Search** 61/35, 39, 50, 63; 37/81, 37/82, 86

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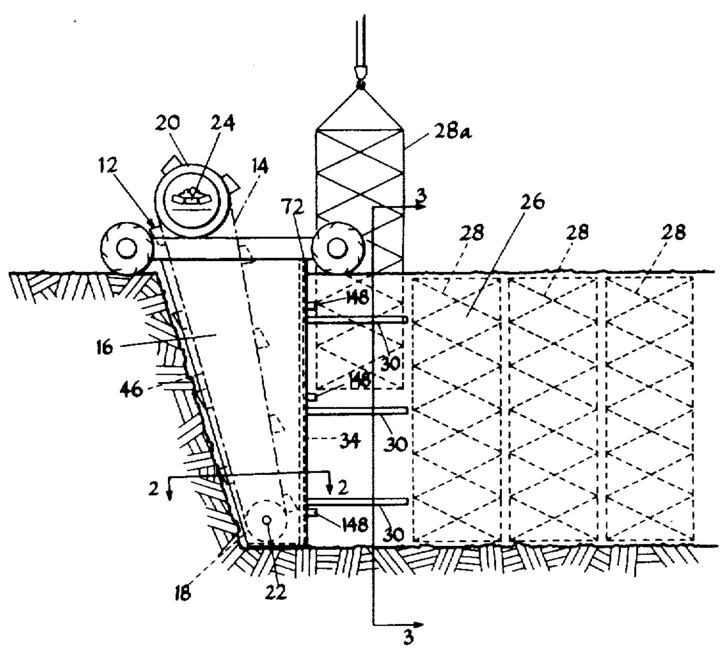
Primary Examiner—Jacob Shapiro

[57] **ABSTRACT**

Excavation of trenches and constructing walls in the trenches employing an excavating machine which has a rearwardly directed surface exposed to fluid filling the trench. By employing concrete as the filling fluid the trench walls are supported as excavation proceeds, and the wall is formed on a continuous basis, permitting placement of continuous reinforcement in the concrete. The fluid in the trench applies forward thrust to the excavating machine useful in propelling the machine forward and assisting the excavating elements in their operation at the working face of the trench. By use of a thrust surface which is movable relative to the forward excavator portion of the machine, under the influence of force-applying devices distributed along the height thereof, the machine can be given a supplementary forward thrust, as when recommencing operation after concrete at the machine has set. A stand pipe over the trench at the back of the machine using a hydrostatic leg or a cover providing a closed trench volume and using a pump, augment the fluid force acting upon the thrust surface. A guide rail unit removably suspended in the trench from the back of the machine guides reinforcement members into place throughout the height of the trench, advantageously adjacent sections of reinforcement along the length of the trench being overlapped or interconnected to transfer tension loads between them. An elastomeric mat member removably suspended from the top of the machine and covering the thrust surface allows the machine to readily move forward from concrete which has set next to the machine and provides a seal and expansion joint when imbedded by later-poured concrete. Shield walls on each side of the excavator prevent collapse of the tunnel sides, structurally support the excavating elements, and support and transmit thrust from the rearwardly directed thrust surface. The shields are shown constructed of telescopic sections or may taper toward each other rearwardly of the trench. A chain and bucket excavator is shown, the buckets having hinged side teeth for opening space for the shields, then passing between the shields. Also supplemental augers for forming side protrusions of the trench and a dual counter-rotating auger trencher are shown.

