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ABSTRACT OF THE DISCLOSURE

A top-down system earth retention system constructed with a top-down process that can be used for permanent below-grade structures provides a “green” solution for managing water rather than the typical raft-slab foundation which has a substantial environmental footprint. Vertical piles having a skeletal structure coupled thereto is finished with reinforced concrete applied in a sequential manner. The concrete facing is placed pneumatically using shotcrete. The system is well-suited to constructing below-grade portions of buildings where excavation lay back is not practical or cost effective and can incorporate permanent lateral support from tieback anchors. The below-grade structure is constructed by excavating down part way, constructing a waterproof "lift" portion of the ultimate structure, excavating down another part way, constructing another waterproof lift portion in a manner to be tied in with the lift portion immediately above, and repeating these steps until the below-grade structure is constructed to the desired depth. After the completion of the wall seeping behind the wall at ground level, if any, is measured and a determination is made as to whether the step of curtain grouting is required. If not, then any water that may be present can be directed for local gray water use.

SYSTEM AND METHOD FOR EXCAVATING AND CONSTRUCTING A SHORING SUPPORT WALL AND WATER MANAGEMENT SYSTEM

FIELD

This invention relates generally to the top-down excavation and construction of a waterproof shotcrete wall for use as a shoring wall and as a permanent water management system for lessening the carbon footprint on construction sites.

BACKGROUND

In the construction of in-ground foundation walls for large buildings, it is typical to dig out and excavate the earth to the desired depth of the foundation while building shoring infrastructure suitable to the proposed final installation and then build up the foundation walls from the bottom up. The use of temporary shoring structures are necessary to prevent cave-ins of the earth adjacent to the excavation and add to the cost and time required to construct the final installation. Most temporary shoring walls are constructed as the site is excavated to facilitate the proposed works. Construction industry methods typically incorporate a two-step process utilizing temporary lagged soldier beams cantilevered, rakered, or tie back supported, ready-mix poured in place concrete caissons, sheet piling, soil nailing, plate girders, or incrementally placed reinforced structural shotcrete to restrain the soil during excavation until a permanent structure can be built. A major problem with these temporary structures is that water leaks through walls' ties and joints. Water may come from the excavation reaching the water table, or it may come from cutting into smaller glacial deposits upon excavation. The flow of water may be negligible or it may be unexpectedly large. Accurately estimating the exact amount of water that may seep into a construction excavation site is challenging. Hydrogeologist's reports are often overstated, indicating more water than is actually present, and rarely accurately represents the final flow of groundwater that will result from a particular excavation. Engineers often 'assume' high recharge to avoid responsibility and potential insurance claims. In response to this concern, water management installations commonly known as “bath-tubs” are installed to manage the hydrogeological challenges associated with the site outside of and not inclusive of the shoring wall installations. Constructing a large concrete raft-slab bathtub to accommodate expected water based on a hydrogeologist report may cost several millions of dollars or more, depending on the size of the site. If the hydrogeologist’s report is inaccurate and overly conservative, this extra expense of overbuilding a raft-slab to accommodate a large flow of water from excavation may be unnecessary. The added financial burden and heavy environmental toll for this type of construction may not even be required, but only after the fact is this realized when the flow of groundwater is less than the amount predicted.

What is required, is a less expensive, more environmentally friendly solution to shoring walls and managing an unknown or imprecise expected quantity of ground water in an environmentally sensitive manner.

A preferred and more green solution would be to hold back and prevent groundwater from entering the excavated site. Not only would it save on the cost of building a costly concrete tub-like structure to accommodate the ingress of water from the excavation, it would save on pumping large quantities of greywater and groundwater into the municipal sewer system, which in itself has a large financial and environmental cost. Providing a wall that can hold back water or allow a small controlled flow to the excavated area that could be used locally would be a tremendous advantage. Of course, at the same time, it is preferred not to overbuild the shoring wall and it must be suitable for holding back an unexpected large flow of water in the instance that this occurs.

Therefore, most excavation shoring systems have not suitably addressed this problem. In fact, many of these systems exemplify the problems described hereinabove.

United States Patent 8,635,833 in the name of Anderson entitled “Top-down method for constructing below-grade structures” describes a system having a waterproof membrane between a concrete mudsill wall and a final concrete wall. Although the ‘833 patent provides a substantially waterproof barrier between two walls so that the inner wall furthest from the ground being excavated provides a dry support wall, a trough at the base of the wall closest to the excavated wall collects and carries water to a water collection system or piping to carry the water away. Constructing a first mudsill wall followed by a waterproof membrane with a final outer wall of concrete is costly and does not address alternative solutions for managing the flow of water from behind the wall in a temporary construction phase and a permanent final phase. Furthermore, this is not a particularly environmentally sensitive solution.

When water from the water table flows out from beneath a support wall, as in Anderson's disclosure in the '833 patent, and if the flow is considerable, a dewatering plan should be implemented which provides a protocol for handling the outflow. Dewatering can affect the soil from which the water is draining, thereby affecting lands adjacent to the excavation site. The instant invention described hereafter provides a method of managing water and lessening heavy flows that would otherwise be present. Lessening heavy flows, has multiple advantages. Large amounts of water do not have to be pumped off and treated; and, ground adjacent to the site does not have its water table altered significantly which can have profound deleterious effects. Thus both of these deleterious environmental consequences can be lessened or avoided.

Due to the errors, and over estimating of presence of ground water by hydrogeologists, it would be advantageous to build a shoring wall which serves as a groundwater management system, obviating the need for an expensive concrete bathtub to be built which has little or no use after the water collected is pumped out and which has very high environmental and material costs. Furthermore providing a raft-slab bathtub to collect water as has been done in the past, requires excavating large amounts of fill which is again deleterious to the environment. This is not required using our invention.

Accordingly, it can be seen that a need exists for an improved method for constructing a temporary drained shoring and final waterproofing support wall system.

