

13 OCT 2000

An excavation tool and a method for forming a column of consolidated soil

The present invention relates to an excavation tool of the type defined in the preamble to Claim 1; the invention also relates to a method for forming a column of consolidated soil.

Various methods are known in the art for consolidating ground by forming cylindrical columns of consolidated soil, based on the binding of soil particles with binders, usually cementitious mixtures.

A first conventional method, which relies on predominantly mechanical mixing, exploits the rotary motion of tools operable to dig and break up the soil. With reference to Figure 1, an excavation tool 10 includes a tubular shaft 11 with members 12 at its lower end for breaking the ground; above these, the tool has a pair of opposing blades 13 which extend radially from the shaft 11 and are arranged at opposite angles of inclination. The particles of soil broken up by the teeth 13a of the blades are mixed with a cementing mixture pumped at low pressure (1-2 MPa) through apertures 14 in the tubular shaft 11 just below the blades. The angular orientation of the blades enables the tool to be screwed into the ground during the digging step; rotation of the tool in the opposite sense during the extraction step, pushes treated soil downwards so as to compact it in the borehole, thereby reducing the percentage of voids.

In a second conventional method, known as jet grouting, (see Figure 2) mixing depends exclusively on the kinetic energy of a

consolidating fluid which is pumped at high pressure (15-40 MPa) through small radial nozzles 15 formed in the tubular shaft 11 proximate to the lower end of the tool so as to produce high-speed and high-kinetic energy jets 16. The radius of action of the jets, which are perpendicular to the shaft 11, is limited and affected by the nature of the ground, whereby the diameter of the column of consolidated ground obtained by this method is neither constant nor predictable.

With reference to figure 3, a third method makes use of a tool 16 which includes a tubular shaft 11 and one or more helical blades 17 with ground-breaking teeth 17a on their lower ends. One or more radial ducts 18 extend from the shaft 11, substantially aligned in respective vertical axial planes with the end portions of the helical blades bearing the teeth 17a. The ducts 18 are securely fixed to the helical blades, communicate with the interior of the shaft and have a plurality of nozzles 19 through which jets of a pressurized concrete mixture are injected at high speed into the ground, already partially broken down by the mechanical action of the lower ends of the helical blades and possibly by the ground-breaking members 12. By using high pressure, generally around 10-20 MPa, the jets are finely mixed into the broken soil, thus obtaining a consolidated column with a constant diameter.

By exploiting the combination of the mechanical action of the tool's breaking members and the kinetic energy of the high-pressure jets, this method stands out from other methods by virtue of its rapid completion time, which brings considerable

financial benefits. Examples of this prior art are described in U.S. Patents No. 4,958,962 and No. 5,396,964.

The object of the present invention is to provide an excavation tool of an advanced type which makes it possible further to reduce friction between the tool and the ground and enables work to be carried out at even greater speeds than those achieved with prior art tools.

This object is achieved, according to an aspect of the invention, by providing an excavation tool as defined in Claim 1.

Another object of the invention is to provide a high-yield method which makes it possible to cut the working time and operating cost of the equipment used to dig and form columns of consolidated soil.

According to another aspect of the invention, this further object is achieved by providing a method as claimed in Claim 16.

Other important characteristics of the tool and the method of the invention are claimed in the dependent Claims.

Several preferred but non-limitative embodiments of the invention will now be described, with reference to the appended drawings, in which:

- Figures 1 to 3 are perspective views of three respective excavation tools of conventional types;

- Figure 4 is a schematic perspective view of a first embodiment of an excavating tool according to the present invention;
- Figure 5 is a perspective view of a detail of the coupling system of a tool alternative to that shown in Figure 4;
- Figures 6 and 7 are schematic perspective views of a second and a third embodiment, respectively, of the excavation tool of the invention; and
- Figure 8 is a schematic sectional view of a portion of a further variant of the tool.

With reference to Figure 4, a tool according to the present invention is generally indicated 20. The tool 20 includes a central tubular shaft 21 having securely attached thereto a plurality of, in this case two, angularly spaced ground-breaking helical blades 22 which extend radially from the shaft 21. The tool 20 can be fixed to an upper drive transmission shaft 23 so as to carry out a combined movement of vertical translation and rotation about the longitudinal axis x of the shaft 21.

The tool 20 and the shaft 23 are releasably coupled, preferably by means of a splined coupling 24a, 24b (see Figure 4) or a form coupling device 25a, 25b (see figure 5) with the addition of axial retaining means such as pins 26 which are inserted through holes 27 in the shaft 21 so as to engage corresponding seats 28 formed in the shaft 23. A form coupling of this type locks the tool to the transmission shaft for rotation in both senses about the axis x , as will be explained in greater detail below.

