Feb. 19, 1946. F. L. FITZPATRICK 2,395,216

MEANS AND METHOD FOR COMPRESSING NEWLY FORMED CONCRETE ARTICLES

Filed April 29, 1944 2 Sheets-Sheet 1

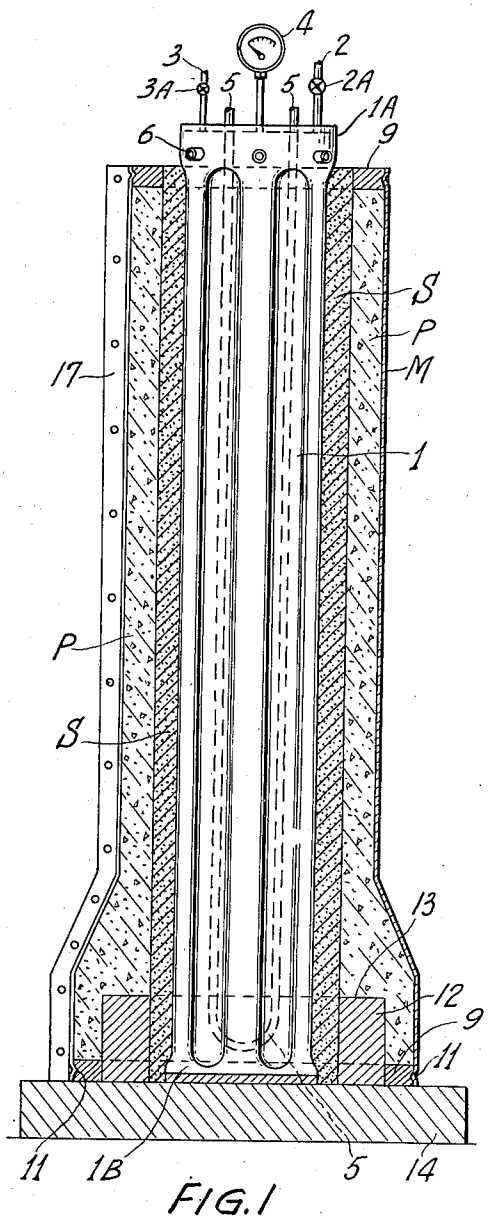



FIG. 1

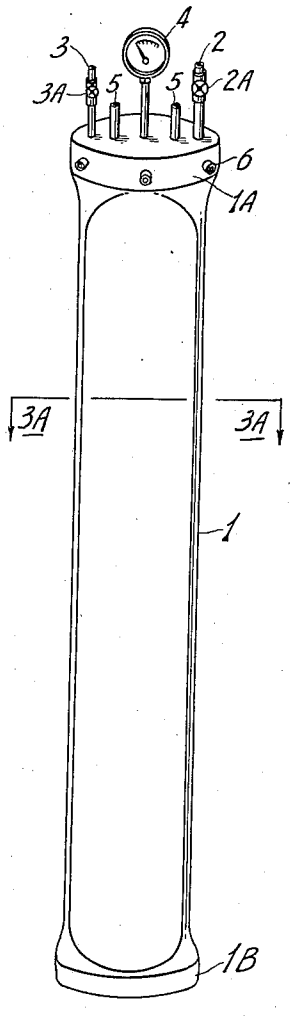



FIG. 2

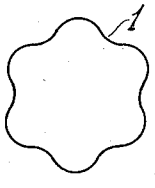



FIG. 3B

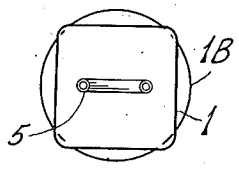



FIG. 3A

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MEANS AND METHOD FOR COMPRESSING NEWLY FORMED CONCRETE ARTICLES

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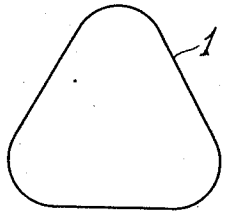



