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(54) Improvements relating to cementitious structures.

(57) A method of protecting and/or stabilising a cementitious structure from adverse effects due to ground heave and/or thermal shrinkage is disclosed. The method comprises embedding into the cementitious structure during its construction and before the cementitious material has hardened at least one tube (1) having on its outer surface one or more spirally formed grooves (3) in order to assist bonding between the tube and the cementitious material and additionally to provide a zone or zones of weakness in the tube; and, after the cementitious material has hardened, injecting grout under pressure (8) through said tube, whereby grout has access through any ruptured zones (7) in the tube to fractures in the hardened cementitious material of the structure itself.

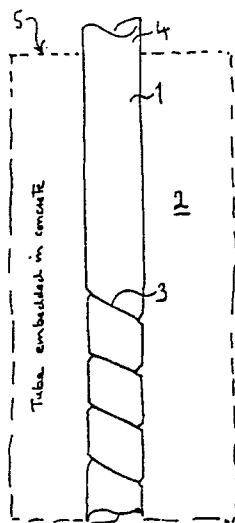


Figure 1

EP 0 398 762 A1

IMPROVEMENTS RELATING TO CEMENTITIOUS STRUCTURES

This invention relates to a method of constructing cementitious structures, in particular (but not exclusively) underground concrete structures, for example piles. For convenience, reference will be made hereinafter principally to the application of the invention in constructing piles, although it will be appreciated that the invention is not restricted to use in the construction of piles.

5 When a pile is formed in a pre-formed bore in the ground, the pile has a tendency to crack as a result of mechanical or thermal stresses before the load which the pile is intended to carry is emplaced.

In recent years, various aspects of crack development in cast in place concrete piles have become apparent through the use of sonic pulse integrity testing equipment. When a crack forms across the concrete section of a pile, a pulse of this kind is reflected from the location of the crack. Investigation of
10 such cracks detected by sonic pulse equipment has shown that cracks of width between 5 and 15mm tend to occur, often in the central region of the length of a pile. By measuring parameters such as soil heave, which occurs when a significant volume of soil is excavated within the site area after one or more piles have been placed, and the temperature within piles during and after the setting of the concrete, we have found that these cracks result from mechanical and/or thermal stress.

15 Heave is an inevitable result of post pile construction excavation. The removal of soil by excavation in the vicinity of the piles results in a decrease in the load carried by soil beneath the normal ground level of the site. This load reduction causes the soil beneath the site to expand. In London clay, this can result in upward movement of the soil at the base of the excavation by as much as several tens of millimetres. The effect is greater near to the surface and decreases with depth, so that piles which have already been cast
20 within the ground are stretched. Our calculations show that piles 1.5m diameter and 20m deep in London clay may experience forces up to 3750kN at a point below the final excavation level around the pile.

Temperature measurements made in piles after casting show that the heat of hydration of cement leads to temperatures of 60°C or greater. The ambient temperature of the ground in the vicinity of such piles is 15°C or less, so that over a period of months, the pile cools and as it does so it shrinks, perhaps by 5-
25 10mm over the length of the pile. Friction between the pile and the surrounding ground seeks to prevent this shortening taking place, and as in the case of heave the result is that a tensile crack forms in the middle region of the pile.

If such cracks are small - of the order of 5-10mm width - they are not particularly significant, but if the cracks become larger, as happens when large excavations are undertaken, there is a significant danger that
30 differential settlements may arise which would damage the structure which is to be supported by the piles. Naturally, this danger is of concern to engineers, as well as to statutory and local authorities concerned with construction.

These problems have led to suggestions, by some engineers, that piles should be reinforced throughout their length. Because of the large forces involved, this is a costly remedy. Nevertheless, where the loads
35 from the building which is to be supported on the piles are less than the total weight of soil removed during excavation, there is a long-term heave problem and pile reinforcement is essential.