24 Claims, 25 Drawing Figures



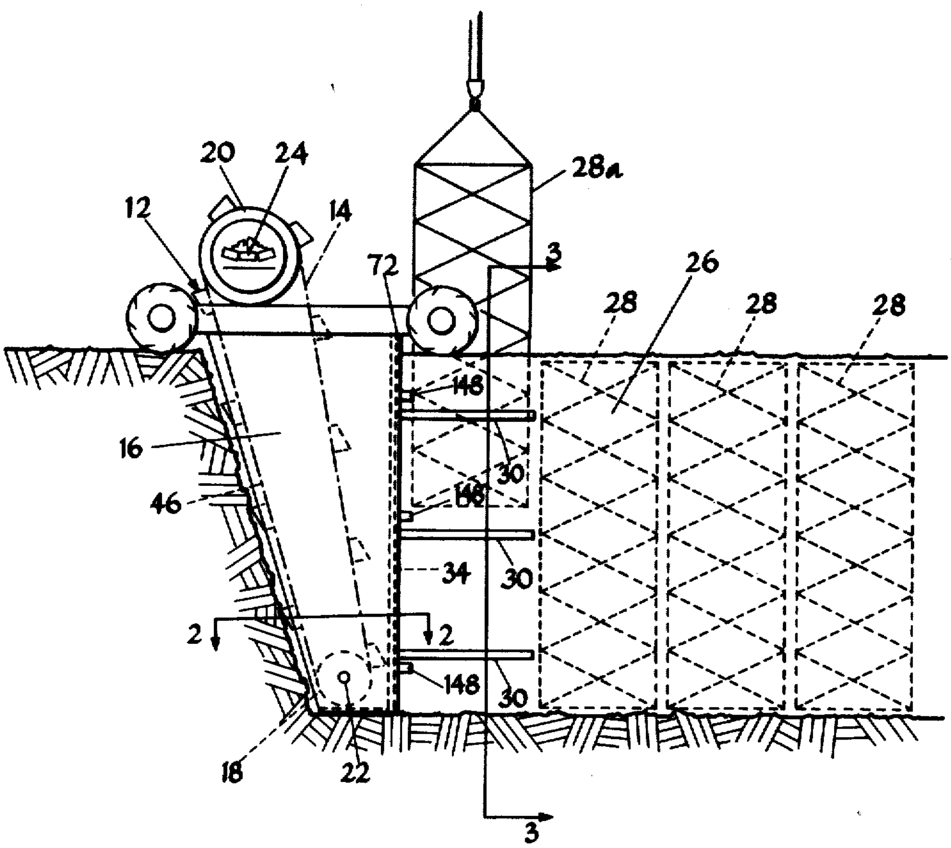


FIGURE 1

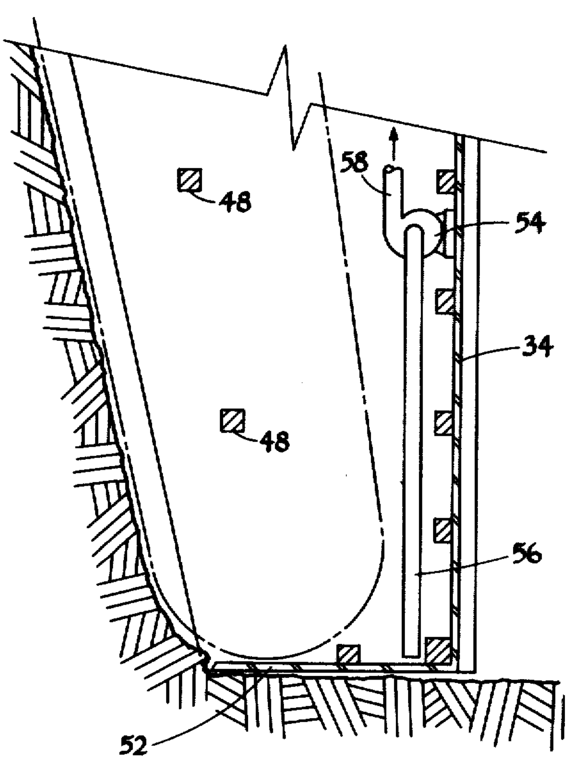


FIGURE 2a

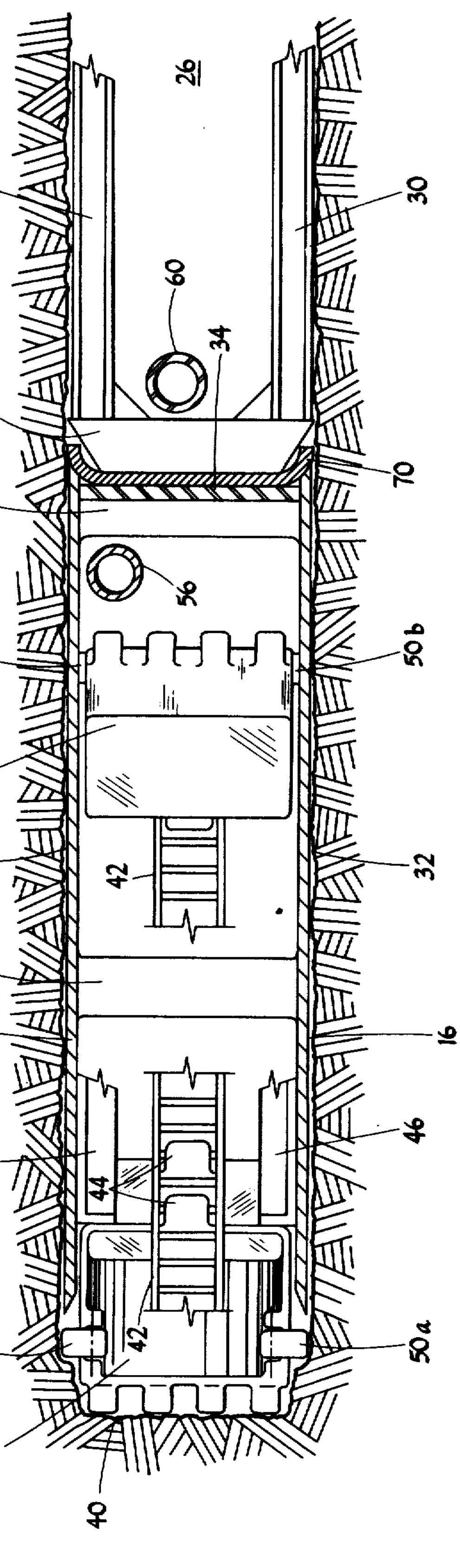


FIGURE 2

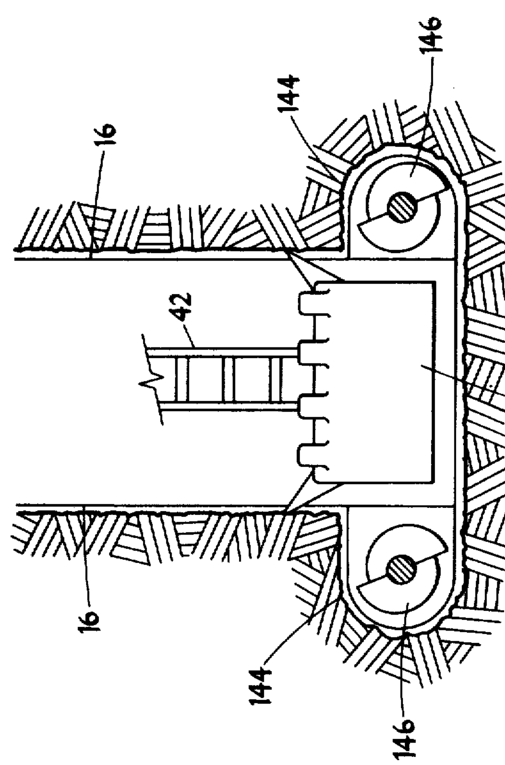


FIGURE 17

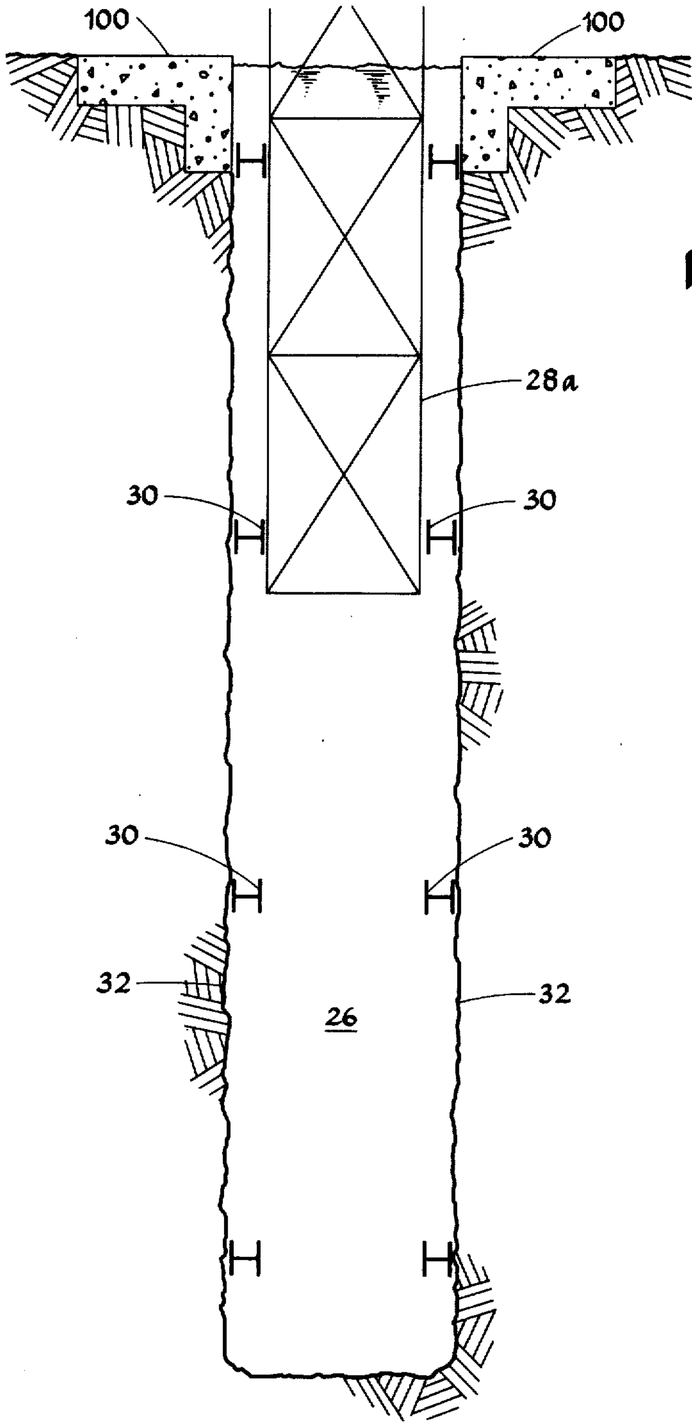


FIGURE 3

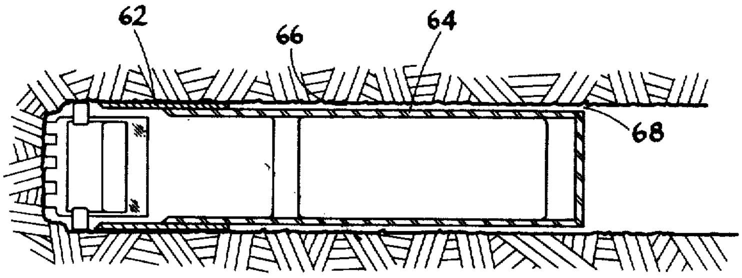


FIGURE 4

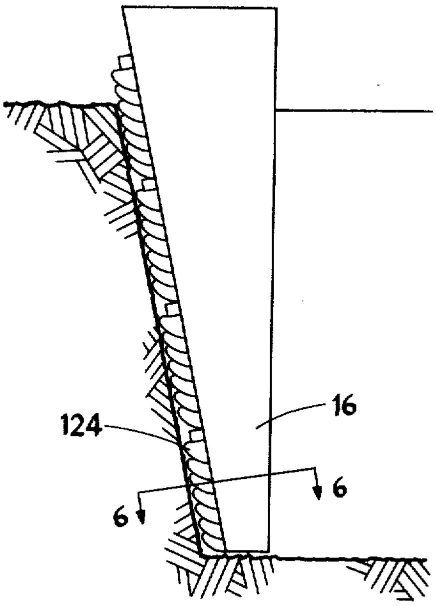


FIGURE 5

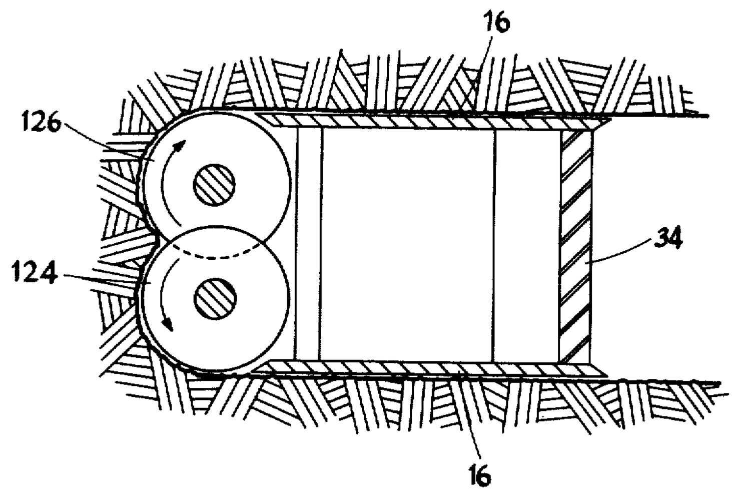


FIGURE 6

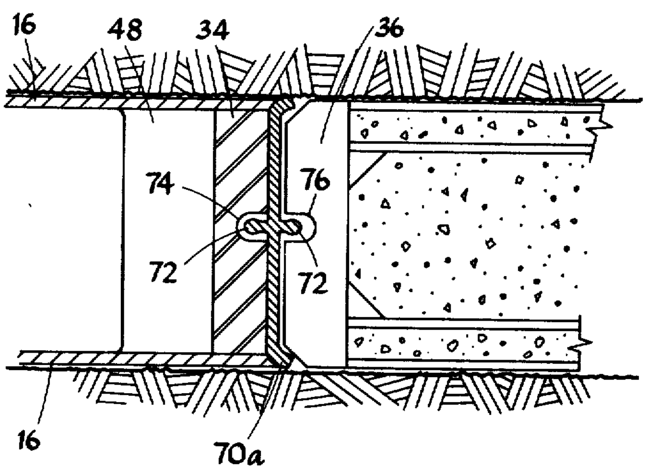


FIGURE 7a

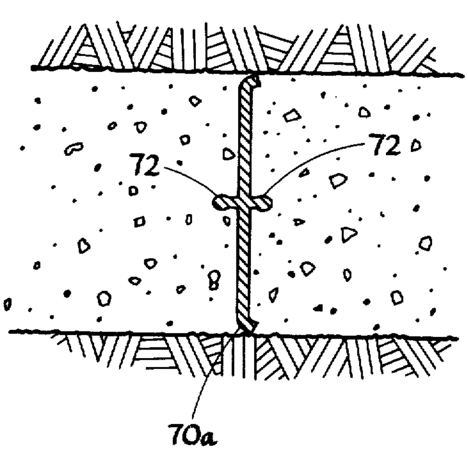


FIGURE 7b

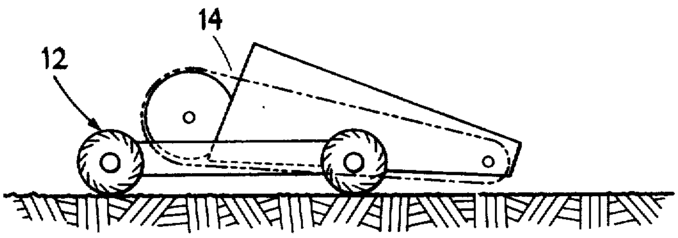