At the lower edges 29 of the helical blades 22, the tool has radial ducts 30 communicating with a central axial cavity 21a in the shaft, through which a concrete mixture is fed under pressure; the ducts 30 are secured to the lower surfaces 31 of the helical blades 22, or the rear surfaces thereof with reference to the sense of rotation during excavation.

As used here, the terms "radial" and "axial" should be understood to refer to the longitudinal axis x of the shaft 21, unless indicated otherwise.

The bottom of each duct 30 has a plurality of nozzles 32 distributed along the length of the lower edge 29 of each helical blades, which eject jets 33 of pressurized consolidating mixture at high speed. The lower nozzles 32 are orientated substantially axially or slightly inclined to the vertical, so as to direct the jets 33 directly onto the unbroken ground at the bottom of the excavation 34, in such a way that it is at least partly broken up by the jets before it is engaged by the lower edges 29 of the helical blades, which break it up further and remove the soil encountered in their movement.

The breaking action of the vertical jets comes before that of the helical blades, so that the latter encounter ground which they can easily penetrate as it has been lubricated and fairly well broken down, as shown at 34 in Figure 4.

In dependence on the pressure used, the number of jets and the mechanical characteristics of the ground, the bottom of the

excavation is broken up by the vertical jets 33 to a depth which varies between around 20 and around 40 centimetres. It is advantageous for the pressure of the jet to be of the order of 30-40 MPa so as to achieve optimum performance of the tool.

Further nozzles 35 are preferably arranged on the bottom of the tubular shaft 21, directed downwards and associated with breaking members 36.

It will be understood that the present invention makes it possible to reduce the boring torque applied to the tool or, at equal torque, to achieve a greater penetration speed when compared to methods discussed in the introduction to this description.

The essentially vertical direction of the lower jets 33, together with the shape of the helical blades 22, ensures the formation of a column of consolidated ground of constant diameter.

During the extraction step, the tool is withdrawn by rotating it in the opposite sense to that used during the boring step, thereby compacting the column of treated soil. To this end, a splined or form coupling between the tool and the drive transmission shaft, as described above and shown in Figures 4 and 5, is preferable to a threaded coupling which could allow the tool to become unscrewed accidentally during rotation in one sense or the other.

With reference to Figure 6, in an alternative embodiment of the invention, inclined nozzles 37, directed upwardly and outwardly, are arranged near the shaft 21 for producing jets 38 which pass through apertures 39 in the helical blades, thereby further fluidising and breaking down the excavation material which is rising along the upper or front surfaces 40 of the helical blades.

With reference again to Figure 6, further nozzles 41 can be provided on the shaft 21 in addition to or as an alternative to the inclined nozzles 37, directed radially outwards, preferably arranged on a slightly lower level than that of the vertical nozzles 32 and angularly offset relative to the radial ducts 30. The nozzles 41 produce radial jets 42 which interfere with the downwardly directed axial jets 33, thereby producing vortex motion flow patterns as shown schematically at 43 which encourage the homogeneous breaking down of the soil. As a result of this nozzle arrangement, the soil particles moved by the mixture jets 33 and 42 are first pushed downwards and outwards and then are forced by the surrounding soil to return upwards and inwards.

In a further embodiment of the invention, illustrated in Figure 7, the excavation tool 20 can have one or more pairs of oppositely inclined radial blades 44, in concordance with the volutes of the helical blades. The pairs of radial blades 44, arranged above the helical blades 22 and preferably axially spaced according to the pitch of the latter, have further radial ducts with axial nozzles 45 directed downwards and, optionally, nozzles 46 directed upwards and acting to supply

vertical jets 47 which prolong the breaking down of the soil above the helical blades. The vertical jets 47 can either be jets of pressurized concrete mixture or, in a possible variant to the invention shown in Figure 8, jets of the mixture 47 combined with jets of compressed air 48. Advantageously, each jet of mixture 47 is surrounded by a tubular jet of compressed air 48 by providing an inner duct 49 which ejects the mixture through a nozzle 45 and an outer duct 50 which supplies compressed air and ejects it through an air nozzle 51 coaxial to the mixture nozzle 45. This forms sleeves of compressed air which surround the jets of mix, thereby increasing the range of action thereof and providing particularly energetic mixing and breaking down of the ground.

Naturally, the principle of the invention remaining unchanged, the embodiments and manufacturing details may vary widely from those described and illustrated here purely by way of non-limitative example. In particular, the number and the shape of the soil-breaking helical blades, their inclination to the vertical axis and the angle formed by the lower edges of the helical blades and the vertical axis may be altered by those skilled in the art without departing thereby from the scope of the invention as claimed in the following claims.



