AMENDED SPECIFICATION

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PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvements in or relating to Concrete and the like Piles

We, GAMMON (MALAYA) LIMITED, a Company organised under the laws of the Colony of Singapore, of 9¼ Milestone, Bukit Timah Road, Singapore, 23, formerly of 63, Geylang Road, Singapore, Straits Settlement, and JOHN BRITTON MURRAY, a British Subject, of the said Company's address, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the casting of piles "in situ" under conditions where water or some other liquid exists above the ground or bed for example in the sea or in a river bed.

The casting of piles, in situ, is now common practice on dry land, and the use of such piles has resulted in many economies when constructing foundations for building or engineering structures. The problem of constructing foundations for marine structures, however, presents difficulties owing to the presence of water and these difficulties are generally overcome by driving long "preformed" piles, such as reinforced concrete or steel, through the water into the bed of the sea. Sometimes cofferdams are constructed to exclude the water from the vicinity where the foundations are to be built. Where "preformed" piles are used, these must be prepared on dry land, and then transported to the driving site. They must be strong enough to withstand considerable handling stresses.

According to the present invention a pile is cast through a casing which extends from above the water level at least down to the bed and preferably into the bed and which contains a column of a suitable filling material such as sand or earth to displace water therefrom and to serve as a mould to retain that part of the liquid or semi-liquid pile above the bed until such time as it has developed sufficient strength to maintain itself and which can be removed after the pile has set.

In this way a pile can be cast in situ in the presence of water above the level of the ground in a manner similar to the casting of piles in situ on land except for the provision of said filled casing.

A further feature of the invention is a method which consists in driving a hole in the ground with the aid of a driving tube, enclosing the driving tube, either before or after the hole is driven or at some stage in the driving of the hole, with a casing extending from above the water level at least down to the bed and preferably into the bed, feeding into the space between the tube and casing a suitable filling material such as sand or earth so as to form a column of the material surrounding the tube and then casting the pile in the hole formed in the ground with the said column.

The said column may be contained by means of a casing which consists of a tube of greater diameter than the diameter of the pile to be formed and arranged substantially concentrically with the position of the pile to be formed. After the pile has been formed said tube may be removed by raising it over the top of the pile. Alternatively the enclosure or casing may be formed of a number of sections of steel, timber or other suitable materials so that it can be dismantled and the individual sections removed separately.

By means of the present invention it is possible to form a series or row of piles by using a casing which consists of two substantially parallel wall members between which the piles are cast in situ and in which columns of filling material are formed with the aid of a partition or partitions extending across the space between the walls. Such piles may be formed closely adjacent to one another so that they merge into one another to form a wall or dam. If a ring of piles is to be cast said casing may consist of two substantially concentric cylindrical wall members or if a line of piles is to be cast the casing may consist of two or more substantially parallel straight or suitably curved wall members.

Thus with the aid of the method of the present invention, cast in situ piles may be formed either to construct cofferdams, or to

[*Price 3s. 0d.*]

act as load bearing piles, or both, and these piles can be formed even in a considerable depth of water.

In placing piles by the method of the present invention the hole is preferably driven rather than bored whereby to obtain a greater compaction of the earth around the hole below the bed or surface of the ground and instead of feeding ready mixed concrete into the hole it is preferable to feed thereto a suitable aggregate such as stone and an intensively mixed cement and sand grout capable of flowing into the voids of the aggregate and into the interstices in the face of the hole as described in British Patent Specification No. 694,242. By "intensively mixed cement and sand grout" we mean a grout which behaves as a liquid from the point of view of flow and of its ability to build up hydrostatic pressure and which, because of the intimate mixing of the ingredients, is repugnant to water in that it will not easily mix with water and is of a character such that settlement or segregation of the solids from the liquid and in particular settlement or segregation of the sand is considerably delayed as compared with ordinary grout formed in an ordinary mixer. A suitable intensively mixed grout may be prepared in a machine as described in British Patent Specification No. 536,444 or No. 694,117. The feeding into the hole of a suitable aggregate and an intensively mixed grout instead of ready mixed concrete has the advantage of affording good contact between the grouted aggregate and the earth with penetration of the grout into the interstices of the earth under the natural hydrostattic pressure of the grout with a consequent elimination in most cases of the danger of waisting and the necessity for tamping or ramming.