FIGURE 8

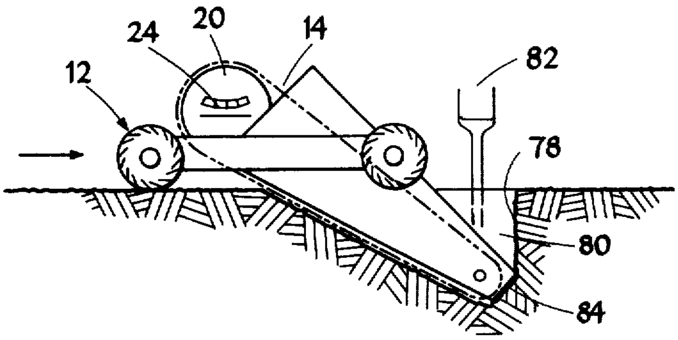


FIGURE 9

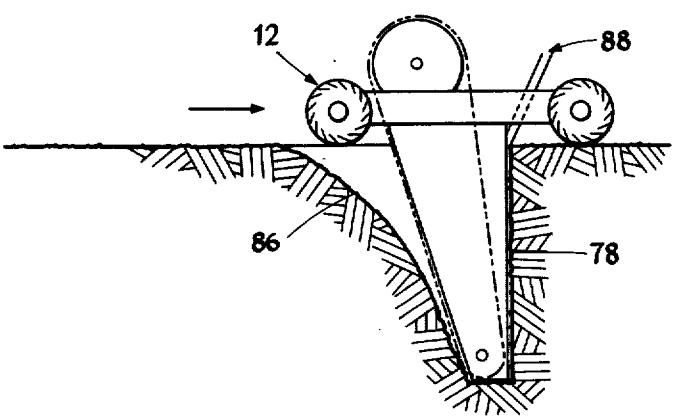


FIGURE 10

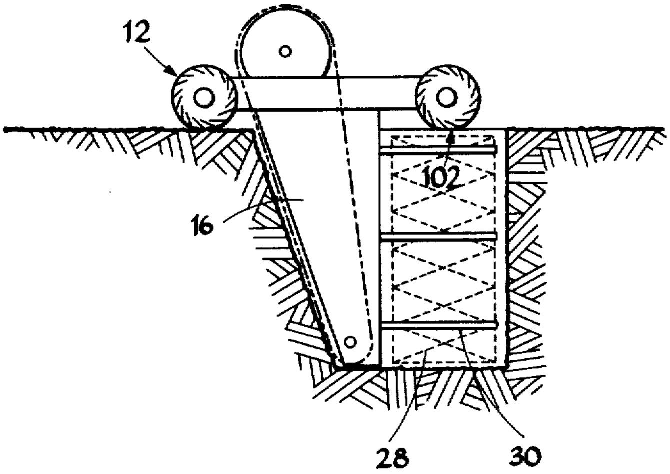


FIGURE 11

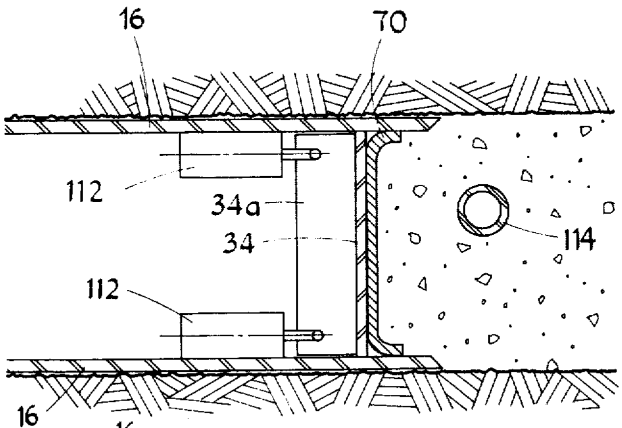


FIGURE 12a

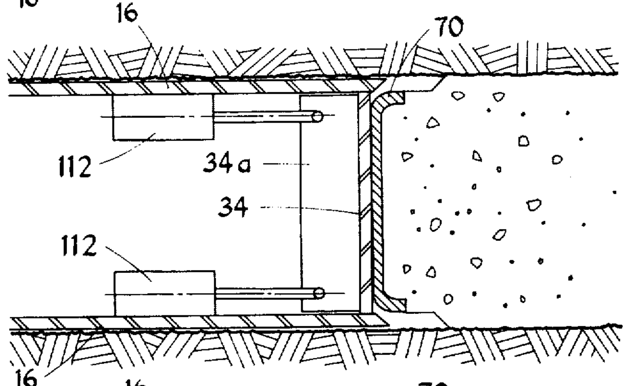


FIGURE 12b

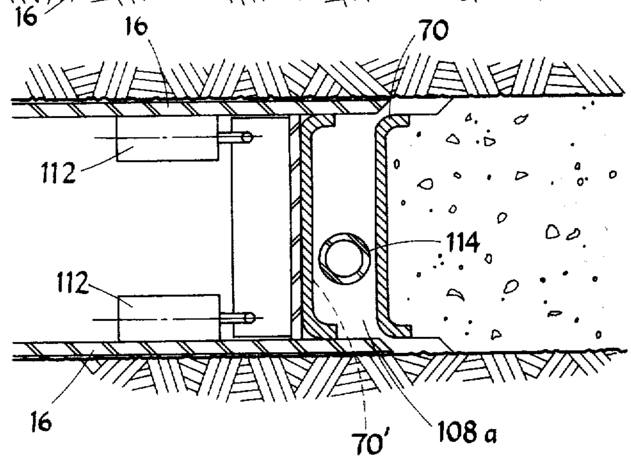


FIGURE 12c

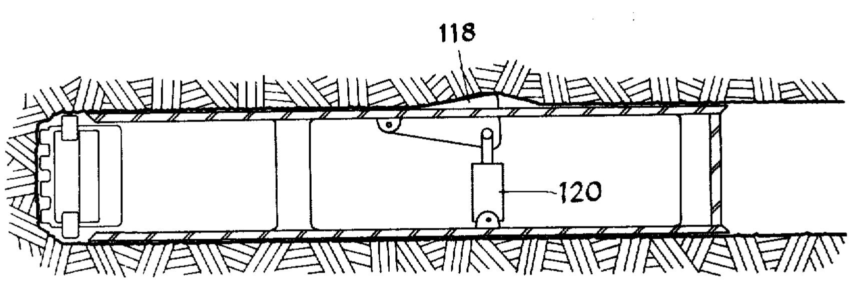


FIGURE 13

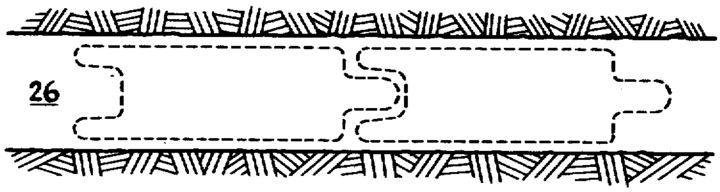


FIGURE 14a

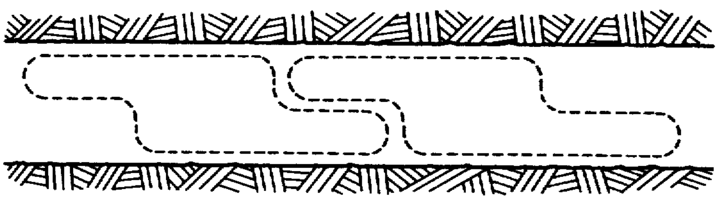


FIGURE 14b

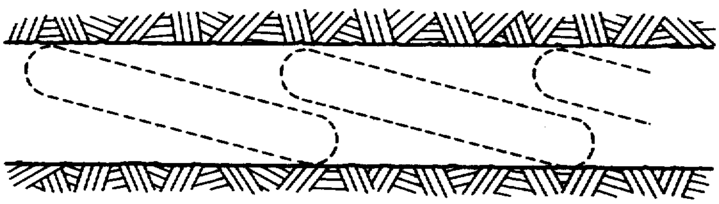


FIGURE 14c