SUMMARY

Advantageously a single permanent waterproof shotcrete shoring wall is provided constructed in-situ using a top downward construction; the initial waterproof wall allows for a curtain grout application about the base, to seal off water after an assessment of flow, if the rate of flow exceeds a predetermined amount. Another feature of this system is that in instances where the water flow from behind the wall is negligible or acceptable, that is, less than the predetermined amount, no curtain grouting is applied; and this negligible flow can be used in local applications, for gardens and other local green use. Thus, this negligible or acceptable amount of water flow, can be directed to green applications where the ground/storm water is utilized rather than entering the municipal sewage system. Constructing a substantially waterproof wall down to a depth where 'true' flow is measured, and having the option of applying curtain grouting at the base to seal off the flow, is an environmentally "green" solution compared to constructing double walls with a waterproof membrane therebetween, or installing a large and thick concrete slab bathtub to resist water pressure between footings and slabs and later pumping the water to a municipal drain. Building a single permanent waterproof shoring and support wall in accordance with this invention allows for a choice, dependent upon a flow of water coming from behind a wall. There are numerous ways in which the flow can be measured. For example, a catch basin can be placed at the bottom of the wall in a particular region, for example spanning a bay. In this instance the amount of water collected over a period of time can be measured and if the amount collected exceeds an acceptable amount, chemical curtain grouting can be used. Of course there are a myriad of other ways in which flow can be determined. If sealing is not required, dependent on water flow, sealing is not provided and substantial costs and materials are saved compared to conventional methods of building a concrete bathtub to capture and hold back water. This solution of building a drained temporary shoring wall for contingency, so that the wall can be waterproof, allows for the containment of flow that may result when chemical curtain grouting is applied. Notwithstanding, the construction of a wall that is waterproof and which is designed to hold back significant amounts of water is not trivial, and a novel and inventive method of construction and structure is described hereafter.

Chemical curtain grouting is most commonly used in industrial and civil work where excavation costs are extremely high, such as subways, tunnels, bridges, manholes, seawalls, and vaults, etc. However, chemical curtain grouting is also used in the restoration of older foundations ground improvement. Examples of chemical grouting can be found in United States patents 5,026,215, 8,272,811 and 10,106,943.

It may seem counterintuitive to build a wall that can withhold substantial amounts of water when the actual amount of water that may present upon excavation is unknown and may be a lesser amount than predicted by hydrogeology reports. However, by doing so, this method allows for an even larger amount of water specified in a hydrogeology report to be prevented from flowing and pooling when curtain grouting is applied. The curtain grouting can be applied in such a manner as to essentially stop the flow of water or to limit the flow in a controlled manner. The grouting is applied by injecting a polymer concrete mix into rows of holes at high pressure into locations in the ground.

Thus, a shoring wall is built in a multi-stage process as described hereafter wherein, in a first stage, the wall is constructed in a top down excavation and is waterproof and in a second stage a measuring device measures the outflow of water from the base of the wall built in the first stage. In a particular embodiment a determination is made in dependence upon the measured flow and if the flow exceeds a predetermined amount, a third stage is enacted, where curtain grouting is applied. Although in some instances, the waterproof wall built in the first stage, may be considered by some as overbuilt, if there is little or no water present, we have found that this is a much less costly method and is an environmentally more sound choice than typical shoring wall solutions that in a temporary functionality holds back water pressure that require a raft-slab bathtub to accommodate large water flows, and subsequently pumping the water into a municipal sanitary drain which in some municipalities such as the greater Toronto area is metered and charged for.

Conveniently, whether curtain grouting is applied, or not, the water, termed hereafter, ground/storm water is made usable on the site and can be used locally rather than to be added to the sanitary sewer system further saving costs.

The proposed installation combines a unique and waterproof liquid cementitious application, in the form of waterproof "shotcrete" with the site shoring and hydrogeological requirements into a single installation. This significantly reduces the cost, schedule and overall carbon footprint associated with the site. Furthermore, there is less excavated material that needs taken off-site.

Generally described, the present disclosure relates to a novel method of constructing a high strength low shrinkage (ZCWS) shoring foundation wall system and monitoring and managing groundwater flowing from behind the wall system.

The method generally comprises drilling a series of holes in the ground and installing a series of spaced-apart vertical structural steel beams in the holes; filling a space around the vertical structural beams with concrete having a strength sufficient to prevent twisting and movement of the structural steel beams installed in the holes, that would jeopardize the integrity of the shoring foundation wall, resulting in cracking; beginning at a first level of the structural steel beams and working downwardly, making the foundation wall in multiple horizontal sections, one horizontal section at a time from top to bottom, each horizontal section made by:

(i) excavating soil between 3 and 6 feet creating a soil wall and providing a limited excavated space for constructing a portion of a concrete wall;

(ii) providing an excavation support system placing widths of drain board adjacent to the soil wall within the excavated space and constructing a wall using rebar coupled to the structural steel beams and applying a waterproof ZCWS spanning and coating the structural steel beams, the rebar and the drain board with waterproof shotcrete; and,

(iii) monitoring an amount of water collected about the base of the ZCWS waterproof shotcrete wall in a containment region by using a measuring instrument to determine flow and if the flow is greater than a predetermined amount or the water collected from the base of the wall residing in the containment region exceeds a predetermined amount, applying curtain grouting to a region about the base of the wall so as to stop water from draining from behind the wall through to the containment region.

In order to ensure that the finished wall is waterproof and has substantially no cracks an inventive method of tying together regions of applied ZCWS to form a single uniform wall is used which will be described hereafter. This relies on feathering joints on all 4 sides of a finished region.

We believe that step (ii) of constructing the excavation support system is just one or several novel and inventive aspects of this invention and will be described in detail hereafter. Preferably the present invention comprises an earth retention method and system constructed with a top-down process that can be used prior to constructing permanent below-grade structures.

In accordance with an aspect of this invention, there is provided, a method of building a support wall and managing water comprising:

a) drilling a series of holes in the ground and installing a series of spaced-apart vertical structural steel beams in the holes;

b) filling a space around the vertical structural beams with concrete having a compressive strength of at least 5 mPA to secure the steel beams within the holes and to lessen twisting and movement of the structural steel beams installed in the holes;

c) beginning at a first level of the structural steel beams and working downwardly, making the foundation wall in multiple horizontal sections, one horizontal section at a time from top to bottom, each horizontal section made by:

(i) excavating soil between 3 and 10 feet creating a soil wall and providing a limited excavated space for constructing a portion of a concrete wall;

(ii) providing an excavation support system by placing drain board adjacent to the soil wall within the excavated space;

installing a meshwork of rebar wherein the rebar is coupled to the steel beams.

