Nov. 12, 1968 L. A. TURZILLO ET AL 3,410,095

METHOD OF MAKING WATER-SEALING PILE BARRIER AROUND AN EXCAVATION CUT-OFF AREA

Filed April 5, 1965

2 Sheets-Sheet 1

Fig 1

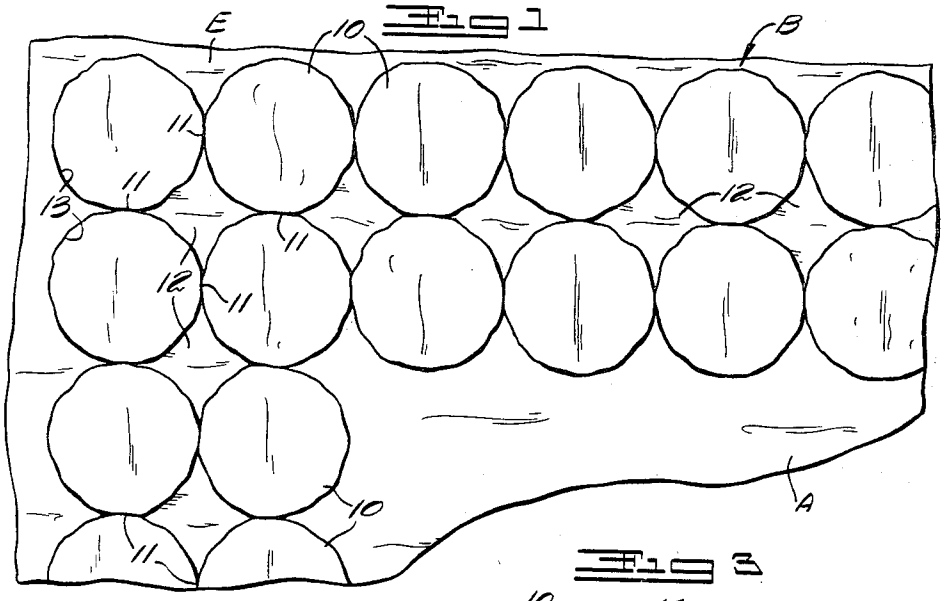


Fig 2

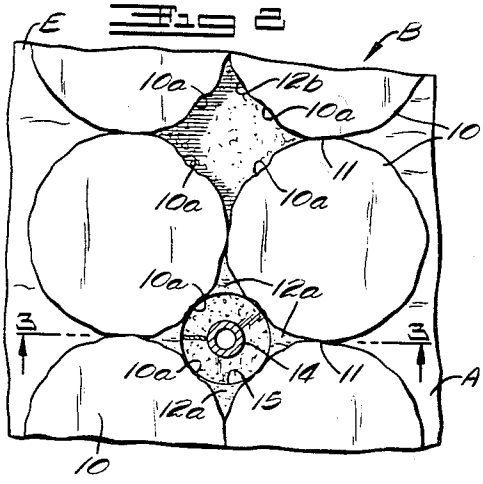


Fig 3

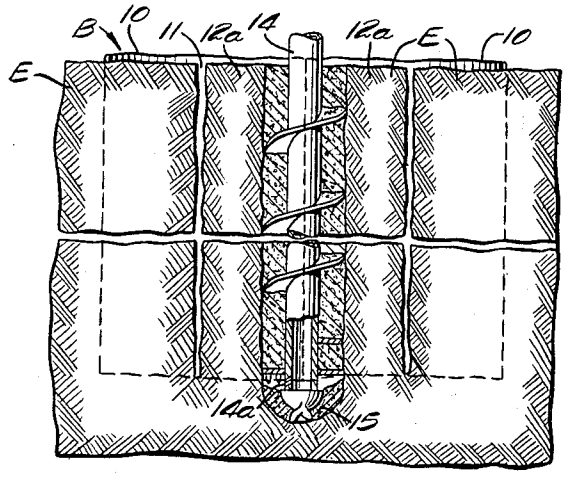