The invention is further described by way of example with reference to the drawings accompanying the provisional specification in which:—

Figs. 1, 2 and 3 illustrate three stages in the forming of a cast in situ pile through water;

Fig. 4 illustrates a development of the method illustrated in Figs. 1, 2 and 3.

Figs. 5 and 6 illustrate a method of forming a sequence of piles in a circle, and

Fig. 7 illustrates a method of forming a sequence of piles in line.

Referring to the attached drawings, Fig. 1 shows the method employed when driving piles singly. A driving tube A, with a detachable shoe B, is driven into the bed of the sea, or river as the case may be, until sufficient penetration is reached to carry the load which will be imposed on the pile. The tube can be driven either from a temporary staging or from floating pile driving equipment. While lowering the driving tube A, into the water it is desirable to ensure that water does not enter the tube, and a seal is therefore placed between the shoe B and the tube A. A suitable seal may consist of mastic or hemp rope soaked in mastic.

After the driving tube A has been driven, a casing C is lowered over the tube, this casing being long enough to extend from above water level to a few feet into the bed of the sea. It may be driven lightly into the ground by means of the pile driving hammer until it takes up a position as shown in Fig. 1. The casing C may consist of a circular tube or pipe, slightly larger in diameter than the driving tube A, or it may be built up from sections of steel or timber in the form of a circle or an octagon or any other desired shape. A filling material D such as sand, is then poured into the cavity between the driving tube A, and the casing C. The filling material D displaces the water in the cavity, and the water overflows at the top of the casing. If the driving tube A, is 12" diameter, a suitable size for the casing C, would be 18" diameter, thus giving a thickness of 3" of filling material D. The condition of the driving tube A is now similar to what it would be if the tube had been driven on dry land, and a cast-in-situ pile may be formed inside the driving tube A by any one of the generally approved or conventional methods, and the driving tube A then withdrawn.

Fig. 2 shows the completed pile E and its reinforcement F, the top portion of the pile, i.e. between bed level and water level, being protected by the casing C and the filling material D. The latter acts as a mould to retain the liquid or semi-liquid pile until such time as the material in the pile has developed sufficient strength to maintain itself. The pile thus can be formed in concrete, or cement grout or cement grout and stone aggregate, or by any other method used for forming cast-in-situ piles on dry land.

In certain sub-soils such as clay, the clay surrounding the driving tube A tends to cling to the tube and a coating of clay or earth may be extracted with the driving tube. This would tend to expel some of the filling material D, and in such cases it would be advantageous to fit a cap or cover G (Fig. 2) at the top of the casing C, before extracting the driving tube A.

After the pile has matured sufficiently the casing C is removed, and the filling material D falls away leaving the completed pile as shown in Fig. 3. If the casing consists of a pipe it may be pulled up over the top of the pile by means of the pile driving equipment, or by a crane, or any other suitable means. If the casing consists of built sections of steel or timber, it may be dismantled and the individual pieces removed separately.

In order to achieve greater rigidity, and to protect the piles while they are maturing, the casing of one pile may be braced to the casing of another or to a pile already formed, or the casing may be braced to a temporary staging.

Fig. 4, shows in plan a group of completed piles E, a group of completed piles EC still protected by casings, and temporary bracing H.

The invention can also be applied in cases where a continuous line of piles is required to form a sea or river wall, or a cofferdam, or to form groups of piles in any form or shape.

Figs. 5 and 6 illustrate a method of placing a foundation to carry a bridge pier or any other heavy structure which has to be built above water. An inner casing J, is lowered on to the bed of the sea, and thus is surrounded by an outer casing K. Both casings are circular in plan and extend from above water level to a few feet into the sea bed. Guides in the form of opposed projections S. are provided on the opposing faces of the casings J and K to facilitate the positioning of the driving tubes. It will be noted that the spacing between the opposed projections S is less than the diameter of the driving tube.

A driving tube T_1 is driven inside the casings in the position M. A second driving tube T_2 is then driven, touching tube T_1, in the position N.

A filling material R, such as sand, is then poured into the cavity between the driving tubes and the casings. The filling material is retained by means of a temporary stop or partition L and the guides S. A pile is then formed in the position M and the driving tube T_1 is withdrawn, and re-driven in position O. Filling material is packed round the driving tube at position O and a pile is formed in position N. Driving tube T_2 is then withdrawn and re-driven in position P. By continuing this method a complete circle of piles is driven, each pile during its formation being encased in filling material, retained in position by the casings.