(iii) installing anchors having anchor heads coupled to the structural steel beams to secure the steel beams to the soil wall;

(iv) coating exposed structural steel beams, drain board, rebar, and anchor heads with a first layer of shotcrete forming side-by-side regions, neighbouring sides of two adjacent regions having a complementary feathered edges, together forming a feather joint therebetween wherein one feathered edge overlaps the other such that one of the feathered edges is an under-feather and the other is an overlapping over-feather; and, wherein the under feather is formed before an over-feather, and wherein the under feather is first troweled and a water proofing compound is applied to the under feather, before the over-feather is formed,

wherein adjacent regions of neighbouring horizontal sections are joined with feather joints such that lower edges of regions of an upper horizontal section are under-feathered and upper edges of regions of a lower neighbouring horizontal section have complementary over-feathered edges;

applying a second layer of shotcrete over the first layer, and

curtain grouting a region about a bottom of the wall to lessen a flow of water from behind the wall.

This invention provides a method and system for building a wall capable of withstanding forces and pressure as a function of excavating and disturbing the water table or glacial deposits.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic flow chart of a method of constructing below-grade structures according to a first example embodiment of the present invention, showing steps for carrying out the method.

FIGS. 2A-2E are schematic illustrations of a step portion of the method of FIG. 1, showing the installation of vertical structural steel beams/soldier piles in the earth.

FIGS. 3A-3B are schematic illustrations of a step portion of the method of FIG. 1, showing the excavation of earth for an initial lift.

FIG. 4 shows and ZCWS-1 under-feather edge after troweling.

FIG. 5 is a cross section showing a feather joint created by applying high strength waterproof shotcrete over a first region and wherein the feathered region is covered by a second application of shotcrete over an adjacent region which spans and covers the feather joint of the first region.

FIG. 6 is a drawing showing the tabs welded to the structural steel beams.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

FIG. 1 shows a schematic, high-level flow chart depicting a method 10 of constructing below-grade structures according to a first example embodiment of the present invention, showing steps for carrying out the method. As shown therein, the first step 100 in the process is to survey the site to lay out the position of the foundation walls and steel pilings. The next step 200 is the installation of the steel pilings. Holes are drilled and the steel piles are each placed within a hole. Support piles ranging in size from W12 to W24 may be used and are placed in holes having a diameter of 0.75m to 1.2m respectively. The space between the pile and the hole wall is then backfilled with concrete having a compressive strength of at least 2 megapascals (mPA) and preferably 6 mPA to 10 mPA. Reinforcing the piles in this manner obviates or lessens any twisting of the piles that would likely otherwise occur. Eliminating twisting is critical so that the final wall is crackless and waterproof and can stand up to forces over time.

This is followed by step 300, the excavation of a first "lift"; a vertical excavation of some 4-8 feet, typically 5-6 feet extending laterally as far as needed. Due to the sheer size of these walls on large projects, and the amount of shotcrete that can be applied in a single day, each lift or level is comprised of multiple side-by-side regions that are constructed and knitted together in a particular fashion over days of applying shotcrete. In step 400 a first level of the crackless waterproof wall is constructed. The term “crackles” used hereafter is to mean a wall with zero or no cracks visible to the human eye or cracks that water leaks from referred to in this document as zero crack waterproof shotcrete (ZCWS),. Drain board is positioned in place between the steel pilings and tabs 62a and angled tab 62b shown in FIG. 6 are welded to the steel pilings 64; rebar is wire tied to the welded tabs. The welding of the tabs is done as the piles at each lift are exposed through excavation. Holes are drilled into the soil and ties or rods having anchor heads are installed into special tabs welded to the steel pilings to secure the steel pilings, rebar and drain board to the ground behind.

Referring once again to step 200, the vertical structural elements in the form of steel piles are installed. These piles can consist of steel piles in the form of H-piles, wide flange sections or pipes or concrete piles.

As shown in the example depicted in FIGS. 2A-2E, the piles 101-105 are installed at regular intervals around the perimeter of the planned excavation prior to commencement of the excavation. The face of pile is set back from the planned face of wall location by the design thickness of the concrete facing and waterproofing. The steel piles are installed to a depth below the planned bottom of excavation as determined by the structural design of the excavation support system.

Once the H-pile locations have been laid out by a registered land surveyor, the pilot hole is drilled to the design bottom of pile elevation (see FIGS. 2A-2B). The H-pile section is then lowered into the pilot hole plumb (vertical) and back filled with concrete having a compressive strength of preferably 6-10 mPA. See FIGS. 2C-2D. This step is repeated until all of the H-pile sections are installed (FIG. 2E).

Referring now to Step 300 after installation of the H piles, the general excavation commences. The excavation is typically made in 5-foot deep lifts, but this may vary depending on the soil type and construction requirements. See FIGS. 3A-3B. The depth of the lift 110 is indicated generally as L. The general idea behind using 5-foot lifts is to make an excavation that allows for easy work by the construction workers without requiring ladders, scaffolding, etc, and which generally avoids the need to temporarily shore up the earth face where the workers are working. In this regard, note that if the excavation were thirty feet deep, substantial shoring would be required in order to protect the workers from the substantial hazard of such a high unsupported earth face. Moreover, to work at the top of a thirty-foot excavation would require very long ladders and/or high scaffolding. The present invention avoids these problems by breaking the excavation down into sections scaled to the general working range of a human worker and scaled to minimize or avoid the need for temporary shoring. In this regard, the five foot depth of the excavation lift is not inflexible. Indeed, excavation lifts from a few feet to perhaps as much as eight feet work well. The more preferred range is between about four and six feet, with the most preferred excavation lift depth being about five feet.

The earth is excavated flush with the interior face of the steel piles to create a first lift 110 (see FIG. 3B). The earth surface should be vertical and smooth to receive the drainage board. Loose soils may be present at the top of the excavation and the initial lift may require some additional preparation to obtain a vertical smooth surface.

Once the concrete back-fill surrounding the H-piles has had ample time to set (at least 12 hours), the first excavation lift is made. This lift 110 is typically in the range of about 4 to 6 feet, as previously described.

Once excavated, the soils can be removed some 2-4 inches behind the face of the pile to create a "cavity" within each bay (between two H-piles) to accept drainage board.