Fig 4

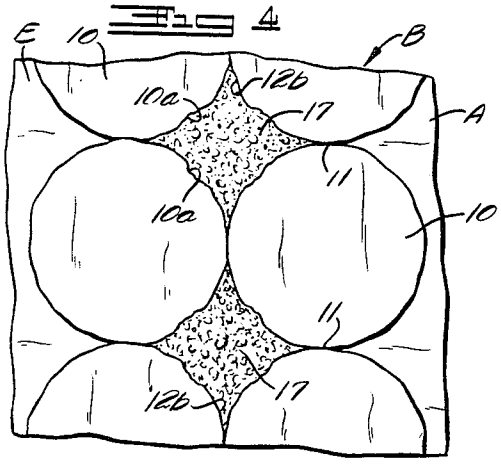
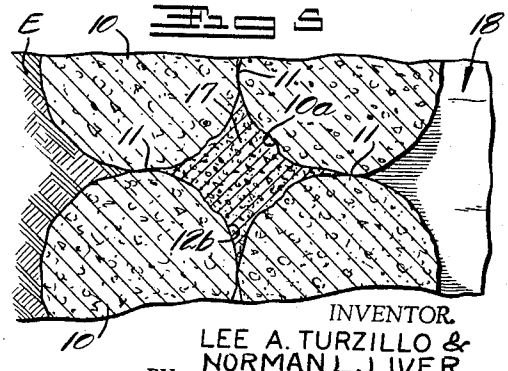


Fig 5



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Fig 6

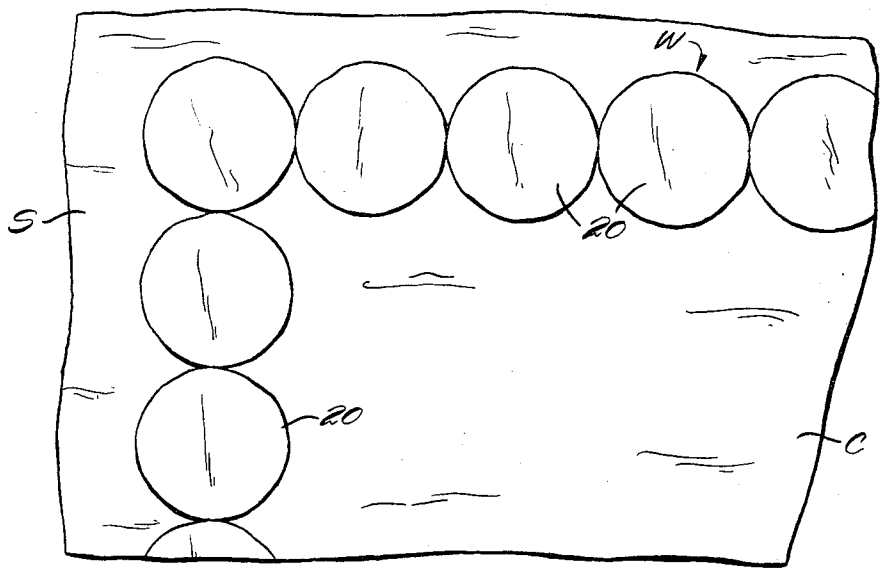


Fig 7

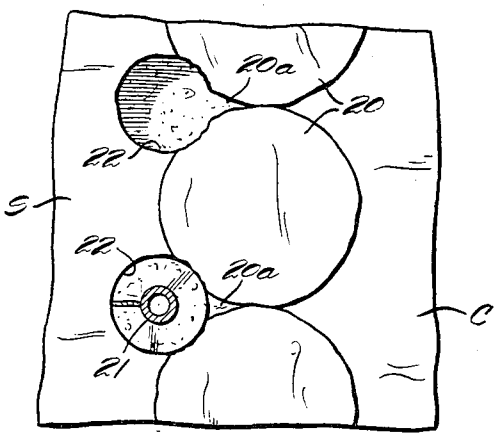
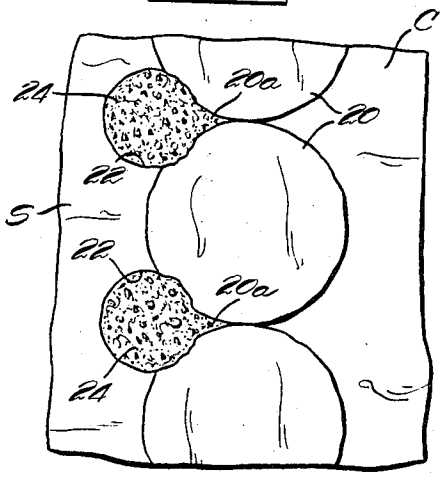


