United States Patent

[11] 3,581,780

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[21] Appl. No. **817,514**
[22] Filed **Apr. 18, 1969**
[45] Patented **June 1, 1971**

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[32] Priority **July 23, 1968**
[33] **Japan**
[31] **43/51595**

[54] **DOUBLE LAYER HIGH STRENGTH CONCRETE PIPE**
3 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **138/175,** 138/177
[51] **Int. Cl.** **F16l 9/08**
[50] **Field of Search** ..... 138/175, 177, (Examiner); 106/100, 103, (Inquired)

[56] **References Cited**

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ABSTRACT: A reinforced concrete pipe having an inner layer and an outer layer, said outer layer comprising Portland cement and said inner layer comprising a blend of a cement expanding agent and Portland cement in a proportion of from 4:96 to 20:80 by weight, said cement expanding agent comprising a pulverized, sintered material having a molar CaO/Al_2O_3 ratio of 2/6 and a molar $CaSO_4/Al_2O_3$ ratio of 2/4, said pulverized, sintered material having a grain size distribution of particles of less than 44 microns representing less than 10 percent, particles of 44—250 microns representing more than 70 percent and particles of more than 250 microns representing less than 20 percent. A method of making a high strength reinforced concrete pipe, which comprises molding a reinforced concrete pipe having the above-noted composition, curing until said pipe has a strength sufficient to resist the mold releasing, releasing said pipe from the mold and subjecting said pipe to curing.

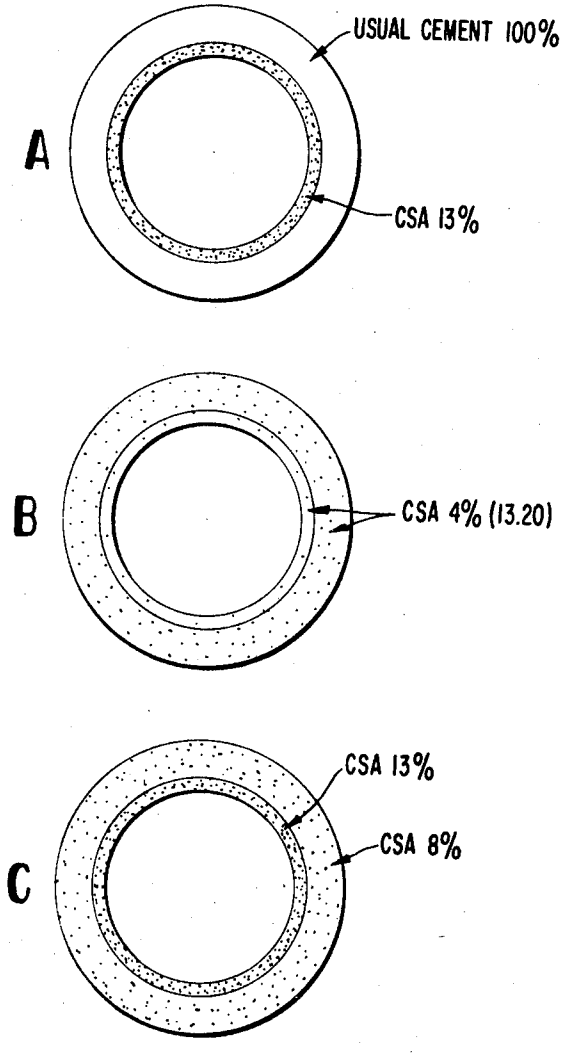


FIG. 1

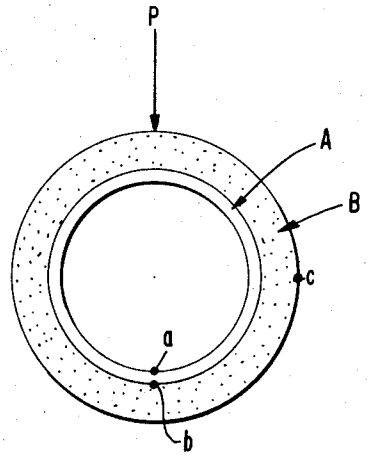
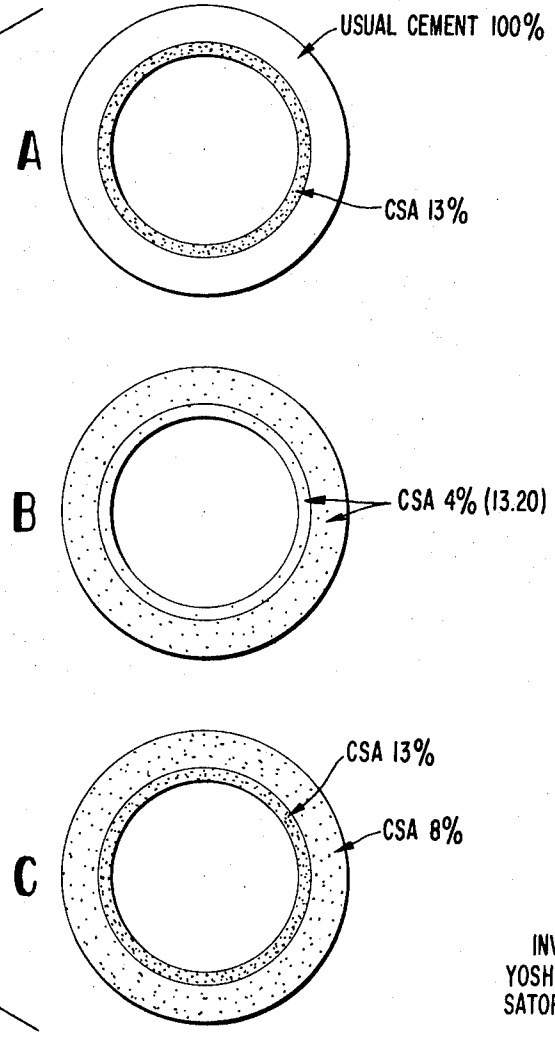


FIG. 2



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DOUBLE LAYER HIGH STRENGTH CONCRETE PIPE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method of making a high strength, reinforced concrete pipe.