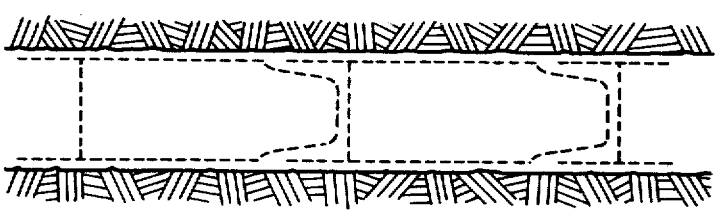


FIGURE 14d

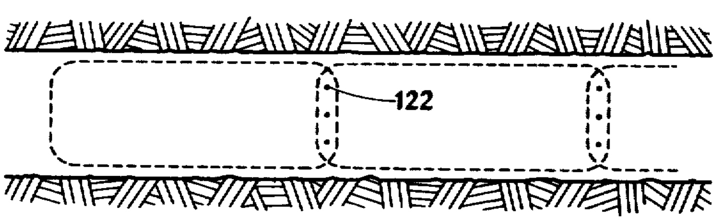


FIGURE 14e

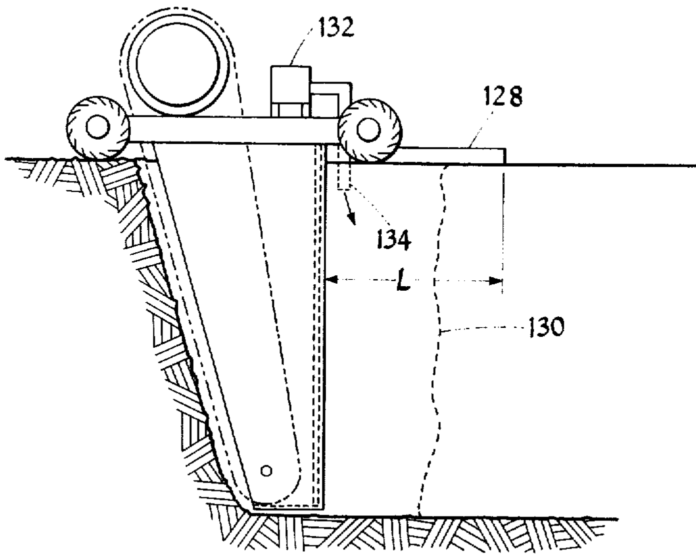


FIGURE 15

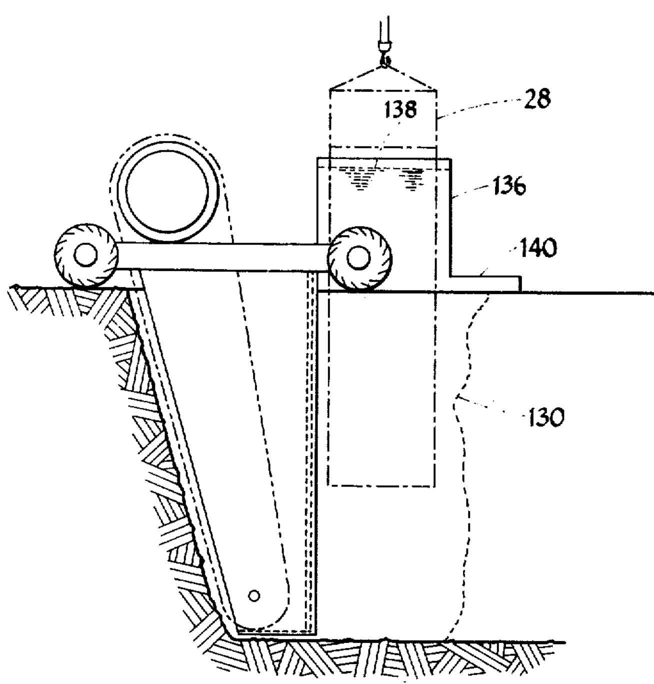


FIGURE 16

MACHINE AND METHOD FOR EXCAVATING TRENCHES AND FOR CONSTRUCTING WALLS IN TRENCHES

BACKGROUND OF THE INVENTION

This invention relates to the excavation of trenches in the earth and to the construction of walls in such trenches. The invention is particularly suitable for trenches and walls which are relatively narrow (e.g., 2 feet wide) and deep (e.g., 20 feet or more in depth).