FIG. 3C

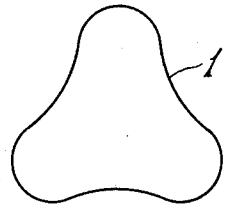



FIG. 3D

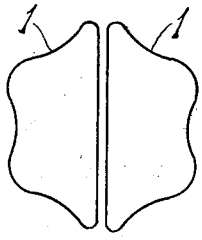



FIG. 3E

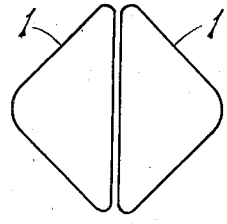



FIG. 3F

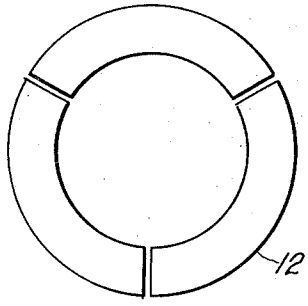



FIG. 4

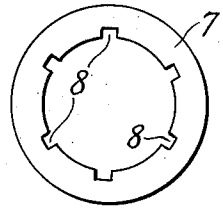



FIG. 5

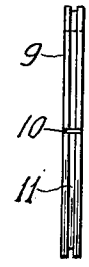



FIG. 7

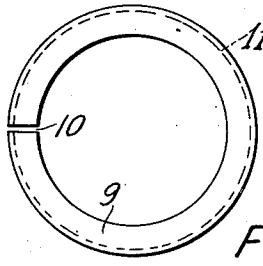



FIG. 6

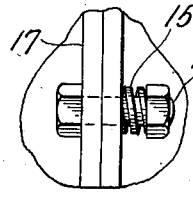



FIG. 8

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Patented Feb. 19, 1946 2,395,216

# UNITED STATES PATENT OFFICE

2,395,216

## MEANS AND METHOD FOR COMPRESSING NEWLY FORMED CONCRETE ARTICLES

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Application April 29, 1944, Serial No. 533,308
In Australia October 5, 1943

4 Claims. (Cl. 25—128)

This invention relates to the application of pressure to the inner faces of newly formed concrete pipes (whether reinforced or not) or other hollow articles of concrete having cylindrical or approximately cylindrical cavities as, for example, hollow fence posts or hollow columns. The term "pipe" is used hereinafter in the description and claims to include any such other hollow article.

The primary objects of my invention are to enable this pressure to be thus applied in a simple and efficient manner and by means not readily damaged. Subsidiary objects will be obvious from the description of the invention.

The term "concrete" is intended to cover mixtures of Portland or other hydraulic cement with water and one or more of the following solids—sand, gravel, crushed stone, or the like, or asbestos or other suitable fibrous material.

I attain the objects of my invention by the means illustrated in the accompanying drawings, in which—

Figure 1 is an elevation of a corrugated hollow metal core shown in position in an upright mould and concrete pipe, with an intervening sandy layer, the mould, pipe and sandy layer being shown in vertical central section;

Figure 2 is a perspective view of a core which is of approximately square cross-section except at its end portions which are rounded, and which is provided with means for supplying water to it, and also with a steam-heating pipe;

Figure 3A is a cross-section on the line 3A—3A of Figure 2;

Figures 3B, 3C and 3D are section profiles of the non-circular portions of alternative shapes of core, and

Figures 3E and 3F are similar illustrations of twin cores;

Figure 4 is a plan view of a segmental filler block for the faucet of a spigot and faucet pipe;

Figure 5 is a plan view of a sand-restraint ring;

Figures 6 and 7 are plan and side views of a thickness-determination ring radially cut to allow it to expand;

Figure 8 is a fragmentary view of a mould seam, showing a spring washer.