CLAIMS

1. An excavation tool for forming a column of consolidated soil, including:

a tubular central shaft (21) rotatable about a longitudinal axis (x) and translatable along the said axis, the said shaft having an axial central opening (21a) for supplying a soil-consolidating fluid through nozzle means arranged in the lower portion of the tool;

at least one blade element (22) extending radially from the central shaft and having a lower edge (29) extending substantially radially;

characterised in that it includes nozzle means (32) arranged along the said edge (29) and communicating with the said opening (21a) for directing at least one high pressure jet (33) of consolidating fluid, generally downwardly in such a way as to break up at least partially the soil before this is engaged by the blade element (22).

2. An excavation tool according to Claim 1, characterised in that the said blade element is inclined to the longitudinal axis of the shaft (21).

3. An excavation tool according to Claim 1, characterised in that the said blade element (22) is helicoidal.

4. An excavation tool according to Claim 1, characterised in that a plurality of the said nozzle means (32) are distributed along the length of the said lower edge (29) so as to direct downwards a corresponding number of jets (33).



5. An excavation tool according to Claim 1, characterised in that the said nozzle means are provided by an essentially radial duct (30) fixed to a rear surface (31) of the blade element (22) with reference to the sense of rotation of the tool during an excavation step.

6. An excavation tool according to Claim 1, characterised in that it includes a plurality of blade elements (22) arranged in a helicoidal pattern around the shaft (21).

7. An excavation tool according to Claim 1, characterised in that it can be fixed to an upper drive transmission shaft (23) by means of a form coupling (24a, 24b; 25a, 25b) operable to lock the tool for rotation with the transmission shaft in both senses about the said axis (x).

8. An excavation tool according to Claim 1, characterised in that it also includes nozzle means (37) positioned near the shaft (21) for directing jets (38) of pressurized consolidating mixture upwards and outwards in such a way as to act on the excavated material which is rising along the blades (22).

9. An excavation tool according to Claim 1, characterised in that it also includes nozzle means (41) near the shaft (21) for directing substantially radial jets (42) of pressurized consolidating mixture outwardly so that they interfere with the said downwardly-directed jets (33).



10. An excavation tool according to Claim 9, characterised in that the said nozzle means (41) are arranged at a slightly lower level than that of the vertical nozzles (32).

11. An excavation tool according to Claim 9, characterised in that the said nozzle means (41) are orientated so that the said jets (42) are angularly offset with respect to the lower edge (29) of the blade element (22).

12. An excavation tool according to Claim 1, characterised in that it has at least one pair of opposite radial blades (44) inclined in concordance with the volute of the said blade element (22), the said radial blades (44) being arranged above the said blade element (22) and having associated nozzle means (45, 51) directed downwards.

13. An excavation tool according to Claim 1, characterised in that it has at least one pair of opposite radial blades (44) inclined in concordance with the said blade element (22), the said radial blades (44) being arranged above the said blade element (22) and being associated with upwardly directed nozzle means (46).

14. An excavation tool according to Claim 12 or Claim 13, characterised in that at least one of the said nozzle means (51) is connected to a supply of compressed air.

15. An excavation tool according to Claim 14, characterised in that the said air nozzle means (51) is arranged so as to



direct a jet of compressed air (48) coaxial of and surrounding the jet (47) of mixture ejected by the said nozzle means (45).

16. A method for forming a column of consolidated soil which includes the steps of:

(a) providing an excavation tool (20) having a tubular central shaft (21) with a vertical axis (x) and a central axial opening (21a) for supplying a soil-consolidating fluid through nozzle means (32) which are directed generally downwards and are arranged along a lower radial edge (29) of at least one blade element (22) which projects radially from the central shaft (21) and is inclined thereto in a helical configuration;

(b) driving the said tool to rotate about the said axis (x) and to translate along the said axis of rotation and, simultaneously

(c) directing at least one high pressure jet (33) of consolidating fluid generally downwardly through the said nozzle means (32) so as at least partially to fluidise and break up the ground before the blade element (22) engages it in its excavating movement.

17. A method according to Claim 16, which includes the subsequent step of:

(d) withdrawing the said tool upwardly by rotating it in the opposite sense to that of step (b) so as to press the soil mixed with the consolidating fluid downwardly.



18. A method according to Claim 16, in which the pressure of the said jet (33) of consolidating fluid is between about 30 and about 40 MPa.

19. A method according to Claim 16, which also includes the step of:

(c1) directing at least one jet (48) of compressed air through further nozzle means (51) directed axially and positioned at a higher level on the excavating tool (20) than that of the blade element (22) so as further to break down the excavated soil above the said blade element.

20. A method according to Claim 19, in which the said step (c1) includes the step of:

(c2) directing at least one jet (48) of compressed air which surrounds coaxially a jet (47) of consolidating mixture.