An alternative method is first to fill the space between the two casings with filling material, and then drive the tubes T_1 and T_2 through the filling material.

After the piles have matured the casings J and K are removed leaving a ring of piles all touching and merging into each other. If desired, the earth inside this ring of piles can then be excavated by grabbing or other suitable means, down to any required depth, and the cavity filled with concrete, or filled with stone and cement grout. The ring of piles, however, can act not only as a cofferdam, but also to take the weight of the structure, as each pile can be driven to a depth sufficient to carry the load to be imposed.

Any number of such rings of piles can be formed to carry one structure, for example a bridge pier could be built on three such rings, which would take the place of cylinders or caissons which are sometimes employed. In the case of a river or sea wall, where piles have to be driven continuously in a straight line, or curve, or other profile, the same principle would be employed, but the casings instead of being circular in plan would follow the alignment of the wall.

Cofferdams of any shape or size can be constructed by the same method, by placing the inner and outer casings in the required positions.

Where a long line of piles is required, the casings need not extend the full length of the structure, as they can be removed as the work proceeds and refixed further ahead, as shown in Fig. 7. The shape of the line of completed piles is shown in Fig. 7.

In the cases where a continuous line of piles is required such as in the examples illustrated in Figs. 5 and 7, two or more separate tubes such as T_1 and T_2 may be driven simultaneously or may be replaced by a single element generally in the shape of two or more contiguous tubes similar, for example, to the shape of the line of completed piles as shown in Fig. 7. This single element may be driven in the usual manner, a suitably shaped helmet being placed on top of it to receive the impact of the hammer. Thus, two closely adjacent holes or two merging holes may be driven simultaneously.

This method herein described of forming cast-in-situ piles under water is particularly suitable for use in conjunction with the method of British Patent Specification No. 694,242 in which an intensively mixed cement grout is used which exerts a hydrostatic pressure and causes the grout to penetrate to a certain extent into the filling material D, and thus to afford a good area of contact between each two adjacent piles.

What we claim is:—

1. A method of casting piles in situ under conditions where water or some other liquid exists above the ground or bed for example in the sea or in a river bed in which the pile is cast through a casing which extends from above the water level at least down to the bed and preferably into the bed and which contains a column of suitable filling material such as sand or earth to displace water therefrom and to serve as a mould to retain that part of the liquid or semi-liquid pile above the bed until such time as it has developed sufficient strength to maintain itself and which can be removed after the pile has set.

2. A method of casting piles in situ under conditions where water or some other liquid exsts above the ground or bed for example in the sea or in a river bed which consists in driving a hole in the ground with the aid of a driving tube, enclosing the driving tube, either before or after the hole is driven or at some stage in the driving of the hole, with a casing extending from above the water level at least down to the bed and preferably into the bed, feeding into the space between the tube and said casing, a suitable filling material such as sand or earth so as to form a column of the

Fig. 4, shows in plan a group of completed piles E, a group of completed piles EC still protected by casings, and temporary bracing H.

The invention can also be applied in cases where a continuous line of piles is required to form a sea or river wall, or a cofferdam, or to form groups of piles in any form or shape.

Figs. 5 and 6 illustrate a method of placing a foundation to carry a bridge pier or any other heavy structure which has to be built above water. An inner casing J, is lowered on to the bed of the sea, and thus is surrounded by an outer casing K. Both casings are circular in plan and extend from above water level to a few feet into the sea bed. Guides in the form of opposed projections S, are provided on the opposing faces of the casings J and K to facilitate the positioning of the driving tubes. It will be noted that the spacing between the opposed projections S is less than the diameter of the driving tube.

A driving tube T_1 is driven inside the casings in the position M. A second driving tube T_2 is then driven, touching tube T_1, in the position N.

A filling material R, such as sand, is then poured into the cavity between the driving tubes and the casings. The filling material is retained by means of a temporary stop or partition L and the guides S. A pile is then formed in the position M and the driving tube T_1 is withdrawn, and re-driven in position O. Filling material is packed round the driving tube at position O and a pile is formed in position N. Driving tube T_2 is then withdrawn and re-driven in position P. By continuing this method a complete circle of piles is driven, each pile during its formation being encased in filling material, retained in position by the casings.

An alternative method is first to fill the space between the two casings with filling material, and then drive the tubes T_1 and T_2 through the filling material.