In those cases where the building load fully replaces the weight of earth excavated, cracks formed in the piles as a result of mechanical and/or thermal stress tend to expand until the piles receive the building load. If such cracks can be filled with a cement grout when soil excavation is at its maximum depth, the
40 need for reinforcement of the piles is obviated. Current practice in such situations varies; some engineers demand pile reinforcement to avoid the initiation of cracks, but this is still a relatively expensive procedure for dealing with what is merely a temporary condition. Furthermore, there are disadvantages in using pile reinforcement in that the pile is still subject to high tensile forces and this could have a detrimental effect on its performance under load.

45 The present invention proceeds from an appreciation that the cost of heavy reinforcement in pile construction is unnecessary, provided that proper corrective measures for treating cracks in piles can be achieved. Pressure grouting of such cracks after such site excavation is completed will satisfactorily deal with the temporary cracks, and if the grout pressure is sufficiently high, the shortening of the pile can to a large extent be negated and pile performance can be preserved. The costs of drilling through a concrete
50 pile to the location of a crack in order to permit pressure grouting is however unacceptably high. The present invention therefore aims to provide a technique whereby pressure grouting can be achieved relatively simply and therefore relatively cheaply.

According to one aspect of the present invention, there is provided a method of protecting and/or stabilising a cementitious structure from adverse effects due to ground heave and/or thermal shrinkage, which comprises embedding into the cementitious structure during its construction and before the cemen-

titious material has hardened at least one tube having on its outer surface one or more spirally formed grooves in order to assist bonding between the tube and the cementitious material and additionally to provide a zone or zones of weakness in the tube; and, after the cementitious material has hardened, injecting grout under pressure through said tube, whereby grout has access through any ruptured zones in the tube to fractures in the hardened cementitious material of the structure itself.

The or each tube is advantageously formed of a metal, e.g. mild steel. The requirement for the tube is that it should be formed of a material capable of forming a strong bond to concrete, but which can easily be fractured. As an alternative to metals, brittle plastics materials may be used.

Preferably, the ratio between the diameter of the or each metal tube and the pile diameter is in the range of 1:12 to 1:60. It is also advantageous for two or more tubes to be embedded at or close to the periphery of the pile, and in order to provide access for grouting purposes, the or each tube should extend to the top of the pile, thereby giving ready access to its interior.

Preferably, the spirally formed groove or grooves make an angle of not less than 20° with respect to the axis of the tube. The or each groove may be in the form of a helix (i.e. a continuous running groove) or it may be in the form of arcuate sections which may or may not extend to a complete revolution about the tube.

The depth of the or each spirally formed groove is advantageously in the range 0.5mm to 10mm. The pitch of the or each groove is advantageously in the range 20mm to 400mm.

For use in the construction of piles 1.5m in diameter typically four metal tubes each 25mm inside diameter and of 4mm wall thickness will be located at the periphery of the pile while the cementitious material is still fluid. Each tube (or pipe) may be grooved with a helical groove (e.g. formed on site by means of lathe), and typically a groove depth of 2mm and a pitch of 100mm mm will be satisfactory. In such a case, the helical groove makes an angle of 33.82° with the longitudinal axis of the metal tube.

The groove formed on the outside of the or each tube provides a good bond with the cementitious material of the pile in which it is embedded. The force necessary to disrupt such a metal tube would be about 50kN if the tube is made of mild steel; this force is well below the level of forces which generate cracks in piles. As mentioned earlier, forces of the order of 3500 kN are frequently experienced by 1.5m diameter piles.

When the cementitious material of the pile hardens in contact with the or each tube, the tendency to form cracks as a result of thermal or mechanical stresses will result in the tube splitting in the region of a crack in the hardened cementitious material. The groove formed on the outside of the tube forms a line of weakness, so that the splitting of the tubes will occur along the lines of the groove. This splitting serves to give access to the crack area for grout under pressure. Thus by feeding pressurised grout into the tube from the surface, the crack can be flooded with grout. Furthermore, the grooves in the tube should crack only where the concrete itself has also cracked, so that provided the grooving has been carried out over a sufficient length of the tube, access for grout to any potential cracking level may be obtained.