Fig 8



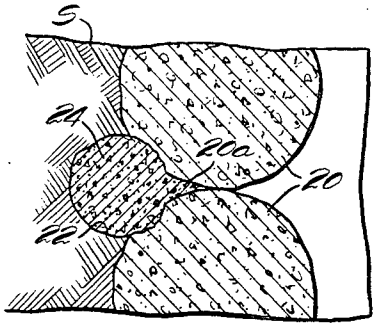


Fig 9

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METHOD OF MAKING WATER-SEALING PILE BARRIER AROUND AN EXCAVATION CUT-OFF AREA

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9 Claims. (Cl. 61—35)

ABSTRACT OF THE DISCLOSURE

Concrete barrier made by forming series of concrete piles in earth situs to have earth columns contained by convex surfaces of adjacent piles touching along vertical areas of line contact. Flushing water pumped into cavities provided in earth columns removes retained earth from bights between contacting piles. Flushed cavities filled with self-hardening fluid hydraulic cement, which hardens in fluid-sealing contact with resultantly bared convex surfaces of piles, including areas within the bights between the same.

This invention relates to forming concrete piles in the earth and, in particular, relates to an improved method for constructing a water-sealing barrier or retaining wall around an excavation site, for example.

Heretofore, concrete piles have been contiguously formed in an area of an earth situs as a barrier or bulkhead for retaining earth, building walls, or other structures, against collapse into an excavation made within the confines of the retaining barrier. Such contiguous pile barriers, however, were generally insufficient to prevent flow of surface or sub-surface water, and soil, through interstices between adjacent piles and into the excavation area.

One known method of providing a fluid seal between the piles involved augering a hole contiguous to a previously formed and hardened pile; coating the portion of the hardened pile exposed within the augered hole with fluid-sealing cement or a chemical composition; and filling the hole with grout or concrete to harden in contact with the sealing cement. This method was unsatisfactory because there was no way to determine if the sealing cement adhered effectively or uniformly to the limited area along the coated pile exposed within the hole. This method was impractical for other reasons, including the fact that in forming a barrier of contiguous piles, the sealing step had to be performed with respect to each pile before the next pile could be formed. Accordingly, as each pile required to harden at least to a certain extent before each subsequent sealing and pile-forming step, the total time required to surround an excavation cut-off area was necessarily long and uneconomical.

One object of the present invention is to provide an improved method of making an effective and efficient water-sealing pile barrier in an earth situs by which the normal time for installing contiguously arranged concrete piles is not necessarily impeded, and by which water-sealing of the installed pile barrier may be otherwise economically accomplished.

Another object of the invention is to provide a method of making a pile barrier of the character described about an excavation cut-off area, by which an effective seal is provided against passage of water through the pile barrier, and by which the water-sealing means serves as a strong reinforcement for the pile barrier.

These and other objects of the invention will be manifest from the following brief description and the accompanying drawings.

Of the accompanying drawings:

FIGURE 1 is a top plan view of a portion of an earth situs, illustrating an initial step of providing a double row of contiguous concrete piles about an excavation cut-off area;

FIGURE 2 is an enlarged fragmentary top view of a portion of FIGURE 1, but illustrating steps in the method by which earth is removed from the interstices between series of four contiguous piles;

FIGURE 3 is a vertical fragmentary cross-section taken on the line 3—3 of FIGURE 2, and on the same scale, to illustrate a step preliminary to full removal of earth from said interstices;

FIGURE 4 is a top plan view corresponding to FIGURE 2, illustrating the condition of the pile barrier after the spaces left in the barrier by said removal of earth have been replaced by hardenable sealing and reinforcing material;

FIGURE 5 is a sub-surface horizontal cross-section through four piles, after said replacement by hardenable sealing material, as in FIGURE 4, and after an excavation has been made in the earth within the barrier; and

FIGURES 6, 7, 8, and 9 are views corresponding to FIGURES 1, 2, 4, and 5, respectively, illustrating a modification of the method to construct a fluid-sealed pile barrier utilizing a single row of piles.

Referring to FIGURES 1 to 5, in general, and FIGURE 1, in particular, one embodiment of the present invention has to do with cylindrical concrete piles **10, 10** cast in place side-by-side in the earth E at a situs, as for use as a soil-retaining barrier or bulkhead B. The barrier is shown as comprising a double row of piles **10** contiguously arranged so that series of four contiguous piles, in pairs aligned in two directions defining a vertical shaft of substantially undisturbed earth or soil defined by converging adjacent, inwardly convex surfaces of the respective four contiguous piles. Such a barrier, as an example, serves to retain earth E of the situs outwardly thereof against collapse when the cut-off area within the confines of the barrier is excavated. Piles **10** alone, however, may not always be effective to prevent collapse of the barrier, due to water seepage past crevices **11, 11** between vertical contacting portions of next adjacent piles **10**.

