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Chitis

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[54] **METHOD AND APPARATUS FOR CONSOLIDATING SOILS AND IMPROVING THE BASE BEARING FOR FOUNDATION STRUCTURES**

[76] Inventor: **Wolf Chitis,** Corso Vittorio Emanuele 167/c, Napoli, Italy

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[51] **Int. Cl.** **E02d 3/12**
[58] **Field of Search** ..... 61/36 R, 36 A, 35, 51, 50, 61/63

[56] **References Cited**

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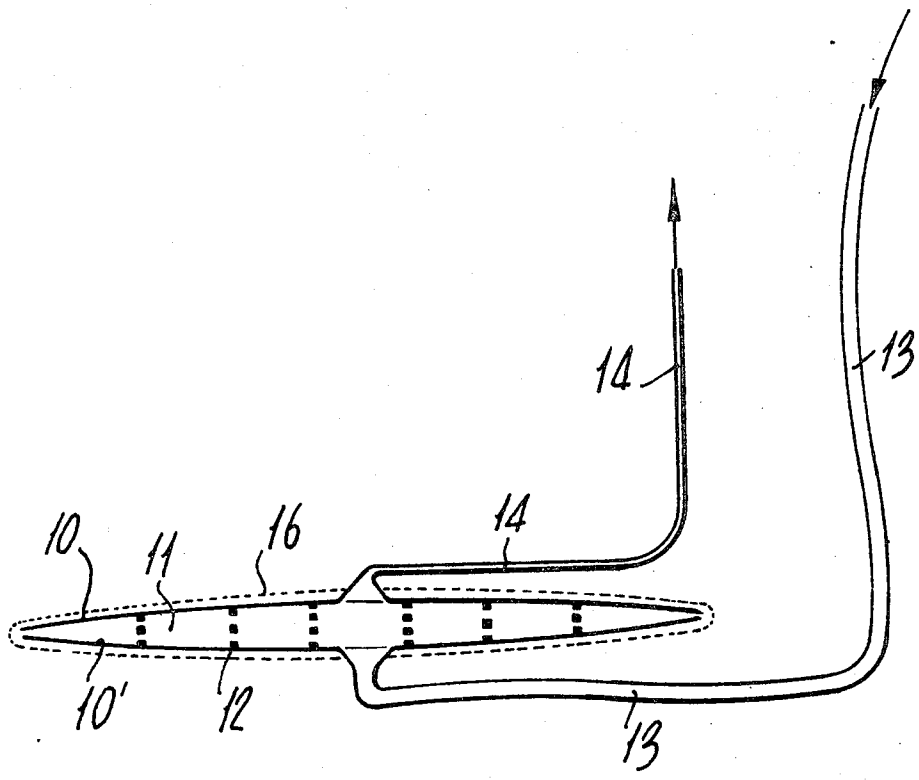
Primary Examiner—Mervin Stein
Assistant Examiner—Alex Grosz

[57] **ABSTRACT**

A method for consolidating soils and foundation structures. Under the zone to be consolidated, a hollow impermeable rigid wall pressure cell or chamber is inserted, this cell communicating with the outside by means of an injection conduit and a vent conduit, then over said chamber or cell erecting the foundation structures (piles, walls, etc.), next injecting through the injection conduit a pressure binder mixture within the chamber previously introduced into the soil, then closing the vent conduit and continuing to inject pressure binder mixture until destroying the impermeability of said chamber and enabling a tamping or stuffing up of the neighbouring soil, then closing also the injection conduit and maintaining it at closed condition until the binder mixter injected into the soil has set, and finally washing or scavenging in site the pressure cell, whereupon the injection operation of the pressure binder mixture into the cell can be repeated also for many times by following the same method and through the same device above described.