Typically the or each tube is capped and left protruding from the pile head until required. Capping of the pipes at their upper (and, if desired, lower) ends may be achieved by using screw caps. The tube caps should be readily accessible in order to permit injection of grout at the end of the site excavation stage. The upper length of the tube close to the pile head needs no grooving, since the tube is not required to disrupt at these levels.

Since the zone where cracks are liable to form can be estimated with reasonable accuracy from known operational parameters, a tube used in accordance with method of this invention needs to carry its external grooving only over that region of its length which corresponds to the zone of anticipated cracking. Since the exact location of any crack or cracks cannot be predicted, a continuous helical groove over the predetermined portion of the length of the tube is necessary.

When a crack occurs in the concrete of the pile, the full tensile force may be instantly transferred to three or four tubes located in the pile, and these forces are such that they will disrupt the tubes at the level of the cracks, thereby providing access for grout which can be forced into the crack under pressure and up any tubes not connected to the grout inlet.

In one embodiment of the invention, a plurality of tubes are embedded in the cementitious structure during its construction and before it has hardened, and pressurised grout is inserted into the tubes in a plurality of stages, one or more of the tubes undergoing grouting at each stage. With such a sequential grouting operation (which may, if desired, extend over a period of years), long term stress relief may be provided for the cementitious structure. Thus in large cementitious structures liable to damage as a result of long term thermal movements or ground deformation, the invention provides a means of preventing damage to the structure and of repairing any internal cracks which may have formed.

For a better understanding of the invention, and to show how the same may be carried into effect,

reference will now be made, by way of example, to the accompanying drawing, in which:

Figure 1 illustrates a first stage in carrying out the method of this invention; and

Figure 2 illustrates a subsequent stage in the method.

Referring to the drawing, Fig. 1 shows a mild steel tube 1 embedded within, but at the periphery of, cementitious material 2 which, when hardened, will form a pile. The tube 1 has an inside diameter of 25mm and a wall thickness of 4mm. Four such tubes are positioned equidistantly around the circumference of the shaft containing cementitious material 2, which is 1.5m in diameter and 20m deep. A helical groove 3 is formed in the outer surface of tube 1 over the lower 12m of the tube; the uppermost part 4 of the tube 1 projects above the ground level 5 at the top of the shaft containing material 2. Groove 3 is 2mm deep and has a pitch of 65mm.

Initially, the grooved pipes such as 1 are positioned in the fluid cementitious material 2, which is then allowed to harden. Mechanical and/or thermal stresses during hardening cause cracks such as 6 (Fig. 2) to form across the width of the pile 2'. Such cracks are typically 5-20mm wide. The tensile forces acting to create crack 6 also affect tube 1, which by this time has become intimately bonded to the hardened cementitious material. This results in fracture of the tube 1 along a part 7 of the groove 3. In order to maintain the load bearing capacity of pile 2', grout is supplied under pressure at 8 to the top of tube 1, and travels downwardly to the base of the tube. Fissure 7 in groove 3 permits the grout to enter crack 6, where the grout hardens in due course and, in effect, restores the integrity of pile 2'.

The principle of the invention will be illustrated further in the following Example.

EXAMPLE

A length of cold rolled mild steel tubing of 30mm outside diameter (o.d.) was cut into 300mm sections. The tubing size was not significant other than that it was readily available from current stocks. A helical groove was machine cut (4 turns/inch) into each of the sections surface, each section having a different remaining wall thickness.

The tube sections were mounted in a load frame (modified Contraves ZM50a) and stresses in tension at a rate of 2.5mm/min were applied until failure.

Mock Pile

From the above tests a tube of 30mm o.d. and wall thickness 2mm was selected. The helical groove was cut at 4 turns/inch leaving a wall thickness of 0.5mm (i.e. groove depth was 1.5mm). This corresponds to an expected failure load of 3.5 Tonnes.

A box 230 x 230 x 850mm was constructed with the groove tube placed centrally. 16mm diameter studding was used as anchor bolts so that the tensile load could be applied through the block once it had been cast. The box was filled with concrete and compacted using a small diameter poker vibrator. A plastic sheet was introduced midway to act as a crack inducer to the concrete.