Accordingly, initial steps of the process include forming the double row of contiguous concrete piles **10** in the earth situs E to encompass a cut-off area A, and at the same time leaving inner shafts **12, 12** of earth defined between converging adjacent, inwardly convex surfaces of each four immediately adjacent piles. For this purpose, the piles may be successively cast in place as by the method described in prior U.S. Patent No. 2,729,067, filed Jan. 3, 1956, which generally includes: screwing an auger-type drill (not shown) into the earth to define the location and depth of the pile cavity **13** while retaining the surrounding earth in said location; forcing fluid, hydraulic cement or grout into the space below the drill with requisite pressure progressively to fill the pile cavity with grout simultaneously with withdrawal of the drill to remove the earth from the cavity; and allowing the grout to set as a hardened pile.

Referring now to FIGURES 2 and 3 the next step in the process, after providing at least the respective series of four contiguous hardened piles **10**, includes screwing a relatively small, hollow-shafted rotary drill or an auger **14**, of known type, into each respective earth shaft **12** to define a cylindrical core cavity **15** of diameter greater than the shortest distance between opposing convex walls of said four piles (see FIGURE 3, and the lower portion of FIGURE 2). That is, the size of the drill is such that it will cut into the four convex walls, as indicated at **10*a***, **10*a***, to provide etched or skinned portions vertically

along the same for improved bonding of concrete thereto in a subsequent step in the method.

Now, while slowly withdrawing the auger **14** from earth shaft **12**, without necessarily rotating it, water under pressure is pumped down the hollow shaft of the auger, and through suitable outlet ports **14***a* at the lower end thereof, to displace residual earth portions or extensions **12***a*, **12***a* of the respective earth shaft **12**, to the space **12***b*, defined or circumscribed by the bights between said inwardly convex walls. That is, substantially all traces of earth are removed from said convex walls.

Upon withdrawal of the auger **14**, and removal of all said traces of earth from space **12***b*, as shown at the upper portion of FIGURE 2, said auger with all earth removed therefrom is reinserted within space **12***b*, and chemically hardenable fluid. As the auger is again progressively withdrawn, hydraulic grout is then pumped through the auger passage and into said space **12***b*, starting at the bottom of the same, until any or all water and/or residual soil in space **12***b* has been removed by displacement, and space **12***b* has been filled with grout. Upon self-hardening of the grout within the space **12***b*, as shown in FIGURES 4 and 5, the resultant grout column **17** therein will be structurally bonded or adhered to the converging walls of the piles defining said space, including bights between the same. This bonding of grout is materially enhanced by firm adhesion thereof to the etched or scored surfaces **10***a* vertically along the piles **10**. An expandible material, such as bentonite, may be used in place of grout, if necessary or expedient.

The resultant hardened concrete columns **17**, **17** when formed all along the barrier B, provide an effective seal against passage of surface or sub-surface water and/or soil into the inner excavation cut-off area A, so that excavation of earth can be safely accomplished, as indicated at **18** in FIGURE 5.

In the above steps of pumping water into the spaces **12***b* between each series of piles **10**, to displace and remove the soil shaft **12**, most of such soil is undoubtedly "boiled out" at the top of the piles, while some may be absorbed into surrounding earth through cracks and crevices. Possible flushing of earth from one space **12***b* into another at contacting points **11**, however, is of little consequence, especially when the space-cleaning and filling steps of the method are completed in succession around the barrier B.

Another embodiment of the method invention is illustrated in FIGURES 6 to 9 of the drawings. FIGURE 6 corresponds to FIGURE 1, but shows a preliminary step of utilizing the improved method to fluid-seal a single row of contiguous piles **20**, **20** cast-in-place about a cut-off area C in an earth situs S.

Referring to the lower portion of FIGURE 7, a small drill, such as a continuous flight auger **21**, may be screwed vertically into the earth soil structure extending into the bight between each two adjacent piles **20**, at the side of the pile row away from the excavation cut-off area. The drill **21** may be used to score or etch the surfaces of the piles for purposes described in connection with FIGURES 1 to 5.