After the piles have matured the casings J and K are removed leaving a ring of piles all touching and merging into each other. If desired, the earth inside this ring of piles can then be excavated by grabbing or other suitable means, down to any required depth, and the cavity filled with concrete, or filled with stone and cement grout. The ring of piles, however, can act not only as a cofferdam, but also to take the weight of the structure, as each pile can be driven to a depth sufficient to carry the load to be imposed.

Any number of such rings of piles can be formed to carry one structure, for example a bridge pier could be built on three such rings, which would take the place of cylinders or caissons which are sometimes employed. In the case of a river or sea wall, where piles have to be driven continuously in a straight line, or curve, or other profile, the same principle would be employed, but the casings instead of being circular in plan would follow the alignment of the wall.

Cofferdams of any shape or size can be constructed by the same method, by placing the inner and outer casings in the required positions.

Where a long line of piles is required, the casings need not extend the full length of the structure, as they can be removed as the work proceeds and refixed further ahead, as shown in Fig. 7. The shape of the line of completed piles is shown in Fig. 7.

In the cases where a continuous line of piles is required such as in the examples illustrated in Figs. 5 and 7, two or more separate tubes such as T_1 and T_2 may be driven simultaneously or may be replaced by a single element generally in the shape of two or more contiguous tubes similar, for example, to the shape of the line of completed piles as shown in Fig. 7. This single element may be driven in the usual manner, a suitably shaped helmet being placed on top of it to receive the impact of the hammer. Thus, two closely adjacent holes or two merging holes may be driven simultaneously.

This method herein described of forming cast-in-situ piles under water is particularly suitable for use in conjunction with the method of British Patent Specification No. 694,242 in which an intensively mixed cement grout is used which exerts a hydrostatic pressure and causes the grout to penetrate to a certain extent into the filling material D, and thus to afford a good area of contact between each two adjacent piles.

What we claim is:—

1. A method of casting piles in situ under conditions where water or some other liquid exists above the ground or bed for example in the sea or in a river bed in which the pile is cast through a casing which extends from above the water level at least down to the bed and preferably into the bed and which contains a column of suitable filling material such as sand or earth to displace water therefrom and to serve as a mould to retain that part of the liquid or semi-liquid pile above the bed until such time as it has developed sufficient strength to maintain itself and which can be removed after the pile has set.

2. A method of casting piles in situ under conditions where water or some other liquid exsts above the ground or bed for example in the sea or in a river bed which consists in driving a hole in the ground with the aid of a driving tube, enclosing the driving tube, either before or after the hole is driven or at some stage in the driving of the hole, with a casing extending from above the water level at least down to the bed and preferably into the bed, feeding into the space between the tube and said casing, a suitable filling material such as sand or earth so as to form a column of the

material surrounding the tube, and then casting the pile in the hole formed in the ground and in said column.

3. A method as claimed in claim 1 or 2 in which the column is contained by means of a tube of greater diameter than the diameter of the pile to be formed or of the driving tube and arranged substantially concentrically with the position of the pile to be formed.

4. A method as claimed in claim 1 or 2 in which said casing is formed of a number of sections of steel, timber or other suitable material so that it can be dismantled and the individual sections removed separately.

5. A method as claimed in claim 2 or 3 in which the lower end of the driving tube is sealed against the ingress of liquid.

6. A method as claimed in claim 2, 3, 4 or 5 in which the space between the upper end of the casing and the driving tube is closed before the driving tube is withdrawn to prevent filling material from being withdrawn from the casing by the withdrawal of the driving tube.

7. A method as claimed in any of the preceding claims 2 to 6 in which the casing of one pile is braced against the casing of another or against a pile already formed or against a temporary staging.

8. Forming a series or row of piles by the method claimed in any of the preceding claims by using a casing consisting of two substantially parallel wall members between which the piles are cast in situ and in which columns of filling material are formed with the aid of a partition or partitions extending across the space between the walls.

9. A method as claimed in claim 8 using a casing which consists of two substantially concentric cylindrical wall members.

10. A method as claimed in claim 8 or 9 in which the positioning of driving tubes for driving holes for the piles is facilitated by guides in the form of opposed projections on the opposing faces of the wall members, the spacing between said projections being less than the diameter of each driving tube.

11. A method as claimed in claim 8, 9 or 10 in which the piles are formed closely adjacent to one another so that they merge into one another to form a wall or dam.