7 Claims, 2 Drawing Figures



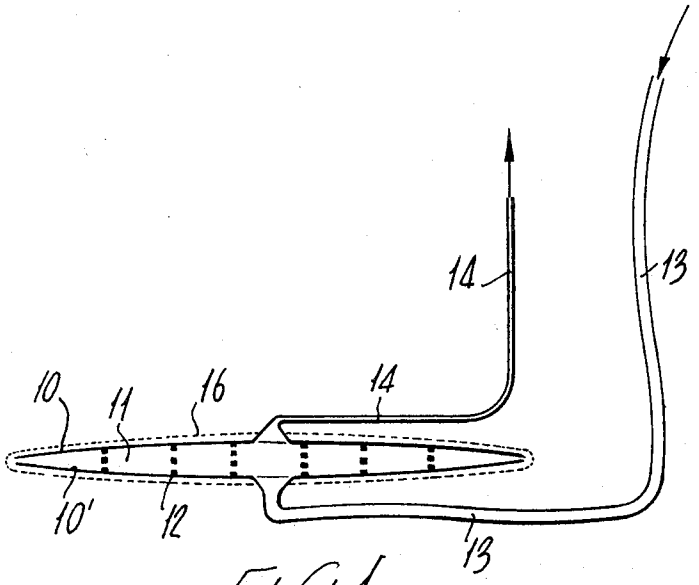


FIG. 1

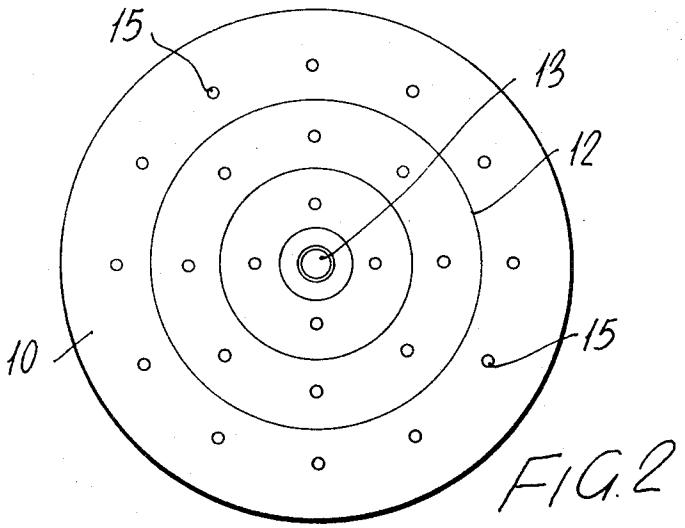


FIG. 2

METHOD AND APPARATUS FOR CONSOLIDATING SOILS AND IMPROVING THE BASE BEARING FOR FOUNDATION STRUCTURES

Site cast concrete piles are known, the load bearing capability of which is generally committed to the side friction soil resistance against the pile surface and base resistance on the soil bearing. Either would depend on the mechanical characteristics of the soil, as naturally such.

Evidently, where this base soil should be subjected to precompression, such as to increase the consistency thereof, the pile usable load bearing capability would be increased. A similar effect could be provided, where possible, by grouting the soil adjacent the pile base or foot.

Therefore, the device according to the present invention aims to provide at the base of a pile or similar structure, as site cast, a distributed pressure and pile base soil tamping and, subordinately, a soil grouting, such that a strain is exerted both against the pile base (or similar structure) and neighbouring soil. The device eseentially ccmprises a hollow impermeable resistant shell (pressure cell) which is introduced into the soil prior to casting and arranged at the pile base. The shell wall is made watertight and impermeable to prevent the internal cavity from being filled with cement liquid as the pile or similar structure is cast.

Upon cast completion, said shell is pressurized by injecting therein a binding mixture (either of a cement or chemical type), that is capable of setting and hardening after some time.

Among its features, the device according to the invention is characterized in that the impermeable shell wall, or even the shell alone, will break up as a result of the expansion caused by the binding mixture pressure, thus allowing the pressure liquid to diffuse within the soil and impregnate the same. Thus, the soil grouting effect will add to the mechanical tamping effect.

A possible device, such as described, is diagrammatically shown in the accompanying drawing in which:

FIG. 1 is a vertical section of the device; and

FIG. 2 is a plan view of the device.

The inventive device comprises two plates **10** and **10'** facing each other so as to provide an inner space **11** which is maintained by spacing means **12.** An injection conduit **13** terminates in said cavity **11** and a vent conduit **14** branches therefrom. The device walls or plates **10, 10'** are provided with a set of through holes **15** and the whole device body is enclosed by an impermeable shell **16.** For example, this shell can comprise one or more layers of jute cloth or the like, externally coated with an impermeable plastic sheet. This serves the purpose of facilitating through the cloth thickness the ejection of water forming the injection binder mixture, whereby the latter may exhibit a higher density and strength.

The device is placed on the soil at the cast base or foot (pile, wall, etc.) whereupon the casting for said overhanging structure (pile, wall, etc.) is effected. When the overhanging cement casting has set and consolidated, the device cavity (which has remained free of contamination owing to the impermeable shell **16**) is filled with binding mixtures through the injection hole **13.** Air exits from the vent tube **14.** Then, by closing said vent tube **14** and pressurizing the injected liquid, the latter will cause the whole assembly to expand,

that is plates **10, 10'** will separate, the impermeable shell **16** will be filled with pressure liquid and break up at a plurality of locations, particularly towards the soil, and the liquid binding mixture will exit, thus impregnating and tamping the soil. When deeming that a convenient operation stage has been attained, for example when the soil has absorbed a sufficient amount of cement binder for its consolidation, the injection of binding mixture is shut off, the injection tube **13** is tightly sealed and maintained at a constant pressure, such as by means of a gate or other system, until said pressure liquid has set. Whereupon, washing or scavenging can be effected for the whole assembly comprising the cell and the two injection and vent tubes, so that a second injection operation at a higher pressure can be repeated.