A typical use of the present invention is in the construction of retaining walls along the margins of a tunneling site at which the "cut and cover" tunneling technique is to be employed. Such walls are necessary to prevent the shifting of earth adjacent the tunneling site and to keep to a minimum the surface width of land disturbed in the construction of the tunnel, important e.g. in urban areas.

Previous techniques for digging trenches and providing underground retaining walls have been costly and slow and often involve use of clay-like wall supporting slurries which are undesirable to handle. Furthermore, prior art techniques typically resulted in walls which have consisted of separate panels of reinforced concrete in which the joints between adjacent panels created weak spots in the total wall and which allowed the seepage of water through the wall.

SUMMARY OF THE INVENTION

It is the principal object of the present invention to provide an improved technique and apparatus for excavating trenches and constructing underground walls which avoids the various drawbacks mentioned above.

To achieve these and other objects, in one aspect the invention comprises a machine for and a method of constructing a trench in the earth, suitable for trenches of **20** feet depth and greater, which comprises the steps of inserting in the earth an excavating machine of a height corresponding to the depth of the trench desired, activating the machine, filling the trench immediately behind the machine with fluid, and providing on the excavating machine a rearwardly facing thrust surface which is exposed to the fluid whereby pressure exerted by the fluid upon the thrust surface applies forward propulsive force to the excavating machine. Preferably, the fluid is fluid concrete which is placed in the trench for the purpose of continuously casting a wall as well as serving to apply hydraulic force to the thrust surface. To increase the fluid pressure acting upon the thrust surface a stand pipe may be provided which extends above the surface of the earth or the fluid may be pumped under pressure into a closed volume to which the excavator thrust surface is exposed, that closed volume being defined by the bottom and sides of the trenches, a rear member in the trench, and a cover overlying the excavation. The cover may be attached to the excavator itself whereby the weight of the excavating machine holds the cover in position against rising.

The invention also includes a technique of "restarting" operation after a prolonged cessation (e.g., overnight stoppages). This technique includes the provision of a rearwardly directed thrust surface which is movable in the direction of the extent of the trench relative to the excavator portion of the machine, and force applying devices which enable the thrust surface to press against set concrete thereby to provide initial propulsive force upon the excavator portion for restarting the operation.

The machine and method may also include the provision of an elastomeric member which covers the rearwardly directed surface of the excavating machine and which is exposed to fluid concrete in the trench. Upon stopping operation (e.g. overnight), the concrete is permitted to set against the elastomeric member and to permanently bond thereto. Upon recommencement, and advance of the thrust wall, the pouring of concrete forward of the left-in place elastomeric member results in a continuation of the desired wall with the elastomeric member forming a tightly bonded joint in the wall.

In another aspect of the invention, a method of forming a wall in the earth is provided which comprises continuously excavating a trench and continuously pouring concrete in the excavation thus formed, the front wall which bounds the pour comprising a member carried by the excavating machine and advancing progressively therewith.

In another aspect of the invention a wall-forming machine for forming walls in the earth comprises a trench excavator having a rearwardly facing hydraulic thrust surface forming a progressing front wall of a form for pouring concrete, the side walls of the form being provided by the earthen sides of the trench. Preferably the thrust surface extends the full depth of the trench; the machine includes a pair of side shield walls disposed on opposite lateral sides of the excavator to engage the sides of the trench to prevent cave-in, the thrust surface being provided by a wall extending between and joined to those shield walls; the shield walls are joined to a bottom which closes the shield against entry of fluid concrete; the shield walls taper toward each other rearwardly and/or comprise telescopic sections enabling movement of the thrust surface relative to the excavator portion of the machine; a guide unit is removably mounted on the machine and provides a guide path for insertion of reinforcement in the trench, preferably overlapped reinforcement sections in the case of concrete; deflector plates are provided on the sides of the machine near the bottom of the trench for guiding the excavator; a pump is provided to remove fluid in the trench forward of the thrust wall; and in the case of a bucket and chain excavator, pivoted side teeth are provided in the extended position to excavate for the passage of the shield and in the retracted position to pass within the confines of the shields.

In the drawings:

FIG. **1** is a partially diagrammatic elevation of a preferred embodiment of the invention at work in the excavation of a trench and the continuous construction of a concrete wall therein;

FIGS. **2** and **3** are cross-sectional views taken on lines **2—2** and **3—3** of FIG. **1**;

FIG. **2***a* is an enlarged side view of a portion of the machine of FIG. **1**;

FIG. **4** is a horizontal cross-sectional view of an alternate shield structure.

FIG. **5** is a side view and FIG. **6** is a cross-sectional view (of enlarged scale) taken on line **6—6** of FIG. **5** of an alternate embodiment of the invention;

FIG. **7***a* is a horizontal cross-sectional view of a machine employing an alternate form of rubber mat member at the back of the machine and FIG. **7***b* is a similar view depicting the detached mat member embedded in the concrete wall;

The series of FIGS. **8–11** are diagrammatic side views illustrating the sequence involved in starting operation of the machine of FIG. **1**;

FIGS. **12***a–c* are a series of horizontal cross-sectional views of an alternative embodiment employing a movable thrust surface member, illustrating use to recommence operation after concrete next to the machine has set.

FIG. **13** is a horizontal cross-sectional view of a guidance system for the excavating machine;

FIGS. **14***a–e* illustrate alternate forms of reinformcement cage constructions for use in the practice of the invention;

FIGS. **15** and **16** are side views of alternative embodiments and

FIG. **17** is a head-on view of still another alternative embodiment.

Referring to FIGS. **1, 2** and **2***a* a tractor **12** supports a bucket and chain excavator **14** extending below the surface of the earth between a pair of side shields or walls **16.** The chain excavator travels between a small idler pulley **18** at the bottom of the trench and drive pulley **20** at the surface, pulley **18** being supported on a shaft **22** carried by shields **16** and drive pulley **20** being carried by the tractor. Drive pulley **20** is an open center device with a transverse conveyor belt **24** passing through its center to carry the spoil that dumps from the buckets in accordance with conventional bucket and chain practice. The machine travels ahead of fluid concrete being poured (from pipe **60,** FIG. **2**) into the trench to form wall **26.**

In FIG. **1** a series of wire cages **28** of reinforcing steel are shown placed in the concrete, one of which, **28**a, is shown being lowered into position by a crane (see also FIG. **3**). Each wire cage while being lowered is guided into position between guide rails **30** which extend from the back of the machine. Pressure of the concrete filling the trench acts against hydraulic thrust surface **34** which faces rearwardly of the machine, this surface **34** being provided by a wall which is joined to and extends between the trailing edges of the pair of shields **16.** As indicated in FIG. **2** these guide rails **30** are carried on a vertical structural member **36** independent of the excavating machine, member **36** and rails **30** being capable of being hoisted out of the fluid concrete as a unit when teminating the pouring of concrete while leaving the excavation machine in the trench.