This first excavation, or horizontal section referred to hereafter as the first lift, is often comprised of a plurality of horizontal regions when the length of the first lift or horizontal section is for example greater than 150 feet. In some instances each horizontal region may be less than 150 feet. This sometimes depends on how much shotcrete can be applied in one application.

In this instance, each horizontal lift or section is made of sub-sections or rectangular regions which are knitted together in a novel manner through feathered joints of applied ZCWS shotcrete. Furthermore, each horizontal section is knitted in a similar manner to an adjacent horizontal section below, through feathered joints of applied ZCWS. Each rectangular region is formed by constructing a wall portion of drainboard, a steel meshwork of rebar connected to the structural steel beams overlaying the drainboard, ties or anchor spigots coupled to the stable vertical structural steel beams drilled into soil behind the drainboard; and waterproof shotcrete layers coating the aforementioned wall components; the regions in each horizontal section form a patchwork of interconnected regions, interconnected by an overlapping meshwork of rebar and feathered joints so that the horizontally and vertically-adjacent sections are tied together in a similar manner to provide excellent structural integrity, as well as effective water-proofing.

Preferably a first layer of ZCWS, referred hereafter as ZCWS-1 is comprised of 300 to 400 kg of Portland cement per m^3. The mix may contain Fly Ash with a preferred range of between 30 kg and 112.5 kg. Alternatively, the mix may contain slag with a preferred range of between 60 kg and 225 kg. The most preferable embodiment of the mix will contain between 6kg and a maximum of 40.5 kg two-part powder containing micro-silica powder. The preferred embodiment of the admixture shall also contain between 5 kg to a maximum of 36 kg of light-burn calcine magnesia powder. The micro-silica in the preferred admix includes a particle specific surface area (SSA) between $20m^2$/gr and $200m^2$/gr with an average particle size of between 15nm and 40nm in order to meet the preferred admix.

The second applied layer of ZCWS (ZCWS-2) which covers the first layer of shotcrete is preferably comprised of 300 kg to 400 kg of Portland cement per m^3 and may contain between 30 kg and 112.5 kg of fly ash. Alternatively, the mix may contain between 60 kg and 225 kg of slag. The preferred mix will contain between 1 kg and up to 6 kg two-part powder containing micro-silica powder. It is also preferable the admixture shall also contain between 5 kg to a maximum of 36 kg of light-burn calcine magnesia powder. The micro-silica should have a preferred particle specific surface area (SSA) between $20m^2$/gr and $200m^2$/gr. The particle sizes preferably have an average between 15nm and 40nm. The mix shall contain between 3 kg to a maximum of 30 kg of micro-silica with an average specific surface area (SSA) of 20m2/gr. Our preferred embodiment of the mix shall contain from 0.09 kg to 0.45 kg of natural rheology modifier and mix stabilizer (Acti-Gel). The mix preferably contains a preferred range from 6 kg to 12.5 kg of liquid crystalline admixture (Velosit™ CA 115) which will contain a choice of melamine, naphthalene and/or polycarboxylate as water reducers. This ZCWS-2 layer is reinforced with microfibres, preferably 3 kg to 4.5 kg per cubic meter of concrete.

The steel piles, drainboard, rebar and ties together form an integrated overall skeletal structure which is coated with a sprayed first layer of ZCWS liquid concrete, preferably so-called "shotcrete" ZCWS-1, sprayed from a hose over this foundation grid work to create a sprayed-in-situ concrete wall section, the outside face of which is then smoothed if desired. A second layer ZCWS-2 is applied over the outside face when the first layer cures. Due to the sheer size of a horizontal lift when building large structures, this application of each layer of shotcrete is done in sections or regions across a lift; a region may span 150 feet or more depending on the rate at which shotcrete can be applied. Thus, when an entire lift is completed it is comprised of a plurality of side-by-side rectangular regions having a substantially same height but which may vary in width. One problem which may lead to leaking and breakdown of such a wall is a lack of integrity at joints or seams where two adjacent wall regions meet. Knitting two sections together presents particular challenges. Notwithstanding, we have discovered a method, wherein the integrity of the wall is not compromised and wherein very large walls can be constructed which can retain water and not crack.

Turning now to the chart below 4 lifts are depicted wherein regions, shown as cells for the purpose of explanation, each of approximately 150 feet wide and approximately 5 feet in height are shown. Cell (1,1) represents the first region of the first lift that is constructed and sprayed with a first layer of high strength low shrinkage (ZCWS) shotcrete. Cell (1,2) represents the second region of the first lift that is constructed and sprayed with the first layer of ZCWS, followed by regions, (1,3) and (1,4). After the first lift regions (1,1) to (1,4) are completed, region (2,1) of lift 2 is constructed and sprayed with a first layer of ZCWS, after which regions (2,2), (2,3), and (2,4) are constructed and similarly sprayed. Then lift 3 is constructed followed by lift 4 in a similar manner.

		above ground	above ground	above ground	above ground
lift 1		1,4	1,3	1,2	1,1
lift 2		2,4	2,3	2,2	2,1
lift 3		3,4	3,3	3,2	3,1
lift 4		4,4	4,3	4,2	4,1

Essentially this is a patchwork of wall regions constructed into a single contiguous crackless waterproof wall where all vertical and horizontal edges of regions are joined to adjacent edges of regions with waterproof crackless joints. A key aspect of the construction is the manner in which these regions (1,1) to (4,4) are knitted together both horizontally and vertically.

Since each region has 4 sides; any sides of a region which meet a side of an adjacent region is feathered. The taper of a feather is preferably less than 35 degrees and preferably more than 19 degrees. Providing a gradual slope is desired to achieve strength and an adequate bond between an under-feathered edge and an over-feathered edge. Referring now to FIG. 4 a feathered edge is shown wherein the average thickness of the applied first layer of ZCWS 40a is shown to be 5 inches thick tapering to a thickness of about 1 inch. The feathered edge is smooth after a wood float has been passed over the feathered area.