It is known that the application of pressure to the fresh concrete of a pipe within the mould imparts improved properties to the concrete; thus, the strength and density of the concrete are increased, the volume change due to variation of moisture content or temperature becomes less, hardening is accelerated, water is expelled (and hence a low ultimate water ratio can be secured without the costly difficulties of working with initially very dry mixtures) and the concrete forms a better bond to the reinforcing steel. This application of pressure, if accompanied by slight relaxation or stretching of the mould, causes pre-stressing of the reinforcement and thus subsequently places the concrete in a state of compression which offsets, or partly offsets, tension stresses due to shrinkage, loading or other factors. As one result, cracking is prevented or delayed. Prior to the development of my procedure, hereinafter mentioned, British specification No. 433,059 (Freysinnet) described an apparatus in which an expansible core formed the inner mould and the concrete was poured between it and an outer mould. The apparatus described is very complicated and would be very costly if it were used in practice for the manufacture of pipes. In my original procedure and also in subsequent developments thereof (including those forming the subject of the present specification) the pipe to which the process is applied is one newly formed by the rotary or any other process which at that stage leaves substantially the whole inner surface of the pipe exposed. The term "newly formed" is used to indicate that the hardening of the concrete has not progressed to any marked degree or, in other words, that the concrete is in such a condition that it can deform, under the pressures and conditions of the process, without cracking. The chemical process of hardening of course commences when cement is wetted, and developes at different speeds for different samples of cement. The rate of hardening varies with the temperature of the concrete materials and other factors.

In my original procedure pressure was applied by an expansible rubber core to the inner surface of a pipe newly formed by the rotary or other process not involving the use of an inner mould; but that procedure necessitated the provision of many cores to suit the many sizes of the pipes. To overcome that difficulty I subsequently evolved the method of inserting a layer of sandy material such as sand or like granular or powdery material between the expansible core and the concrete. This had the additional advantage that the sand acted as an absorbent for water expelled from the inner surface of the concrete. The granular or powdery material used for this purpose must be chemically inert or substantially inert in relation to the pipe and core.

This use of an intermediate layer was a useful advance on previous practice but there are cer-

tain operational difficulties inherent in the use of a rubber or like core. It is necessarily in the form of a long narrow bag which has been found somewhat difficult to handle in practice as it lacks rigidity and is "floppy." Also the rubber bag is costly, tends to deteriorate under repeated heating, is liable to be damaged and has a tendency to develop leakage at its joint with the inflation pipe. Further, it is necessary to provide end restraint plates and retaining rods therefor. After long investigation I have devised a core which increases in volume under fluid pressure but which, nevertheless, is relatively rigid during handling and insertion in the pipe and also during the subsequent insertion of a sand layer around it, and which is less liable than a rubber bag to develop leakage and does not require end restraint plates and their retaining rods. This core is longitudinally corrugated or other non-circular tube 1 formed of light metal plate. The tube is semi-rigid but is formed of sufficiently light gauge plate to enable it to be distorted to a more nearly circular cross-section when fluid pressure is applied within it.

In the construction shown in Figures 1 and 3B, the core 1 is longitudinally corrugated except at its end portions 1A and 1B. These end portions are of circular cross-section and, especially in the case of cores for large diameter pipes, it is desirable that any protruding portions not restrained by the sand packing should be strengthened by enveloping bands or other reinforcement. The core is provided with a water inlet pipe 2 and an air outlet 3 and these are provided with suitable cocks 2A and 3A as shown. Means for connecting a pressure gauge 4 is also provided. If air or other gas is used as the pressure fluid, in place of water, an outlet 3 is not essential but it is usually convenient.

The metal forming the wall of the core does not stretch substantially (if at all) under the fluid pressure. It is merely slightly distorted thereby so that the cross-section of the tube becomes more nearly circular and thus the volume of the tube increases. Sandy material such as sand or other granular or powdery material S (preferably dry or nearly so) is inserted between the inner surface of the pipe P and the outer surface of this distortable core, and fluid pressure is then applied to the core. In this way, pressure is exerted through the sandy material surrounding the core, on to the pipe, thus compressing and compacting the concrete and optionally pre-stressing the reinforcement. Due to the restraint exercised by the pipe reinforcement and by the mould M in which the pipe is enclosed, the amount of distortion of the core is extremely small and does not normally cause a permanent set in the core. The end portions of the core where they project beyond the pipe end are preferably circular or otherwise of relatively smooth contour.

The fluid pressure in the core could be exerted in numerous ways using known mechanical devices; for example, by a pump and piping, or more simply (when using a liquid filler) by fitting the core with a piston at one end or by making the end closures of the tube concentrically corrugated or otherwise flexible and connecting them together by a screw-ended rod and nut. By forcing in the piston, or by turning the nut to draw the end closures nearer together, pressure could be exerted on a liquid enclosed in the core. These devices are not shown in the drawings because their construction is obvious from the description and, as hereunder mentioned, it has been found much preferable to exert the pressure by heating a liquid filler.