Typical excavation buckets **38***a* and **38***b* are shown in FIG. **2,** bucket **38***a* being an upward-traveling bucket digging into the earth at **40,** and bucket **38***b* a downward traveling bucket returning on the back side of the bucket chain excavator. The buckets are carried around the loop on a chain **42,** attached to the chain by lugs **44.** Also in accordance with conventional practice the buckets while traveling upward and excavating the earth are guided by rails **46** to provide the force to keep them against the earth; these rails being mounted on the shields **16.** The outermost teeth on the excavation buckets **38** (FIG. **2**) are hinged to swing outward at **50***a* to excavate a trench as wide as the outer dimension of the shield while on the downward stroke they hinge inward to travel within the innermost dimension of the shield structure at **50***b*. The shield walls **16** are held in position by appropriate cross bracing **48** (FIG. **2***a*) to resist the earth pressure on the outside of the shield.

Referring further to FIG. **2***a* the hydraulic thrust surface **34** is seen again, defined by a rearwardly directed wall. This wall has a bottom extension **52** projecting forward beneath the excavator to seal the bottom of the shield structure. Also in FIG. **2***a* pump **54** is shown with a suction line **56** (and see FIG. **2**) and a discharge line **58.** This pump dewaters the region within the excavation shield.

Referring to FIG. **2** the concrete injection line **60** is independent of the guide structure and the excavation system, capable of being inserted when necessary to pump concrete or to pour concrete into the trench.

Referring to FIG. **4** an alternate shield structure is shown for use where detrimental friction on the sides of the shield is observed. It consists of a shield **62** of full width of the trench extending full height but over a limited horizontal dimension followed by a shield of reduced width **64** leaving a gap **66** between the excavated wall and the reduced dimension shield. This gap relieves the pressure on the sides of the shield. Concrete may leak into the gap at **68;** this concrete being wet and fluid would not exert as much friction on the sides of the shield as would the earth.

In another embodiment the shield walls **16** are tapered toward each other from forward to back of the machine to allow gradual easing of pressure on the sides of the shield; the shield is full width at the front to be sure of a seal against the earth so that concrete does not leak into the excavation zone.

Referring again to FIGS. **1** and **2** hydraulic thrust surface **34** is covered by a rubber member **70** which is unattached to the hydraulic surface. Member **70** hangs from support **72** at the top of the excavation vehicle. Its purpose is to separate the concrete from the excavation structure should the concrete set, the rubber member **70** then remaining bonded to the concrete.

An alternate form to member **70** is shown in FIGS. **7***a* and **7***b*. In this case the member, **70***a*, has a protrusion **72** on both sides at the center fitting within recesses **74** and **76** in the thrust surface **34** and the guide support **36,** respectively. The effect of the protrusions **72** is illustrated in FIG. **7***b* where after the concrete is cured in place the protrusions are embedded in the concrete to provide a water seal from inside to outside of the concrete wall.

Operation of the trenching vehicle starts as shown in the series of FIGS. **8** through **11** for the case where a vertical ended wall is to be formed. The tractor arrives on the construction site with the excavation system **14** held in a generally horizontal position as shown in FIG. **8.** If the excavation system extends too far to the rear to be supported by the tractor auxiliary wheels or an auxiliary derrick are used. In FIG. **9** the excavation system **14** is operated while it is lowered into the ground, the vehicle **12** traversing slightly to the rear to maintain a vertical section at **78.** The buckets as shown in FIG. **9** are moving generally forward, tending to pull the tractor **12** to the rear so that the tractor is restrained from moving rearward except at the desired rate during this part of the excavation. Spoil carried by the buckets travels over the top of the upper excavator wheel **20** and dumps onto the discharge conveyor **24** which is maintained in a horizontal position during this tilted operation. The void **80** created as the excavation moves downward may be filled temporarily with a stabilizing slurry such as bentonite mud from a portable source **82** if wall caving is experienced during start-up.

In attempting to maintain a vertical end of the wall at **78** the heel of the excavation system at **84** may encounter resistance that cannot be overcome by the weight of the excavation system. In this case a start-up hole can be pre-augured so that the heel of the excavation system **14** follows the preaugered hole. As excavation continues to full depth, as shown in FIG. **10,** the tractor **12** continues to move to the rear to maintain the vertical end of the wall **78,** the weight of the excavation system being sufficient to drive the excavation downward. The stabilizing fluid as said to be poured into cavity **80** in FIG. **9** is displaced as the excavator reaches full depth in FIG. **10.** Alternatively, if a long wall is to be constructed, as might be used for a tunnel as opposed to a short foundation wall, the start-up process does not require a vertical entry as shown in **78.** Then the tractor **12** can stand still as the excavation system pivots downward, and describes an arc of entry. The arc behind the excavation system can be filled with concrete to stabilize the walls since it will not be displaced as the excavation system reaches full depth.

Once at full depth, shown in FIG. **10,** the excavating machine begins to move forward in normal fashion with the concrete behind the hydraulic thrust surface being added from a suitable supply through a pipe **88.** When the vehicle has traversed sufficiently in this normal fashion as shown in FIG. **11,** the guide rail system **30** is inserted in the trench now filled with fluid concrete. The first wire cage **28** is inserted between the guide rails and from this point on excavation continues with placement of the wall in normal fashion: that is, concrete is continuously added to the trench behind the vehicle providing thrust for the forward progress of the vehicle and filling the trench to stabilize the wall as the vehicle progresses. A typical step in normal progression is shown in FIG. **1,** where an extensive wall exists behind the vehicle. A row of wire cages is disposed within the wall and each time the vehicle proceeds to excavate the width of one wire cage, shown in FIG. **1,** an additional wire cage is lowered into the soft concrete, the vehicle continuing to excavate forward without interruption as the wire cage is lowered.

Typical operation might consist of a trench **2** feet wide and as deep as 40 feet, the trench being dug between two precast curbs **100,** FIG. **3.** Forward progress is resisted by excavation forces which have no large horizontal components, the excavation forces being largely vertical. The excavation is at a slight slope to provide a stable excavation wall so that the earth from the forward wall does not fall into the trench as excavation proceeds.

In addition forward progress is resisted by friction of the earth pressing against the sides of the shield **16.** Most of this friction occurs at the bottom of the shield since the earth pressure is higher there. Therefore it is difficult to provide adequate tractive effort from the surface both because the tractive effort may be large and because the major resistance is at a considerable depth.

According to the invention, the tractive force is provided, or a portion of it is provided, by the pressure of the concrete acting against the hydraulic pressure surface **34.** An estimate of typical forces involved for a 40 foot by 2 foot trench might be as follows:

The earth pressure may be as high at 1,000 pounds per square foot on each side of the shield **16.** If this average earth pressure applies over a shield 40 feet high by an average length of 5 feet, and, assuming a coefficient of friction of 0.2 between the wet earth and the polished steel shield (polished by continued rubbing on the earth) a resistance of about 80,000 pounds is encountered on the two shields. At the same time the hydrostatic pressure due to the weight of the concrete in the trench 40 feet deep averages about 1,700 pounds per square foot. This pressure acts on the hydraulic thrust surface which is 2 feet wide and 40 feet high. This provides a propulsive force of 136,000 pounds or something over one and one-half times the resistance force due to friction. Excess force over that due to frictional resistance helps to force the excavation components into the earth. Hydrostatic pressure acting on the hydraulic thrust surface increases linearly with depth, the center of force on the hydraulic thrust surface therefore occurring at two-thirds depth. Frictional forces due to earth pressure while not increasing exactly linearly with depth, increase in a similar fashion and therefore the center of the frictional resistance also occurs somewhere near two-thirds depth so that the hydrostatic pressure of the concrete is nicely matched to the resistance of the earth pressure caused by friction on the shields **16.**

Excessive force due to concrete pressure may tend to push the bottom of the excavation system forward faster than the top, forcing the rear of the tractor **12** down at **102,** FIG. **11.** The generally triangular shape of the shield provides a stiff beam whereby this load at the base can be carried to the rear wheels of the tractor at **102** to resist overturning. Additional tractive effort can be applied at the surface by the tractor and in general would be desirable to maintain control of the rate of progress. If excessive force tends to be developed by the concrete for a particular soil condition, the buckets or excavation system can be so designed that they generate very high resistive force if advance is attempted at greater than the desired rate. For instance the forward edge of the bucket can be designed to closely follow the forward edge of the excavation teeth on the bucket so that, as the excavation teeth penetrate behond ½ inch the forward edge of the bucket comes in contact with the excavated soil, thereby resisting further pentration into the soil.