12. A method as claimed in claim 2 and claim 8, 9, 10, or 11 in which two holes are driven closely adjacent to one another between said wall elements and the driving tube is withdrawn from one of the holes which is then filled with concrete or the ingredients thereof, whereupon a third hole is driven closely adjacent to the second hole from which the tube is then withdrawn and the hole filled with concrete or the ingredients thereof whereupon a fourth hole is driven closely adjacent to the third and so on.

13. A method as claimed in claim 11 in which two closely adjacent holes or two merging holes are driven simultaneously.

14. A method as claimed in any of the preceding claims which consists in driving a hole as distinct from boring a hole and in feeding into the hole a suitable aggregate such as stone and an intensively mixed cement and sand grout capable of flowing into the voids of the aggregate and into the interstices in the face of the hole.

15. A method as claimed in claim 14 in which the aggregate and grout are fed into the hole simultaneously or in relatively small quantities alternately.

16. Methods of casting piles in situ under conditions where water or some other liquid exists above the ground or bed substantially as herein particularly described with reference to and as illustrated in the drawings accompanying the provisional specification.

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PROVISIONAL SPECIFICATION

Improvements in or relating to Concrete and the like Piles

We, GAMMON (MALAYA) LIMITED, a Company organised under the laws of the Colony of Singapore, of 9¼ Milestone, Bukit Timah Road, Singapore, 23, formerly of 63, Geylang Road, Singapore, Straits Settlement, and JOHN BRITTON MURRAY, a British Subject, of the said Company's address, do hereby declare this invention to be described in the following statement:—

This invention relates to the casting of piles "in situ" under conditions where water or some other liquid exists above the ground for example in the sea or in a river bed.

The casting of piles, in situ, is now common practice on dry land, and the use of such piles has resulted in many economies when constructing foundations for buildings or engineering structures. The problem of constructing foundations for marine structures, however, presents difficulties owing to the presence of water, and these difficulties are generally overcome by driving long "preformed" piles, such as reinforced concrete or steel, through the water into the bed of the sea. Sometimes cofferdams are constructed to exclude the water from the vicinity where the foundations are to be built. Where "preformed" piles are used, these must be prepared on dry land, and then transported to the driving site. They must be strong enough to

withstand considerable handling stresses.

According to the present invention a pile is cast in situ through an enclosure or casing which extends from above the water-level at least down to the bed and preferably into the bed, which enclosure is filled with a filling material such as sand to displace the water therein or most of it. The enclosure is preferably water-tight, or substantially so.

Thus the invention consists in providing a column of a suitable material such as sand extending from the bed up to a level above the water level and of girth or cross sectional area greater than that of the pile to be formed, and in forming, a pile in situ through the said column and in the ground therebeneath.

In this way a pile can be cast in situ in the presence of water above the level of the ground in a manner similar to the casting of piles in situ on land except for the provision of the filled enclosure.

In the case of a single pile the enclosure or casing may consist of a tube of greater diameter than the diameter of the pile to be formed. If the pile is to be formed with the aid of a driving tube then the enclosure tube may be of considerably less length than the driving tube but of greater diameter. The casing may be put in position either after or before the driving tube has been driven, the annular space between the driving tube and the casing being subsequently filled with a suitable material, for example sand.

With the aid of the method of the present invention, cast in situ piles may be formed either to construct cofferdams, or to act as load bearing piles, or both, and these piles can be formed even in a considerable depth of water.

The invention is further described with reference to the accompanying drawings in which:—

Figs. 1, 2 and 3 illustrate three stages in the forming a cast in situ pile through water;

Fig. 4 illustrates a development of the method illustrated in Figs. 1, 2 and 3.

Figs. 5 and 6 illustrate a method of forming a sequence of piles in a circle, and

Fig. 7 illustrates a method of forming a sequence of piles in line.

Referring to the attached drawings, Fig. 1 shows the method employed when driving piles singly. A driving tube A, with a detachable shoe B, is driven into the bed of the sea, or river as the case may be, until sufficient penetration is reached to carry the load which will be imposed on the pile. The tube can be driven either from a temporary staging or from floating pile driving equipment. While lowering the driving tube A, into the water it is desirable to ensure that water does not enter the tube, and a seal is therefore placed between the shoe B and the tube A. A suitable seal may consist of mastic or hemp rope soaked in mastic.