I have found that, when the core is filled with liquid, the expansion of the liquid by heat is sufficient, on account of the rigidity produced by the sandy packing, to exert a surprising amount of pressure on the concrete and I have found that sufficient expansion can be achieved in quite a short time merely by passing steam through a coil or other pipe 5 immersed in the liquid within the core. Of course, the heating of the core liquid could be effected electrically or by any other convenient means.

This invention thus enables pressure to be exerted on the pipe in a very simple and inexpensive manner.

I have found, for example, that when using a water-filled core of 4½ inches mean diameter, of this type, surrounded by sand in a six-inch diameter reinforced concrete pipe, the raising of the temperature of the water from 30° C. to 72° C. produced a pressure rise of 300 lbs. per square inch in the liquid and thus developed a high pressure upon the sand layer without the use of any pump or piston. The rate of heating depends upon the amount and temperature of steam passed through the coil or other steam fitting but in numerous tests, when feeding through a relatively small quantity of steam at low pressure, the necessary heating to produce an increase of pressure of approximately from 300 to 500 lbs. per square inch was effected in times varying from 15 to 35 minutes. If more rapid treatment were desired it could be achieved by more rapid introduction of steam. Despite this remarkable increase in pressure, the temperature of the water was kept well below boiling point.

The steam pipe can be of any suitable shape, thus, if desired, it could be formed as a coil but a U-tube, as shown, has been found to be quite efficient. Control of steam enables control of pressure rise.

A pump could of course be used in combination with the heating of the liquid but it is not necessary.

It is desirable to keep the temperature of the liquid below 100° C. so that steam will not be generated within the core, as this involves unnecessary difficulties as to control of pressures and the explosive effect associated with gases under pressure.

While steam-heating has been described more specifically, heating could be applied and controlled by circulating hot air, or hot water, through tubes or coils passing into or through the core, or by a number of other standard heating methods.

Its relative rigidity and tightness make such a core convenient for workers to handle, and, being a metal container, fluid-tight connections are much more readily and reliably made to it than to a rubber one. The sectional shape of the core can be one of an almost infinite number of types—the controlling principle being that, on inflation, any sectional profile other than circular will try to reach the circular, and, as the area of a circle is the greatest area that can be enclosed within a given perimeter, an increase in volume is produced; thus the core, instead of being longitudinally corrugated as shown in Figures 1 and 3B, could be approximately square in cross-section as shown in Figures 2 and 3A, or could be approximately triangular as shown in

Figures 3C and 3D. Also, instead of a single core, two or more cores, which may have sand or other sandy material between as well as around them, could be used as, for example, the twin cores shown in Figures 3E and 3F. Other non-circular cross-sections could be used as, for example, oblong, polygonal, or even irregular sections. When the section of the core would otherwise have relatively sharp angles, as in the case of square and triangular shapes, these angles are preferably rounded to prevent cracking under repeated flexure. This rounding also provides more clearance between a relatively large core and the pipe. In the case of polygonal sections with more obtuse angles this is not important.

End closure plates welded to and thus forming part of this core are preferably used to close the ends of the core, but of course any bulkhead of liquid tight type is sufficient. Provided that the thickness of the sandy filling material, in radial direction, is kept to small dimensions, e. g. about two inches maximum, there is normally no damaging tendency for the filling material, under influence of pressure, to move longitudinally in relation to the pipe, when, as is preferable, the operations are carried out with the pipe in a vertical position. Though such a core is capable of only a small expansive movement, the condition of restrain provided by the granular layer and the pipe reinforcement and the mould, causes high pressure to be developed readily, and the small more or less radial movement of the core is adequate. Such a core has not the disadvantage of a rubber core as to free and powerful endwise movement.

The core can thus be used without end restraint plates such as are necessary with a rubber core.