The device pressurization can be repeated also for many times at indefinite intervals. For example and particularly in loose soils, such a repetition would enable to recover or balance any sinkings a pile might undergo in time.

1 The use of the above device will allow to experimentally obtain the values of the side friction strength for a pile. Thus, by gradually loading the base cell **10, 10'**, the diagram can be obtained for the pile stresses of raising, similarly as an ordinary loading test. Thus, the average side strength for side friction against the pile can be obtained.

2. By inserting along the pile trunk suitable commercially available instruments, it is also possible to obtain through the concrete stress condition the various side strength values at the various levels; therefore, instead of the average value of side friction, the value can be obtained as corresponding to the various layers. In any case, by suitably increasing the pressure within the base cell **10, 10'** to sufficiently high values, the total load limit rate, by side friction, for the entire pile can be obtained.

3. Where the pile is of a sufficient length, or sufficiently bounded at the top or head end, the soil strength values for base load bearing can be obtained, and in the case the limit load still for base load bearing, beyond which the soil would collapse.

4. As stated at points (2) and (3), by means of the pressure cell **10, 10'** it is thus possible to effect an actual pile loading test, from which such interest values can be obtained as useful load, limit load, sinkings, etc.

5. Should the pile be provided along its trunk with the instruments as mentioned at point (2), the good provision and continuity for the casting can be controlled. Thus, when pressurizing cell **10, 10'** and should, for example, the pile be interrupted at a section, such instruments would detect stress values only at the trunk below the interruption, while above the interruption the values would be reduced or be zero depending on the discontinuity magnitude. It should be pointed out that at the loading tests mentioned above, the pressure cell **10, 10'** substantially acts as a jack.

However, the invention importance essentially resides in a substantial unlimited cell expansion, when the stroke of an ordinary jack is necessarily limited.

It should be also specified that the sinking of a pile which has been previously pressurized through the base cell **10, 10'** according to the present invention will be at any rate lower than that of an ordinary pile, and this due to both soil tamping and soil chamber laterally of the pile trunk.

6. A further application of the pressure cell **10, 10'** is to be found in the injection field. By inserting a cell of the above type into an injection hole of a convenient diameter, and by tamping at the top, repeated injections can be carried out, which in addition to mixture diffusing, also attain the purpose of soil tamping.

What I claim is:

1. A method for consolidating soil and improving the bearing base for a foundation structure, comprising the steps of (a) introducing beneath the soil surface a hollow enclosed cell member having an injection conduit member and a vent conduit member establishing communication between the interior of said cell member and the atmosphere above the soil surface and said cell having an impermeable, rupturable cover surrounding it, (b) erecting a foundation member in a position above said cell member, (c) injecting into said cell member through the injection conduit member a binder mixture under increased pressure sufficient to rupture said impermeable covering and to cause said binder mixture to penetrate the soil neighboring said cell member, (d) while maintaining said increased pressure, causing said binder mixture injected into the soil to set, (e) injecting into said cell member through the injection member a washing liquid thereby washing all unset binder mixture from the interior of said cell member and from said injection conduit and vent conduit members, and (f) repeating at least once the steps (c), (d) and (e) set forth above.

2. The method according to claim **1,** further comprising the step of providing means responsive to said injection of binder mixture under pressure for measuring physical forces exerted on said foundation structure by the soil as a result of said injection of binder mixture.

3. The method according to claim **2,** wherein said measuring means is incorporated in the foundation member.

4. The method according to claim **1,** wherein said foundation member is a concrete structure.

5. A device suitable for introduction into the soil to effect consolidation thereof and improve the bearing support for foundation structures, comprising a hollow enclosed cell member comprised of two opposing apertured plates separated from one another and mutually supported by a plurality of spacing means, an injection conduit member communicating with the interior chamber of said cell, a vent conduit member communicating with the interior chamber of said cell, and a covering layer surrounding said cell, said cover being impermeable but capable of being ruptured by means of a binder mixture forced under pressure into the hollow interior of said cell through said injection conduit member.

6. The device according to claim **5,** wherein said cell comprises two opposing apertured convex-concave plates separated from one another and mutually supported by a plurality of spacing means.

7. The device according to claim **5,** wherein said covering comprises at least one layer of jute linen and a second exterior layer of impermeable plastic material.

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