After washing dirt off, troweling and smoothing the area, a spray-lock compound for example, a post nano-colloidal silica spray such as SCP-327 for which data can be found at https://spraylockcp.com/wp-content/uploads/2014/08/SCP-327-tech-Data.pdf, is applied to the smooth feathered area. After this step is complete, and 24 hours have passed since the application of the first layer of ZCWS, spraying of shotcrete begins on the second region 40b and the first feather joint 42a is covered with an over-over feather or complementary feather 42b essentially removing any visual indication that there is a feather joint in the wall. This is shown in FIG. 5 where a complete feather joint is shown.

Preferably feather joints are formed in the same manner, however the order in which feather joints are formed is important. For example, the description above delineates how the first region 40a and second region 40b are formed serially, where the feather 42a of region 40a is completed before the spraying of shotcrete of the second region 40b begins. This defines feather joint 42a as being an under-feather and feather joint 42b as being an over-feather covering feather joint 42a.

After the first lift is complete in step 500 excavation takes place and in step 600 execution of the next lift is executed in a similar manner to the first lift.

Referring once again to the chart above, region (1,1) is the first region having shotcrete applied to it. This region has at least two edges which are under-feathered; the edge facing not yet formed region (2,1) and the edge facing region (1,2). The purpose of providing these under-feather surfaces is to accept an over-feather from (2,1) and (1,2) so that these can be knitted together to be crackless and waterproof as described above. Region (1,2) is applied after (1,1) is cured and has an over feather covering the under-feather of (1,1).

This is explained above with reference to under-feather 72a and over-feather 72b. This provides a fully waterproof joint between (1,1) and (1,2). Two other edges of (1,2) which are adjacent to other regions are under-feathered. Thus region (1,2) will have one over-over feather conjoining (1,1) and an under-feather conjoining (1,3) and an under-feather conjoining (2,2). (1,3) and (2,2) will have complementary over-feathers to join with (1,2). Moving downward to lift 2, region (2,1) is constructed. One edge overlaps the under-feather of (1,1) with an over-feather and the other two edges are under-feathered to receive an over-feather from another region. Region (2,2), has two over feathered edges and 2 under feathered edge 2. The over feathered edges cover under feathered edges on (1,2) and (2,1). This method of patterning provides a substantially crackles and waterproof wall. As lifts are completed a second layer of ZCWS-2 is applied over the first layer so that the entire wall has two layers of shotcrete coating.

In shotcrete construction, surface preparation between layers to provide full bond is important. Similar preparation should be considered when an under-feathered joint is being coated with an over-feather of shotcrete. ACI 506.2-13, “Specification for Shotcrete,” specifically addresses this in the requirements of Sections 3.4.2.1 and 3.4.2.2 that: “3.4.2.1 When applying more than one layer of shotcrete, use a cutting rod, brush with a stiff bristle, or other suitable equipment to remove all loose material, overspray, laitance, or other material that may compromise the bond of the subsequent layer of shotcrete. Conduct removal immediately after shotcrete reaches initial set. “3.4.2.2 Allow shotcrete to stiffen sufficiently before applying subsequent layers. If shotcrete has hardened, clean the surface of all loose material, laitance, overspray, or other material that may compromise the bond of subsequent layers. Bring the surface to a saturated surface-dry (SSD) condition at the time of application of the next layer of shotcrete.” The shotcrete specification is actually more stringent than ACI 318-11, Section 6.4, on construction joints, because it requires removal of all potential bond-breaking materials immediately after initial set, as well as the cleaning and SSD conditions provided for in 3.4.2.2.

When the second layer of ZCWS-2 is applied over the first layer, care should be taken to ensure that feather joints of the second layer do not line up and directly cover feather joints from the first layer. Preferably, first and second layer feather joints should be staggered. It is also suggested that the second layer of ZCWS-2 contains non-steel micro-fibers thereby lessening any chance of cracking.

It should be noted, that regions that have an adjacent upper lift and a lower lift a region on each side thereof are feathered to be seamlessly joined to each of the 4 neighboring wall regions. For example, region (2,2) is adjacent regions (1,2) (2,1) (2,3) and (3,2). (2,2) will have an over feather joining (1,2) and (2,1) and will have an under-feather covered by an over-feather of (3,2) and (2,3). An edge that meets a cured under-feather will be an over-feather.

After the second layer of ZCWS-2 is applied it is cleaned and a waterproofing compound is applied to it.

Referring back to the flowchart of FIG. 1 after step 600 and 700 are complete, any flow of water from the bottom of the wall is monitored in step 800. Monitoring can be done in various ways. A visual inspection may indicate that the flow is considerable and that action must be taken to stop the flow, or a flow meter can be used to determine if the flow exceeds an acceptable or predetermined amount. A flow of water in any particular bay may be passed through a flow meter as it is collected, or it can be collected in a basin and measured over a duration of time to determine the flow rate per bay. For example, if the flow exceeds 1 litre per minute per excavation bay, action by way of applying grout to the soil behind the wall may be taken to stop the flow. In this instance, curtain grouting the bottom section of the wall is used to prevent water from flowing. This curtain grouting seals the soil behind the shotcrete wall and the flow of water is abated. In some instances it may be necessary to install a floor slab to carry water pressure that may be present.

It is to be understood that this invention is not limited to the specific devices, methods, conditions, or parameters of the example embodiments described and/or shown herein, and that the terminology used herein is for the purpose of describing particular embodiments by way of example only. Thus, the terminology is intended to be broadly construed and is not intended to be unnecessarily limiting of the claimed invention. For example, as used in the specification including the appended claims, the singular forms "a," "an," and "the" include the plural, the term "or" means "and/or," and reference to a particular numerical value includes at least that particular value, unless the context clearly dictates otherwise. In addition, any methods described herein are not intended to be limited to the sequence of steps described but can be carried out in other sequences, unless expressly stated otherwise herein.

While the claimed invention has been shown and described in example forms, it will be apparent to those skilled in the art that many modifications, additions, and deletions can be made therein without departing from the spirit and scope of the invention as defined by the following claims. For example, while the drawings and description show and describe the exemplar use of H-piles, other shapes of piles can be employed, as known in the art.