In cases where bulging of the sand due to endwise slipping tends to occur, as may happen when the diameter of the core is unusually small in relation to that of the pipe, sand-restraint rings may be used to restrain such bulging. As the metal core itself is capable of great resistance to end thrust of liquid under pressure, and as the tendency of the sand to slip longitudinally is slight, the sand-restraint rings are subject to a comparatively small thrust. A convenient arrangement for such restraint rings is to provide several protuberances 6 (Figures 1 and 2) on the outer face of the core near its ends and to provide two stiff metal sand-restraint rings 7 (Figure 5) with corresponding recesses 8 on their inner peripheries so that they can be slipped down past the protuberances and then given a partial turn to lock them in position.

When, as is usually convenient, the pipe is subjected to the core pressure while in a vertical position, with one end on a base plate 14, this ring and these protuberances are required at the upper end only. As already indicated, except when the thickness of the sand layer is relatively large, no sand-restraint rings or end-restraint plates are necessary provided that the end-closure portions of the core itself are sufficiently strong to resist distortion. Preferably, a connecting rod (not shown) tying one end closure portion of the core to the other is provided inside the core.

Although it is naturally desirable to apply the core pressure soon after the initial moulding of the pipe, the process is effective if applied at any time thereafter up to the point where hardening has progressed to such a marked degree that core pressure would produce cracking of the concrete.

At an air temperature of 60° F. the lapse of one hour or even more after first wetting the cement has not caused damage when a core pressure of 500 lbs. per square inch was applied. The degree of permissible delay is dependent on many factors such, for example, as type of cement, atmospheric temperature, and cement content.

If the core pressure is raised otherwise than by heating the core liquid, hot air or steam can be passed around the concrete pipe to accelerate setting or hot sand or the like can be used for the intermediate layer. In such a case allowance must be made for the rise of pressure that will occur when the heat reaches the core liquid.

After application of an initial pressure—usually 100 to 200 lbs. per square inch—in the core, the mould fastenings may with advantage be slightly relaxed, in the case of a reinforced pipe, so as to throw more tension upon the circumferential steel reinforcement. The pressure is then taken to a higher range. If the best results are desired, and particularly when it is desired to pre-tension the reinforcement, the final pressure is maintained until the concrete is hard. The time necessary is usually about 12 to 24 hours when the temperature of the concrete is about 60° F. or about 2 to 3 hours when the temperature is about 150° F. or more, as when artificially heated; but care must be taken not to relax the mould fastenings too much or too soon, otherwise cracking is possible.

When the sand pressure is 100 lbs. to 200 lbs. per square inch, this is a suitable stage at which to relax the fastenings, and the enlargement permitted by a quarter turn of a half inch whitworth nut on the mould seam bolts is sufficient for a six-inch pipe, for example. The core pressure is then increased to the desired final amount.

In making unreinforced pipes, there is a tendency for cracking to develop if the mould fastenings are too weak in relation to the strength of the mould plate. Therefore extra strong and rigid fastenings are necessary for unreinforced pipes to prevent too much elongation of the mould perimeter at the mould seam. Closable air exits are desirable where the core pressure is induced by water, oil, or such liquids, for use when introducing liquid into the core. Of course, if desired, the core can be filled with liquid and then sealed permanently when expansion is effected by heating.

The sand or like filling is preferably dry enough to run freely. It is convenient to tamp slightly damp sand in the last one or two inches at the top, to restrain any bulging tendency. The finer the particles the smoother will be the internal finish of the pipe but the inner surface may in any case be smoothed or polished by known means after the concrete has hardened.

The size of the core is indeterminate but may conveniently be of mean cross measurement about 70 to 80% of the internal diameter of the pipe.

Solid or hollow fillers could be used in the sand to take up space, e. g. longitudinally placed pipe sections, where a relatively small core is used.

To make the sand filling as nearly incompressible as possible, and so to reduce the amount of core dilation, vibration or tamping can be used.

We have found that reinforced concrete pipes can be made by this core and process, so as readily to sustain considerably more than double the hydrostatic pressure (when so tested) of which pipes of same thickness and reinforcement made by ordinary methods are capable. Consequently in designing a pipe for a given hydrostatic pres-

sure, great savings in materials are possible by the process, and more reliable test performances are secured.