As with any continuous process, trouble can arise when the process is interrupted for any purpose. There may be interruptions in the delivery of concrete or due to changing work crews, or for maintenance. Provision is made for convenient start and stop operations despite the setting of the concrete.

Referring to FIGS. **12*a*–12*c*** in this configuration the hydraulic thrust surface **34** is movably mounted between the shields **16** in the direction of the length of the trench; as shown the movement is controlled by a series of hydraulic cylinders **112** distributed along the height of thrust surface **34,** mounted on the front excavator part of the machine (it could as well be controlled by cams driven by a rod from the surface). FIG. **12*a*** represents conditions when progress has ceased and concrete is left to set in the trench. The guide rails having been removed and concrete placement tube **114** must be removed. In order to restart, shown in FIG. **12*b*,** the thrust surface **34** and its supporting beam **34A** are pushed rearward against the concrete causing, by reaction, the front excavator (now operating) to move forward, along with shields **16.** After sufficient movement surface **34** is then moved forward by cylinders **112** (or appropriate cams). The rubber member **70** is left behind as shown in FIG. **12***c*, bonded to the concrete. At this time, a concrete injection hose or pipe **114** can be inserted, a new rubber member **70'** put in place and concrete pumped into the gap **108***a*. Hydraulic pressure is thus exerted against member **34** to cause advance from this point on.

An alternative to this configuration is to lift the excavator upwardly and forwardly along the excavation slope. The triangular form of the excavator, wider at the top, when moved upwardly provide a gap at the rear of the machine between the thrust surface and the set concrete into which fluid concrete can be pumped to propel the machine forward.

It is necessary to maintain vertical orientation of the excavation system to provide a vertical wall, or a desired angle. Nonuniform conditions at depth may cause the lower portion of the excavation system to migrate to one side from the desired track. To counteract this, deflecting member **118,** FIG. **13,** can be incorporated in the shield at depth. Such surfaces, actuated by hydraulic cylinder **120,** can be extended as necessary to cause side force on the desired side of the lower excavation system, thereby causing it to migrate in the desired direction.

One advantage of the present invention not possible with conventional slurry wall excavation is that, since concrete is continuously poured behind the excavation system, the separate reinforcing cages can be intermeshed to provide continuous steel strength in the final wall. FIGS. **149–***e* are top views of possible wire configurations; FIGS. **14***a* and **14***d* are tongue and groove configurations; FIG. **14***b* is similar to a ship-lap joint (in wood) and FIG. **14***c* shows normal rectangular wire cages set in place at an angle to the length of the trench and overlapping. In all cases there is no intermeshing of the steel, but there is a long overlapping of the steel which carries load from one to the other through the concrete via shear rather than tensile stress. FIG. **14***e* illustrates a scheme whereby the steel intermeshes. It is necessary in this case to lower each cage and then move it rearwardly to engage the already in-place cage behind it. The top of each cage could be easily moved to the rear from the surface. The bottom of each cage could be moved to the rear by a suitable ram mounted at the bottom of the excavation system. Once intermeshed as shown here the loops of the adjacent cages are tied together by dropping long pins **122** vertically within the intermeshing loops.

FIGS. **5** and **6** illustrate an excavation scheme alternate to the bucket and chain device, consisting of a pair of oppositely rotating augers **124** and **126.** These intermesh, and being of opposite lead direction, they rotate together without interference. Such opposite rotation cancels horizontal forces which would otherwise tend to drive the bottom of the excavation system off to one side. An advantage of the auger system is that it requires a smaller longitudinal dimension at the base, thereby requiring a smaller shield, reducing the frictional forces.

In the foregoing embodiments hydrostatic pressure available to propel the machine is limited by the weight of the concrete and the depth of the trench. In circumstances where additional force is required, concrete can be pumped into the trench under pressure, employing a lid or cover **128** (FIG. **15**) on the trench to avoid overflow of the trench. This lid **128** can be attached to the excavation machine so that the weight of the excavation machine assists in holding lid **128** down. The lid **128** extends rearwardly distance L sufficiently to cover the concrete beyond the line **130** of initial set, to resist outflow of the concrete past the rear of the lid. Pump **132,** which may be a conventional concrete pump, pipes concrete directly into the closed cavity behind the machine. Alternatively, the lid **128** may be attached to the precast rails **100,** FIG. **3.** When it is time to insert the wired cage within the system shown in FIG. **21** it would be necessary to temporarily open lid **128.** Pressure will be relieved in the system at this time and excavation will either slow or halt since insufficient propulsive force will be provided by the concrete while the pressure is relieved.

The closed volume system can be employed also with the drive thrust surface as shown in FIGS. **12***a*–**12***c*. In case the machine encounters unusual resistance, with the volume filled and closed, rams **112** may be actuated to force the surface **34** against the confined concrete; by surface **34** reacting thereagainst the rams **112** will be operative to force the forward, excavator portion of the machine forward as it operates.

Referring to FIG. **16,** another means to provide auxiliary force that does not require a removable lid is shown. In this case a stand pipe **136** raises the free surface of the concrete above ground level to **138.** Thus the pressure of the concrete is everywhere increased by the weight of the concrete times the height of the stand pipe. The stand pipe is of sufficient dimension in the direction of the trench so that wire cage **28** can be lowered directly through the open top of the stand pipe. To seal against the higher pressure of concrete, a lid **140** extends to the rear of the stand pipe again to a zone of sufficient strength behind an initial set line **130** to prevent upward flow of concrete behind the stand pipe.

This excavation system provides the opportunity to put underground a shaped cross section which progresses in the longitudinal direction. For example a footing could be placed at the base to the wall shown in FIG. **17.** This is a head on view of the base of the excavation system showing the previously described shield **16** and a typical excavation bucket **142,** carried by the excavation chain **42.** Protrusions from the side of the underground shield, indicated **144,** extend to excavate material to each side of the shield **16** to provide space, in this case, for a footing. If the soil is sufficiently soft, these protrusions can be shaped to channel earth into the excavation bucket **142** and no additional excavation effort will be required. If the soil resists such channeling, auxiliary augers **146** are provided within the extension **144** to excavate the soil in this region and loosen it so that it falls inward to the excavation bucket **142.** Concrete flows into the cavity behind the hydraulic thrust surface just as before but the hydraulic thrust surface is now shaped to match the protrusions **144.**

In order to enhance the flow of concrete, it is common to use vibrators, suspended in the concrete or attached to various structural items over which the concrete must flow. Vibrators **148** of this type can be attached to the guide rail unit to assure good flow of the concrete in this region.

Wall construction of this type is used in three major areas. The first is in foundation construction for buildings adjacent to other buildings where the wall is placed to avoid disturbance of the soil under adjacent buildings. In this application, since the wall is relatively short, it would be desirable to use the vertical entry sequence described in FIGS. **8, 9, 10** and **11.** A second application is in placing impermeable membranes in earthen dams. These membranes are generally long and thin and there would be space to use a circular arc entry which would be easier than that previously described for vertical entry. Similarly for tunnel construction in urban areas where the walls used to retain surrounding soil prevent motion of adjacent buildings, the wall is quite long, and it is generally permissible to start the excavation with a circular entry. The described invention avoids the large vertical heights required by conventional excavation systems or precast wall segments which require a crane to carry either the excavation system or the precast wall segment to a height equal to the depth of the wall. However, as described here the wire reinforcing cages are also of a height equal to the depth of the wall and would require such a crane. This crane would be lighter duty however because the wire cage is not very heavy. Even this crane can be avoided by dividing the wire cage into vertical segments, with provision to fasten these segments together as lowered into the trench. The provision of the guide rail **30** are particularly desirable in lowering and positioning a segmented wire cage. For example if the cage were divided into eight-foot vertical segments, no tall crane would be required and relatively compact equipment could be used to construct a wall in a crowded urban application.