CLAIMS

What is claimed is:

1. A method of building a support wall and managing water comprising:

d) drilling a series of holes in the ground and installing a series of spaced-apart vertical structural steel beams in the holes;

e) filling a space around the vertical structural beams with concrete having a compressive strength of at least 2 mPA to secure the steel beams within the holes and to lessen twisting and movement of the structural steel beams installed in the holes;

f) beginning at a first level of the structural steel beams and working downwardly, making the foundation wall in multiple horizontal sections, one horizontal section at a time from top to bottom, each horizontal section made by:

(v) excavating soil between 3 and 10 feet creating a soil wall and providing a limited excavated space for constructing a portion of a concrete wall;

(vi) providing an excavation support system by placing drain board adjacent to the soil wall within the excavated space;

(vii) welding tabs to the structural steel beams;

(viii) installing a meshwork of rebar wherein the rebar is coupled to the welded tabs.

(ix) installing anchors having anchor heads coupled to the structural steel beams to secure the steel beams to the soil wall;

(x) coating exposed structural steel beams, drain board, welding tabs, rebar, and anchor heads with a first layer of shotcrete forming side-by-side regions, neighbouring sides of two adjacent regions having a complementary feathered edges, together forming a feather joint therebetween wherein one feathered edge overlaps the other such that one of the feathered edges is an under-feather and the other is an overlapping over-feather; and, wherein the under feather is formed before an over-feather, and wherein the under feather is first troweled and a water proofing compound is applied to the under feather, before the over-feather is formed,

wherein adjacent regions of neighbouring horizontal sections are joined with feather joints such that lower edges of regions of an upper horizontal section are under-feathered and upper edges of regions of a lower neighbouring horizontal section have complementary over-feathered edges.

2. A method as defined in claim 1 comprising, coating a second layer of shotcrete over the first layer of shotcrete and forming feather joints where adjacent regions of the second layer of shotcrete meet.

3. A method as defined in claim 2 wherein the feather joints formed in the second layer are in different locations than feather joints formed in the first layer.

4. A method as defined in claim 2 or 3 wherein the shotcrete composition in the first layer is different than the shotcrete composition of the second layer.

5. A method as defined in claim 4 wherein the second layer of shotcrete has microfibers therein.

6. A method as defined in any one of claims 1 to 5, wherein the first layer of shotcrete first includes a shrink compensating admixture including nanometric colloidal silica.

7. A method as defined in claim 6 wherein the average thickness of the first layer is at least 4 inches.

8. A method as defined in claim 7, wherein the feather angle is between 19 and 40 degrees.

9. A method as defined in claim 3, 4, or 5 wherein the first and second layers of shotcrete together have a compressive strength of at least 20 MPA.

10. A method as defined in any one of claims 1 to 9 comprising applying a nano-colloidal silica spray to at least one of the layers of shotcrete.

11. A method as defined in any of claims 3 to 10 comprising float finishing the second layer of shotcrete, maintaining the surface heat above 5 degrees for at least 8 hours.

12. A method as defined in any of claims 1 to 11 comprising:
monitoring a flow of water at a base of the support wall; and,
if the flow of water is more than an acceptable amount, curtain grouting a region about the base to lessen or stop the flow of water.

13. A method as defined in claim 12 wherein the acceptable amount is a predetermined amount.

14. A method as defined in claim 12, wherein the predetermined amount is 2 liters per minute per bay, wherein a bay is approximately a width of a width of drain board.

15. A method as defined in any of claims 1 to 11 wherein curtain grouting is applied to a region about the base of the wall so as to lessen the flow of water.

16. A method of building a support wall and managing water comprising:

g) drilling a series of holes in the ground and installing a series of spaced-apart vertical structural steel beams in the holes;

h) filling a space around the vertical structural beams with at least 5 concrete to secure the steel beams within the holes and to lessen twisting and movement of the structural steel beams installed in the holes;

i) beginning at a first level of the structural steel beams and working downwardly, making the foundation wall in multiple horizontal sections, one horizontal section at a time from top to bottom, each horizontal section made by:

(xi) excavating soil between 3 and 10 feet creating a soil wall and providing a limited excavated space for constructing a portion of a concrete wall;

(xii) providing an excavation support system by placing drain board adjacent to the soil wall within the excavated space; installing a meshwork of rebar wherein the rebar is coupled to the steel beams.

(xiii) installing anchors having anchor heads coupled to the structural steel beams to secure the steel beams to the soil wall;

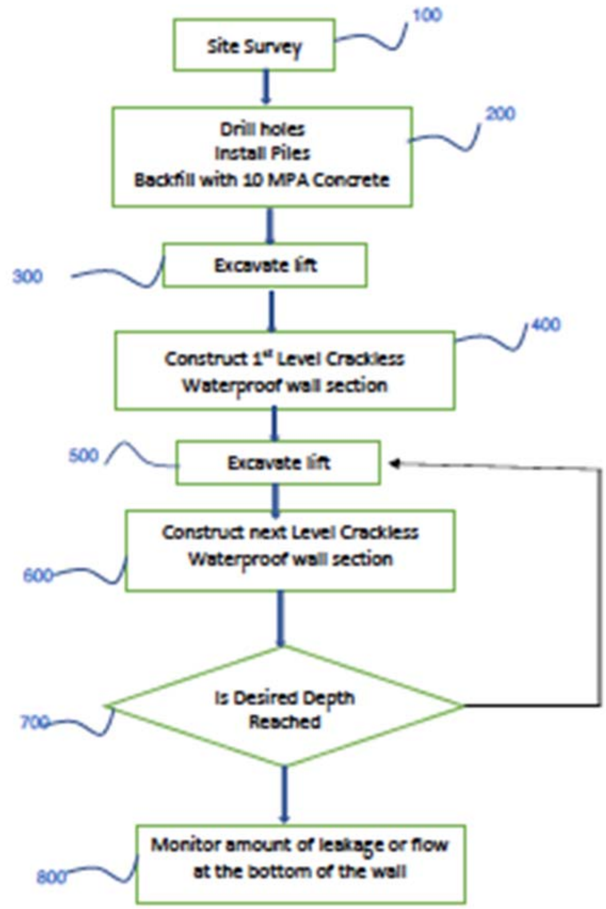
(xiv) coating exposed structural steel beams, drain board, rebar, and anchor heads with a first layer of shotcrete forming side-by-side regions, neighbouring sides of two adjacent regions having a complementary feathered edges, together forming a feather joint therebetween wherein one feathered edge overlaps the other such that one of the feathered edges is an under-feather and the other is an overlapping over-feather; and, wherein the under feather is formed before an over-feather, and wherein the under feather is first troweled and a water proofing compound is applied to the under feather, before the over-feather is formed,

wherein adjacent regions of neighbouring horizontal sections are joined with feather joints such that lower edges of regions of an upper horizontal section are under-feathered and

upper edges of regions of a lower neighbouring horizontal section have complementary over-feathered edges;
applying a second layer of shotcrete over the first layer, and
curtain grouting a region about a bottom of the wall to lessen a flow of water from behind the wall.