In order to allow the determination rings 9 (Figures 1, 6 and 7) at the ends of the pipe mould, to enlarge more readily under the influence of the core pressure, a radial cut 10 may be made completely through the section of each such ring. A groove 11 for engagement by a correspondingly shaped ridge on the mould is provided, as is customary.

The flexible portion of the core (i. e. that part that is non-circular) should extend for approximately the full length of the pipe to be treated.

The core may protrude from both ends of the pipe, but in such case the protruding part is preferably circular in section, though if adequately strengthened as by an outside band this is not necessary.

A richening of the mix near the ends of the pipe, as elsewhere described, offsets to some extent the result of any tendency for the concrete at those parts to receive less effective pressure than the rest of the pipe. Such a tendency is also mitigated by using cut determination rings as previously described.

In spigot and faucet pipes, it is advisable to use a segmental filler block 12 (Figures 1 and 4), to prevent distortion of the shoulder 13 on the inside of the pipe. If desired, the filler block could be replaced by a supporting ring (not shown) carried on three or more legs (not shown) resting on the base plate 14; but the filler block has the advantage that it also maintains the thickness of granular or powdered filling material at those points approximately equal to that elsewhere.

Instead of relaxing the bolts of the mould seam 17, provision to allow the mould to enlarge may be made by use of spring washers 15 (Figure 8) or other flexible washers in conjunction with the mould seam bolts 16.

We will now describe a typical application of the invention, dealing for example with the preparation of a pipe 15" diameter x 8' long, suitable for a test pressure of 200 lbs. per square inch.

The mould consists of a sheet metal cylinder (for example of mild steel plate ⅛ inch thick), having a longitudinal joint or seam fastened by ½ inch bolts set 9 inches apart along it. The wall thickness is controlled by "determination rings" set within the mould near or at each end. The reinforcement necessary will consist of a spiral of No. 2 Imperial Standard wire gauge cold drawn steel wires at 1" centres. Adequate shell thickness is 1½". A concrete mix consisting of 3½ parts graded aggregate to 1 part ( by weight) cement is suitable. A richer mix, e. g. 1½ parts aggregate to 1 part cement, may with advantage be used for that part of the pipe extending 4" to 6" toward the centre from each end, especially when determination rings are not cut as elsewhere described. The mould is placed in steel rings, which are then mounted on the four trunnion wheels of a centrifugal pipe spinning machine. The mould is rotated, and the concrete introduced and finished off, by usual methods. On completion of the spinning, the mould containing the pipe is removed from the machine for the next stage—viz. the pressure treatment.

A hollow core 8' 3" overall length, of substantially square cross section, 12" by 12", with its corners well rounded so as to clear the inside surface of the pipe and made from No. 16 Imperial Standard wire gauge steel plate is used. The sectional shape of the core, for 1" inward from each end is brought to a cylindrical profile. Each end of the core is closed by an end disc of ½" steel plate welded to the inside of the core. To prevent undue longitudinal expansion of the core under pressure, three 1" diameter steel tie rods are welded to these closure discs, extending inside the core from one disc to the other.

The mould containing the pipe is placed in a vertical position and the core is then inserted approximately centrally within the pipe, with the end containing the gauge and pipe fittings uppermost and protruding through the upper end of the pipe. Dry sand passing 30 mesh sieve is then poured into the space between core and concrete until the space is filled to within 2" of the top of the pipe, when damp sand is firmly caulked in to fill completely to the upper level of the determination ring. A steel sand-restraint ring is then placed in position on the core and held by nipples protruding from the upper portion of the core, to guard against any uplift of sand under pressure. The core is then filled completely with water. Alternatively, the core may be filled with water before insertion into the pipe.

To one end of the U-tube is then attached a steam hose and steam is allowed to percolate slowly through the U-tube, so as to heat the water within the core, which then expands.

When the gauge shows a core pressure of about 200 lbs. per square inch the seam bolts (½" Whitworth thread) of mould are relaxed one complete turn each.

The gauge pressure is allowed to rise to about 500 lbs. per square inch and, by controlling the entry of steam to the U-tube, pressure is maintained at 500 lbs. per square inch plus or minus 50 lbs. per square inch for about 2 hours or longer until the concrete is hard.