What is claimed is:

1. In the method of excavating a trench in the earth, said method comprising inserting in the earth an excavating machine of a height corresponding to the depth of the trench desired, said excavating machine having a hydraulic thrust surface facing rearwardly relative to the direction of intended advance of the machine, operating said excavating machine to excavate the trench, and filling the trench immediately behind the excavating machine with fluid, the excavating machine preventing entry of equilibrating fluid to its forward side, whereby pressure exerted by said filling fluid upon said thrust surface applies forward propulsive force to said excavating machine to assist it in its operation, that improvement wherein said filling fluid is fluid concrete, the placing of said concrete in said trench to apply forward propulsive force to the excavating machine serving to continuously cast a wall in the trench and including use of means to exert hydraulic pressure in the fluid concrete at said hydraulic thrust surface in excess of the pressure attributable to the weight of fluid concrete in said excavated trench, said means extending rearwardly of the machine over the filled trench to the point where the concrete has hardened sufficiently to withstand said excess pressure, the resulting hydrostatic force assisting in propelling said excavating machine forward.

2. The method of claim **1** wherein a stand pipe filled with fluid concrete and extending above the surface of the earth is employed to increase the hydrostatic force.

3. The method of claim **2** including lowering reinforcing members into said trench through an open top of said stand pipe.

4. The method of claim **1** wherein the thrust surface of said excavating machine is exposed to a close volume, said volume closed by the bottom and sides of the trench, hardened concrete in the trench, and a cover overlying the excavation, and further including the step of pumping fluid concrete into said closed volume with a hydraulic pump thereby to apply fluid pressure to said thrust surface exceeding the hydrostatic pressure attributable to the weight of fluid concrete within said volume.

5. The method of claim **1** including restarting the operation of said excavating machine and continuing the pour of concrete after prolonged cessation in which concrete placed prior thereto is set, said thrust surface being movable relative to the excavating portion of the machine in the direction of the trench by force-applying members, said method including activating said excavating machine and activating said force-applying members to press said thrust surface rearwardly against concrete thereby to apply forward propulsive force to said machine, and thereafter reversing said force-applying members to draw said thrust surface forward and thereafter filling the space between said thrust surface and said set concrete with fluid concrete.

6. The method of claim **1** including providing an elastomeric member covering said thrust surface and exposed to said concrete, stopping operation of said excavating machine, allowing the concrete to set against said elastomeric member, moving the excavating machine forward leaving the elastomeric member in place permanently bound to said concrete, thereafter pouring concrete forward of said left-in place elastomeric member to apply propulsive force to said excavating machine and permanently imbed said elastomeric member in said concrete.

7. The method of claim **1** including inserting a guide unit in the trench, said unit supported by said excavating machine and moving forward therewith, and periodically sliding downwardly adjacent said guide unit a reinforcement assembly, the guide unit serving to position said reinforcement assembly in said trench.

8. An excavating machine for forming a trench in earth, said machine defining a rearwardly facing surface forming a progressing advancing front wall of the trench, means sealing said surface to prevent fluid concrete filling the trench from entering space forward of said surface, said surface constructed to withstand the pressure of said fluid concrete, said surface comprising a hydraulic thrust surface, said surface sized relative to the drag of the machine to exert substantial propulsive force to said machine, and including means to exert hydraulic pressure in the fluid concrete at said hydraulic thrust surface in excess of the pressure attributable to the weight of fluid concrete in said excavated trench, said means extending rearwardly of the machine over the filled trench to the point where the concrete has hardened sufficiently to withstand said excess pressure, the resulting hydrostatic force assisting in propelling said excavating machine forward.

9. The machine of claim **8** wherein said rearwardly directed surface is defined by a wall movable relative to the excavator portion of the machine in the direction of the trench, and force-applying members adapted to urge said wall against set concrete thereby to apply propulsive force to the excavator portion of the machine.

10. The machine of claim **8** including a pair of side shield walls disposed on opposite sides thereof to engage the sides of the trench being excavated to prevent cave-in, said rearwardly directed surface is provided by a wall extending between and joined to said shield walls and wherein said shields taper toward each other in the rearward direction of the machine whereby rearward portions of the shield allow predetermined expansion of the sides of the trench inwardly of the trench as the machine moves forward.

11. The machine of claim 8 including a guide unit removably mounted on said machine, said guide unit providing a guide path for insertion of reinforcing members into said trench to the rear of said rearwardly directed surface, said guide unit movable forwardly progressively with said machine.

12. The machine of claim 8 wherein said rearwardly directed surface is shaped to receive a vertical insert member for exposure to fluid concrete in the trench, the insert member being detachably held in place upon the machine by a top support from which it hangs.

13. The machine of claim 8 including deflecting plates along the side of the excavator for guidence thereof.

14. The machine of claim 8 having an excavator portion mounted on a frame extending the depth of said trench, said frame mounted on a tractor, said tractor including propulsion means for advancing the tractor along the earth, said frame being rotatable relative to said tractor permitting said frame to rest substantially horizontally on the earth at start-up, whereby driving of said excavator portion of said machine during start-up allows said excavator portion to enter the earth and move to a generally vertical position to initiate formation of the trench.

15. The machine of claim 8 in combination with a cover means extending rearwardly from said thrust surface to overlie said trench and form a closed fluid volume in conjunction with the sides and bottom of the trench and set concrete in rearward portions of the trench and means for increasing fluid pressure within said closed volume above the hydrostatic pressure attributable to the weight of concrete in said volume thereby to augment propulsive thrust applied to said machine.

16. The machine of claim 15 wherein said cover means and the remainder of said machine are arranged so that the weight of said excavating machine holds said cover in sealed relation to the top of said trench.

17. The machine of claim 15 wherein said cover is adapted for attachment to curb members along the sides of the trench for holding said cover in place during application of said pressure.

18. The machine of claim 15 in combination with a fluid concrete pump for introducing into said closed volume fluid concrete under pressure.

19. The machine of claim 15 wherein said rearwardly directed thrust surface is defined by a wall movable relative to the excavator portion of the machine in the direction of the trench and reversible force-applying members adapted to urge said wall rearwardly against fluid concrete contained in said volume thereby to apply propulsive force to advance the excavator portion of the machine, and thereafter operable to draw said wall forwardly closer to the excavator portion of the machine.

20. The machine of claim 8 wherein shield walls have generally upright portions extending downwardly from the surface of the earth and at least one of said shield walls at a point spaced below the surface of the earth having a side protrusion for forming a side protrusion in a wall cast in said trench, said thrust surface having a contour matched to said protrusion, said excavating machine constructed to excavate the space defined by said protrusion.

21. The machine of claim 20 including a bucket and chain excavator for excavating generally between said shields and a supplemental auger positioned at said protrusion of said shield, for excavating and feeding loosened material to said chain and bucket excavator for removal from the trench.

22. The machine of claim 8 wherein said excavating machine comprises a pair of intermeshed, counter-rotating augers disposed between shield walls and extending downwardly along the excavation face of the trench.

23. The machine of claim 8 wherein said means to exert said excess hydraulic pressure includes a stand pipe adapted to be filled with fluid concrete.

24. The machine of claim 23 including means for introducing reinforcement members through the top of said stand pipe through the fluid concrete therein to the concrete-filled trench.

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