Mix Proportions	
OPC (Portland Cement)	370 kg/m ³
Sand (m)	740 kg/m ³
10mm	365 kg/m ³
20mm	735 kg/m ³
Free water	160 l
Plasticiser	2.21
14 day compressive strength = 59 N/mm ²	

Testing Block

The block was mounted in the load frame and a 1m head of water applied to the helical grooved tube. The specimen was stressed in tension at a rate of 2.5mm/min. until failure occurred.

5 Grouting of Crack

Forms were placed on three sides of the block around the crack, the fourth side being left open to a perspex tray to enable observation of the grout's egress. The opc grout had a w/c ratio of 0.4. and was placed with a head of 1m.

Results

Tensile Capacity of Pipe					
Tube o.d. mm	Wall Thickness mm	Reduced Thickness mm	Tensile Load KN	Helix Turns/inch	Remarks
30	2.3	1.15	56	2	Manual cut *
30	2.3	1.15	75	2	Manual cut *
30	2.3	0.39	40	4	
30	2.3	0.77	55	4	
30	2.3	0.62	32	4	
30	2.0	0.5	35	4	

* The initial cut on this tube was a concentric circle causing reduced failure load.

A manual cut could only be produced in one pass of the lathe thus restricting the groove depth.

Block Testing

A crack appeared in the block at a load of 40 KN but without any water leakage. At 43.6 KN the pipe fractured, allowing water to escape through the crack. The rate of loading was held at zero to keep the block in position for inspection. On inspection the crack width was approximately 2mm. It was evident that the helix had opened up as the specimen could be 'stretched' and 'relaxed' thus opening and closing the crack.

Grouting

No problems were experienced in grouting the pipe and crack. Flow was observed on all faces of the block. The grout was allowed to exude into the perspex tray, forming a small block which after hardening successfully sealed the cementitious material.

Claims

1. A method of protecting and/or stabilising a cementitious structure from adverse effects due to ground heave and/or thermal shrinkage, which comprises embedding into the cementitious structure during its construction and before the cementitious material has hardened at least one tube having on its outer surface one or more spirally formed grooves in order to assist bonding between the tube and the cementitious material and additionally to provide a zone or zones of weakness in the tube; and, after the cementitious material has hardened, injecting grout under pressure through said tube, whereby grout has access through any ruptured zones in the tube to fractures in the hardened cementitious material of the structure itself.

2. A method according to claim 1, wherein the or each tube is formed of a metal.

3. A method according to claim 2, wherein the or each tube is made of mild steel.

4. A method according to claim 1, wherein the or each tube is formed of a brittle plastics material.

5. A method according to any preceding claim, wherein the ratio between the diameter of the or each tube and the diameter of the cementitious structure is in the range of 1:12 to 1:60.

6. A method according to any preceding claim, wherein two or more tubes are embedded at or close to the periphery of the cementitious structure.

7. A method according to any preceding claim, wherein the cementitious structure is a pile.

8. A method according to any preceding claim, wherein the spirally formed groove or grooves make an angle of not less than 20° with respect to the axis of the tube.

9. A method according to any preceding claim, wherein the depth of the or each spirally formed groove is in the range 0.5mm to 10mm.