When the concrete is sufficiently hard—usually not less than two hours after cement was first wetted, pressure is relaxed by opening the cock on the water inlet, the sand and the core are removed, and the pipe striped from the mould. Best results are achieved by storing the pipe in water for several days thereafter, and the pipe may be hydrostatically tested, after removal from water bath and drying for two to three hours, at the age of seven days, or even less.

It has been found that the mere pressing of the concrete to a pressure of 100 lbs. per square inch or more, with immediate release of pressure thereupon, has a greatly improving effect on pipe quality, but a still better result follows the maintenance of pressure until the concrete is hardened and the use of higher pressures.

The details as to temperatures, times and other conditions have been given in the preceding detailed description with respect to the use of Portland cement concrete of the sort commonly used for pipe making. In the use of any other type of cement or concrete these conditions would normally be varied to suit the characteristics of the particular material but the general procedure would follow the same principles.

The reinforcement used in this process is preferably cold drawn steel wire or other wire of higher ultimate strength. It is preferably positioned in the outer half of the shell thickness. The process tends to create a tension in the reinforcement, which tension, if maintained until the concrete is hardened to an adequate extent (by maintaining core pressure as elsewhere described) has the advantageous effect of placing

the concrete in a state of compression, when core pressure is released.

One method of pipe design, for manufacture according to this process, using a core pressure of 500 lbs. per square inch on pipes up to say 24" diameter and a core of mean diameter ¾ x the inner diameter of the pipe, consists of—

(1) Calculating the tension (per 1" of pipe length) induced by the hydrostatic test pressure to be sustained by the pipe.

(2) Determining the thickness of shell (using 3½:1 graded mix) by computing as—

$$\text{Thickness} = \frac{\text{Tension in lbs. per sq. in.}}{800 \times \text{length of pipe in inches}} \text{ minus } 5 \times \text{sectional area of reinforcement in sq. ins.}$$

(3) Determining the reinforcement section area $A_s$, (using ordinary cold drawn steel wire) by computing as—

$$A_s \text{ in sq. ins. (per 1" length)} = \frac{\text{Tension per 1" length in lbs. per sq. in.}}{30{,}000}$$

The core pressure should be maintained (heat expansion method) for at least two hours, when prestressing is desired and when ordinary Portland cement was used. Where higher core pressures are used, or special high tensile reinforcing steel, designs involving more economy in thickness and in quantity of reinforcement are possible. In pipe manufacture by the process, we have found that aggregate for the concrete of maximum size ½" has been satisfactory for pipes 6" to 15" diameter, but of course there is no arbitrary limit of size of aggregate.

I claim:

1. Means for applying pressure to the inner surface of a freshly formed concrete pipe comprising a deformable hollow sheet metal core of non-circular approximately symmetrical cross-section, said core being adapted to be inserted into the freshly formed pipe with its outer peripheral wall spaced from the inner peripheral wall of the pipe so as to form with the latter a hollow annular space for the reception of a layer of sandy material, a liquid filling said core, and means for heating said liquid and thus expanding it, said core being deformable to more nearly circular cross-sectional shape and being thus expansible by the expansion of said liquid.

2. Means for applying pressure to the inner surface of a freshly formed concrete pipe as claimed in claim 1, in which a steam pipe extends into the liquid within the core.

3. In a method of applying pressure to the exposed inner surface of a concrete pipe formed freshly in an outer mold, the steps of inserting within the newly formed pipe while the latter is still in the mould and before the concrete has appreciably hardened a hollow sheet metal core of non-circular cross-section and deformable under internal pressure to a more nearly circular cross-section, said core having a maximum diameter less than the inner diameter of the freshly formed pipe and extending over approximately the full length of the pipe, filling said core with a fluid, packing a layer of sandy material between said pipe and said core, and applying pressure to said fluid and thus expanding said core by deforming it to a more nearly circular cross-section.

4. Method of applying pressure to the inner surface of a freshly formed concrete pipe as claimed in claim 3, in which pressure is applied to the fluid within the core by heating said fluid and thus causing it to expand.

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