17. A method as defined in any of claims 1 to 16 wherein at least one region has one or more sides which have an under-feather and one or more sides which have an over feather.

10



Site Survey
100
Drill holes
Install Piles
Backfill with 10 MPA Concrete
200
300
Excavate lift
Construct 1st Level Crackless
Waterproof wall section
400
500
Excavate lift
Construct next Level Crackless
Waterproof wall section
600
Is Desired Depth
Reached
700
Monitor amount of leakage or flow
at the bottom of the wall
800

FIG. 1

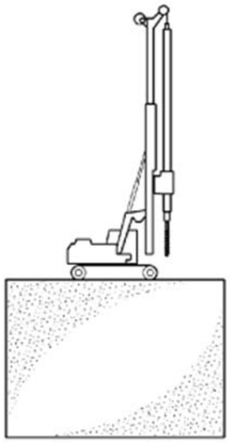


FIG. 2A

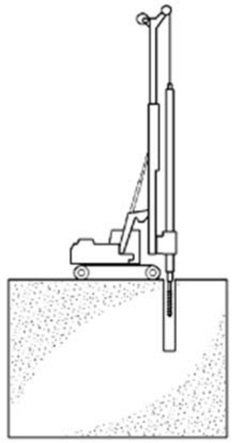


FIG. 2B

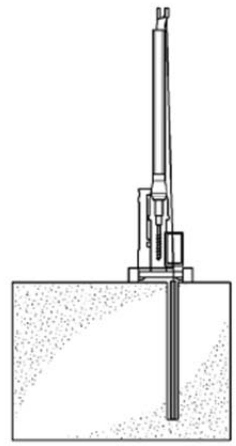


FIG. 2C

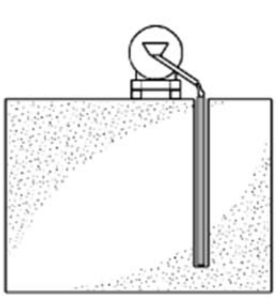


FIG. 2D

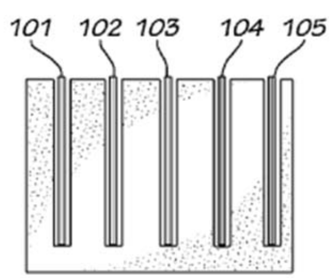


FIG. 2E

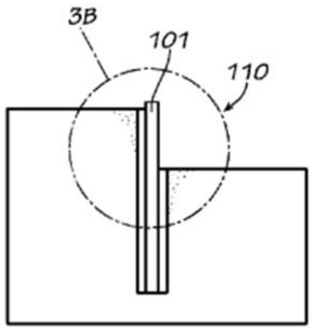


FIG. 3A

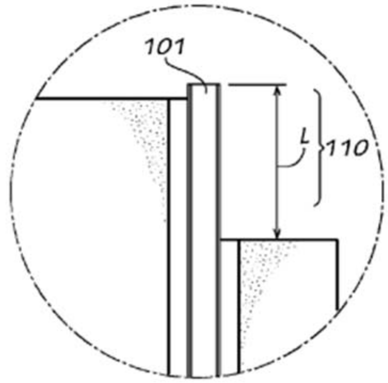


FIG. 3B

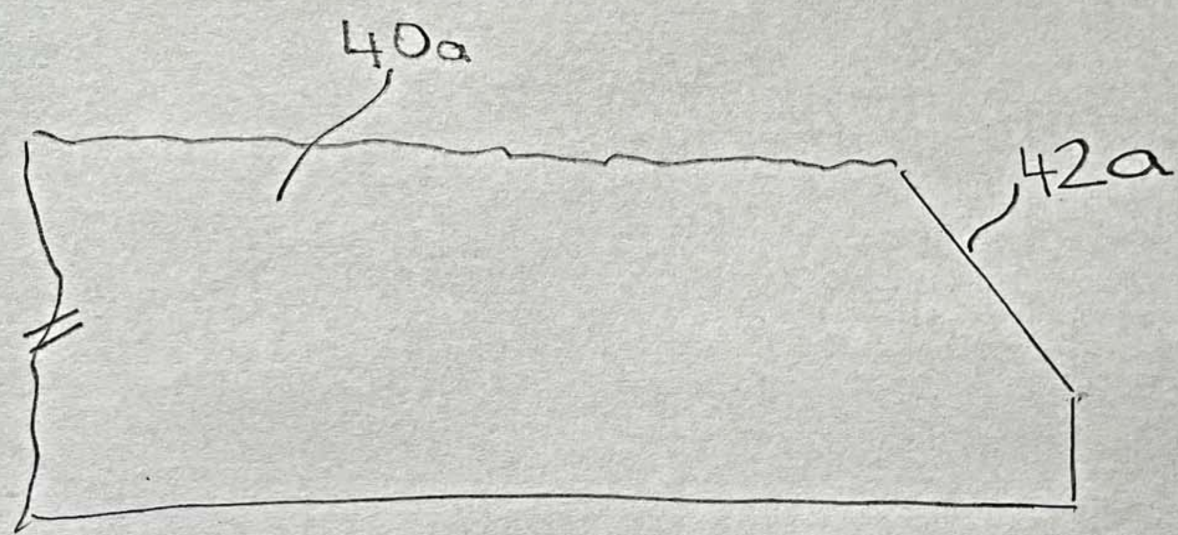


FIG 4

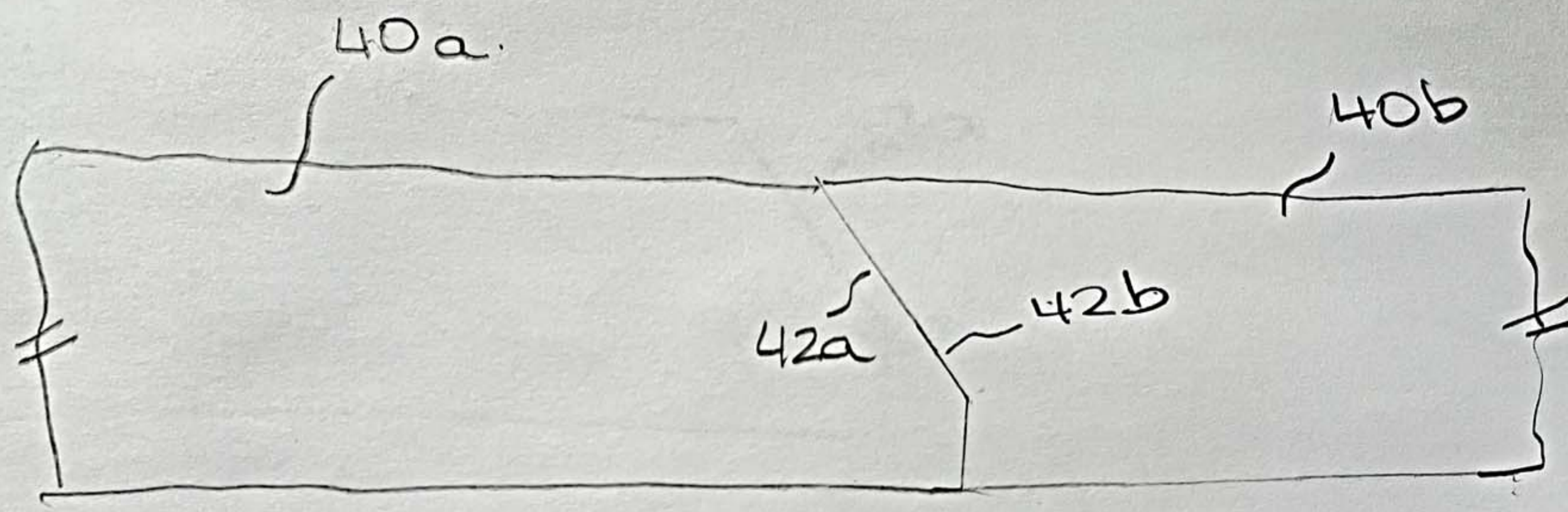


FIG 5

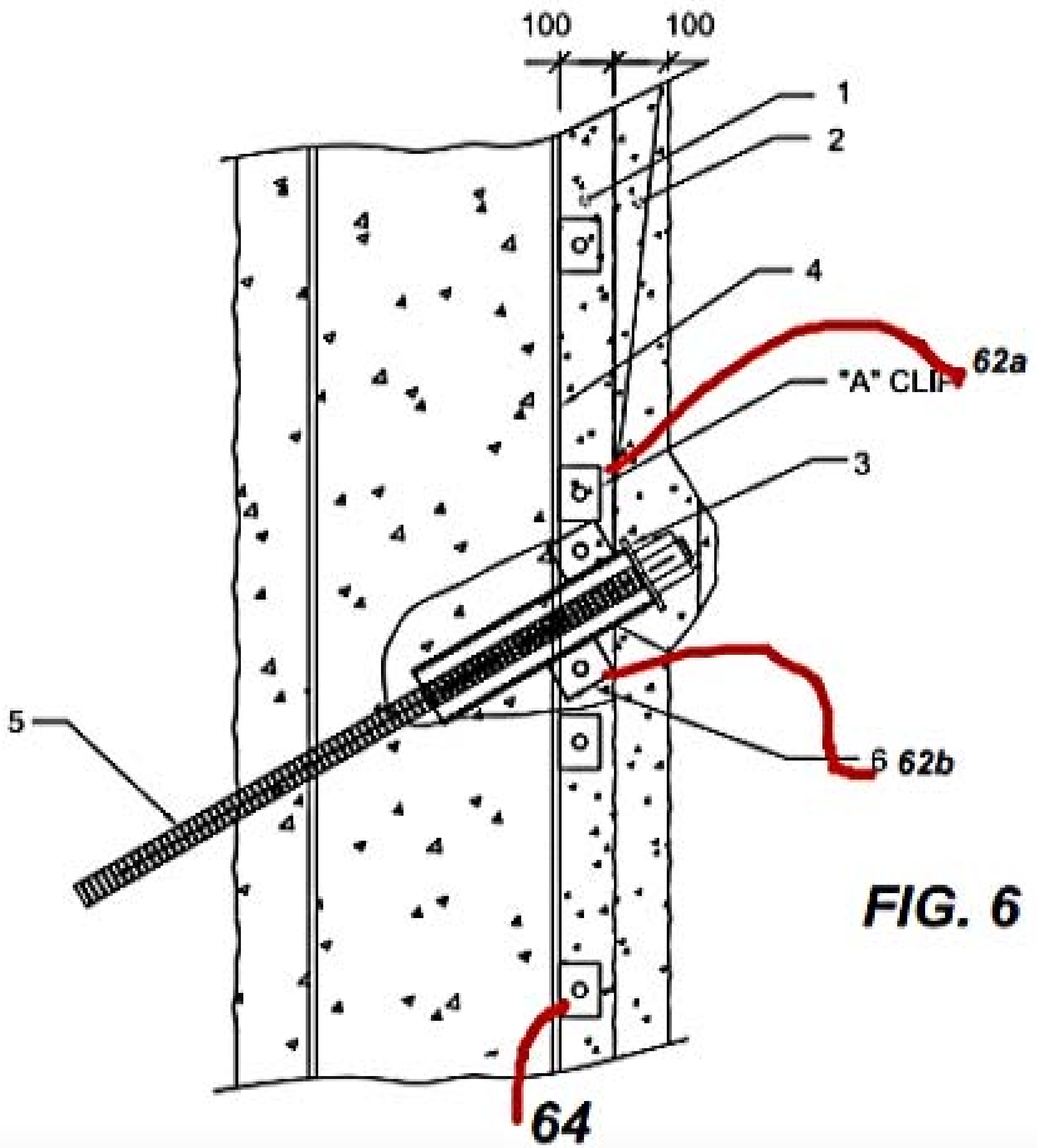


FIG. 6