While progressively withdrawing the auger to define a given hole **22** in the earth of the same depth or extent as the two adjacent piles, water is pumped down the shaft passage of auger **21** to remove residual earth from the bight **20***a* between said two adjacent piles (see upper portion of FIGURE 7). Hydraulic grout, bentonite, or other fluid-sealing material is then pumped into the hole **22**, through the reinserted hollow drill **21**, for example, to fill the hole and form a generally pear-shaped shaft **24** of hardened cementitious material, which becomes firmly bonded to the adjacent wall portions of the pile, including the portions thereof within said bight **20***a*, as illustrated in FIGURES 8 and 9.

Shafts **24** provided around the barrier W, as described, will seal the barrier against passage of water, sand, and other fluid materials, and will also serve to reinforce or strengthen the barrier. Similar sealing and reinforcing shafts may be provided on the cut-off side of the barrier, if desirable. In some instances, a relatively smooth facing of concrete may be applied to the cut-off side of the barrier, including the sealing and reinforcing shafts **24**, thereby to convert the barrier to serve as an inside wall of a building or other structure.

Other modifications of the invention may be restored to without departing from the spirit thereof or the scope of the appended claims.

What is claimed is:

1. A method of constructing a pile barrier or like fluid-sealing structure in an earth situs, comprising: the steps of providing at least one series of contiguously arranged, generally cylindrical, concrete piles longitudinally coextending in the situs to have the next adjacent said piles substantially touching lengthwise along corresponding longitudinal areas of line contact, and to have convergent earth extensions of the situs defined and retained within the bights between the correspondingly convergent walls of next adjacent touching piles; screwing an auger-drill into the earth of the situs to touch along said convergent walls to depth coextensive with the lengths of the respective next adjacent piles, to form longitudinal cavities in the earth extensions and leave tapered shafts of earth in said bights between the convergent walls of the respective touching piles; flushing said longitudinal cavities with pressurized fluid to remove said tapered shafts of earth and bare said convergent walls substantially to said areas of line contact; filling said flushed cavities with hardenable fluid cementitious material; and allowing said fluid cementitious material to harden in fluid-sealing contact with said bared convergent walls to said areas of line contact.

2. A method as in claim **1**, wherein the vertical cavities are formed by screwing a hollow-shafted auger into said earth of the situs, each cavity being flushed by pumping pressurized water down the auger shaft while the auger is retained in the respective cavity.

3. A method as in claim **2**, wherein said cementitious material is a fluid grout progressively pumped into each said flushed cavity, starting at the bottom thereof, to displace water from the space and fill the same with the hardenable cementitious material.

4. A method as in claim **3**, said cementitious material being fluid hydraulic cement grout.

5. A method of constructing a fluid-sealing pile barrier or like structure in an earth situs, comprising: the steps of providing coextending series of contiguously arranged, generally cylindrical, concrete piles longitudinally coextending in the situs to have series of four next adjacent said piles substantially touching lengthwise along four corresponding longitudinal areas of line contact, thereby to retain a four-sided shaft of earth defined within four peripherally adjacent, inwardly convex walls of each said touching series of four next adjacent piles; forming a longitudinal cavity by removing a core of earth from each respective said four-sided shaft of earth, to depth coextensive with the lengths of the respective said series of piles, and thereby to leave a tapered shaft of earth in the bights between said next adjacent piles of the respective series thereof; flushing each said longitudinal cavity with fluid to remove said tapered shafts of earth thereof and bare said convergent walls substantially to said areas of line contact; filling each said cavity defined by the series of four bared convergent walls with hardenable fluid cementitious material; and allowing said fluid cementitious material to harden in fluid-sealing contact with said series of four bared convergent walls substantially to said longitudinal areas of line contact.

6. A method as in claim **5**, wherein said earth cores are removed by screwing a hollow-shafted auger into the four-sided earth shafts to define said longitudinal cavities in the same, and while withdrawing the auger therefrom,

pumping pressurized water down the hollow auger shaft for said removal of said tapered shafts of earth from the bights.

7. A method as in claim 6, wherein said fluid cementitious material is pumped into each said longitudinal cavity through the auger, starting at the bottom of the cavity, to displace water therein and fill flushed cavity with the cementitious material.

8. A method as in claim 7, said cementitious material being fluid, hydraulic, cement grout.

9. A method as in claim 8, wherein upon screwing said auger into said four-sided earth shafts longitudinal extents of said convergent walls are etched for improved bonding of the cementitious material thereto.

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