10. A method according to any preceding claim, wherein the pitch of the or each groove is in the range 20mm to 400mm.

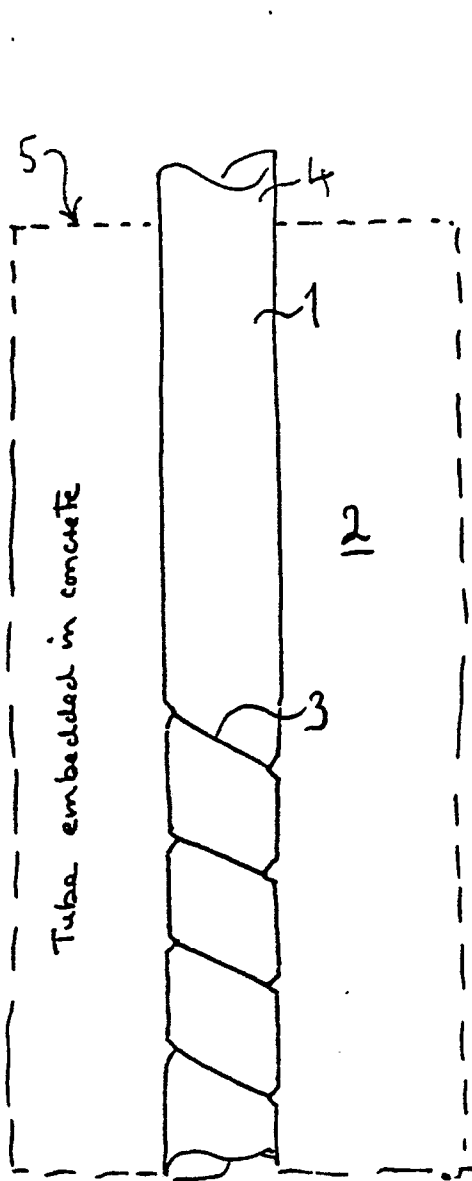


Figure 1

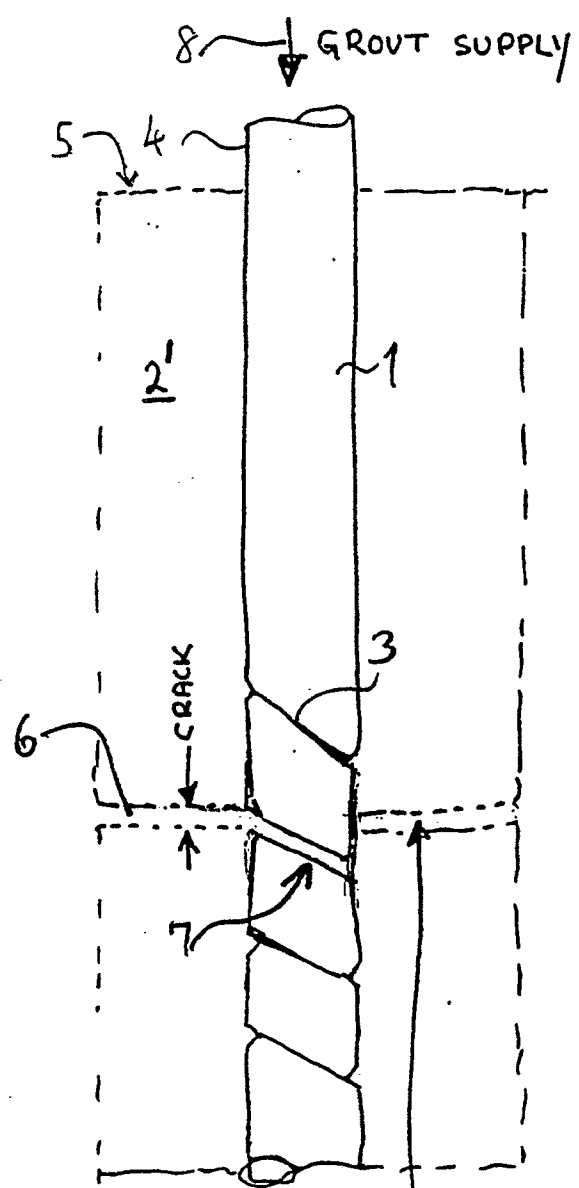


Figure 2
GROUT UNDER
PRESSURE ISSUING
FROM SEVERANCE
OF TUBE



European Patent
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EUROPEAN SEARCH REPORT

Application Number

EP 90 30 5446

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	DE-A-3642919 (RIECK) * column 1, lines 37 - 40 * * column 1, line 65 - column 2, line 55; claim 1; figures 1-3 * ---	1	E02D5/64 E04G23/02
A	GB-A-2192422 (KAKEN KABUSHIKI) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			E02D E04G
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 08 AUGUST 1990	Examiner BELLINGACCI F.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			