After the driving tube A has been driven, a casing C is lowered over the tube, this casing being long enough to extend from above water level to a few feet into the bed of the sea. It may be driven lightly into the ground by means of the pile driving hammer, until it takes up the position as shown in Fig. 1. The casing C may consist of a circular tube or pipe, slightly larger in diameter than the driving tube A, or it may be built up from sections of steel or timber in the form of a circle or an octagon or any other desired shape. A filling material D, such as sand, is then poured into the cavity between the driving tube A, and the casing C. The filling material D displaces the water in the cavity, and the water overflows at the top of the casing. If the driving tube A, is 12″ diameter, a suitable size for the casing C, would be 18″ diameter, thus giving a thickness of 3″ of filling material D. The condition of the driving tube A is now exactly similar to what it would be if the tube had been driven on dry land and a cast-in-situ pile may be formed inside the driving tube A by any one of the approved methods, and the driving tube A then withdrawn.

Fig. 2 shows the completed pile E, the top portion of the pile, i.e. between bed level and water level, being protected by the casing C and the filling material D. The latter acts as a mould to retain the liquid or semi-liquid pile until such time as the material in the pile has developed sufficient strength to maintain itself. The pile thus can be formed in concrete, or cement grout or cement grout and stone aggregate, or by any other method used for forming cast-in-situ piles on dry land.

In certain sub-soils such as clay the clay surrounding the driving tube A, tends to cling to the tube and a coating of clay or earth may be extracted with the driving tube. This would tend to expel some of the filling material D, and in such cases it would be advantageous to fit a cap or cover G (Fig. 2) at the top of the casing C, at the time of extracting the driving tube A.

After the pile has matured sufficiently the casing is removed, and the filling material D falls away leaving the completed pile as shown in Fig. 3. If the casing consists of a pipe it may be pulled up, over the top of the pile by means of the pile driving equipment, or by a crane, or any other suitable means. If the casing consists of built sections of steel or timber, it may be dismantled and the individual pieces removed separately.

In order to achieve greater rigidity, and to protect the piles while they are maturing, the casing of one pile may be braced to the casing of another, or the casing may be braced to a temporary staging. Fig. 4, shows in plan a group of completed piles E, a group of completed piles EC, still protected by casings, and the temporary bracing H.

The invention can also be applied in cases where a continuous line of piles is required to form a sea or river wall, or a cofferdam, or to form groups of piles in any form or shape.

Figs. 5 and 6 show a foundation to carry a bridge pier or any other heavy structure which has to be built above water. An inner casing J, is lowered on to the bed of the sea, and this is surrounded by an outer casing K. Both casings are circular in plan, and extend from above water level to a few feet into the sea bed. Guides S, are provided in both casings to position the driving tubes.

A driving tube T_1 is then driven inside the casings in the position M. A second driving tube T_2 is then driven, touching T_1, in the position N.

A filling material R, such as sand, is then poured into the cavity between the driving tubes and the casings. The filling material is retained by means of a temporary stop L and the guides S. A pile is then formed in the position M and the driving tube T_1 is withdrawn, and redriven in position O. Filling material is packed round O and a pile is formed in position N. Driving tube T_2 is then withdrawn and redriven in position P. By continuing this method a complete circle of piles is driven, each pile being encased in filling material, retained in position by the casings.

An alternative method is first to fill the space between the two casings with filling material, and then drive the tubes T_1 and T_2 through the filling material.

After the piles have matured the casings J and K are removed leaving a ring of piles all touching each other. If desired, the earth inside this ring of piles can then be excavated by grabbing or other suitable means, down to any required depth, and the cavity filled with concrete, or filled with stone and cement grout. The ring of piles, however, acts not only as a cofferdam, but takes the weight of the structure, as each pile is driven to a depth sufficient to carry the load to be imposed.

Any number of such rings of piles can be formed to carry one structure, for example a bridge pier could be built on three such rings, which would take the place of cylinders or caissons which are sometimes employed. In the case of a river or sea wall, where piles have to be driven continuously in a straight line, or curve, or other profile, the same principle would be employed, but the casings instead of being circular in plan, would follow the alignment of the wall.

Cofferdams of any shape or size can be constructed by the same method, by placing the inner and outer casings in the required positions.

Where a long line of piles is required, the casings need not extend the full length of the structure, as they can be removed as the work proceeds and refixed further ahead, as shown in Fig. 7.

This method of forming cast-in-situ piles under water is particularly suitable when an intensively mixed cement grout is used which exerts a hydrostatic pressure, as the grout penetrates to a certain extent into the filling material D, and thus there is a good area of contact between each pile. The shape of the line of completed piles is shown in Fig 7.

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