2. Description of the Prior Art

High strength, reinforced concrete pipe must be made considering the initial cracking load and breaking load as the most important properties required from its structure. In order to raise the initial cracking load, it is necessary to increase the bending and tensile resistance of concrete. For this purpose, it has been proposed (a) to increase the bending tensile strength and tensile strength of the concrete itself, (b) to increase the thickness of the pipe and (c) to apply a compressive stress (hereinafter referred to as prestress) to the concrete. In commonly used Portland cement, however, the bending tensile strength and tensile strength of the concrete itself are small and the shrinkage, when hardened and dried, is large, resulting in the bending tensile resistance and tensile resistance of the actual concrete composing a pipe being markedly small. Therefore, in order to enlarge the initial cracking load of a pipe, there is no alternative but to increase the thickness thereof or apply a prestress thereto.

With respect to increasing the thickness of a pipe, a molding flask must be provided and much material is required. The increase of weight results in difficulties of transporting and laying. In the case of applying a prestress, although it is not necessary to increase the thickness of a pipe, a steel wire must be mechanically tensioned, as in the prior art, and complicated working steps are necessary for effecting prestressing in the circumferential direction. This is a reason why mass production is difficult, resulting in high cost and prohibiting wide use. Various methods are known for raising the breaking load such as (a) increasing the number of reinforcing bars, (b) using reinforcing bars having a high tensile strength and (c) increasing the thickness of a pipe. Since some of these methods have some advantages, it is preferred in the production of the so-called high strength reinforced concrete pipe (I) to enlarge the thickness of a pipe, (II) to apply a prestress and (III) to increase the number of reinforcing bars. It has hitherto been believed there is no other means except these three to accomplish the desired result. However, a remarkably high cost results.

SUMMARY OF THE INVENTION

The present invention provides a low cost and very high strength reinforced concrete pipe obtained by more simplified working steps than in the prior art, comprising molding a reinforced concrete pipe using an expansive cement blended with a cement expanding agent consisting mainly of calcium sulfoaluminate, free lime and free gypsum (referred to as CSA hereinafter), curing in a molding flask until a strength sufficient to resist the releasing therefrom is given, then releasing the molded pipe from the mold and subjecting it to curing in water or by spraying to promote the expansion of the concrete.

In accordance with the present invention, in the production of a high strength reinforced concrete pipe, the initial cracking load and breaking load are raised by blending the usual Portland cement with CSA whereby the nonshrinkage high strength by curing on a flash and the reinforcing bars are tensioned by expansion of the concrete to apply a compressive stress to the concrete.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 are schematic illustrations of the reinforced concrete pipe of the present invention in cross section.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings for (b) purpose of illustration, the pipe wall is divided into two layers, inner layer A and outer layer B, three points (a), (b), (c) being on the inside of said inner layer, inside of said outer layer and outside of said outer layer respectively. In the case of the general centrifugal molding method, for example, the layer near the circumference, including points (a) and (b) is enriched with lighter weight cement than that of the aggregate caused by the centrifugal force acting during the molding and the hardening and drying shrinkage, and in particular, at point (a) is so large that a tensile stress is applied. In a case where an external force P is applied, there occurs a cracking at point (a) when the sum of the tensile stress by the hardening and drying shrinkage of cement and the tensile stress caused by the external force exceeds the strength of the concrete. Consequently, the initial cracking load is small with respect to the tensile stress caused by the hardening and drying shrinkage of the cement, and thus crackings tend to occur.

The present inventors make it possible, as a result of various studies, to make a desired concrete pipe by carrying out molding of a pipe layer by one of the following three methods, and carrying out a sufficient curing after adding a suitable amount of CSA and a mold releasing agent.

1. Making the layer A of a CSA-compounded cement and the layer B of the usual Portland Cement (FIG. 2A)

When a load of external pressure is applied to a pipe, a large tensile stress is generated at the inside of the pipe wall and, when this tensile stress exceeds the tensile resistance at this point, crackings occur. Accordingly, the hardening and drying shrinkage of cement at this point is lowered by the use of a CSA-blended concrete and by applying a prestress to this part by expansion of the concrete, to thus obtain a high strength concrete pipe. In this case, the ratio of the thickness of the CSA-blended concrete to that of the pipe must be determined so that no cracking occurs. Arrangement of reinforcing bars is such that a part or all of the reinforcing bars may be in the CSA-blended concrete. Furthermore, the quality and quantity of the reinforcing bars are determined so as to satisfy the application of prestress as well as the desired breaking load.

2. Making the layer A and B of a CSA-blended cement in a same ratio (FIG. 2B)

Since a CSA-blended concrete is used throughout the entire pipe, a prestress is applied uniformly to any part of the pipe body to thus give a high strength pipe, to a load of external or internal pressure. Arrangement of reinforcing bars is such that a part or all of the reinforcing bars may be outside the center of the pipe thickness. The quality and quantity of the reinforcing bars must be determined according to the foregoing (1).

3. Making the layer A and B of CSA-blended concretes, the blend ratio being larger in the former than in the latter (FIG. 2C)

Since the generation of a tensile stress by a load of external pressure is greater in the interior of a pipe, and since the binding of reinforcing bars does not extend up to the expansion of concrete at the outside of the reinforcing bars, a higher CSA-blended concrete, having a larger expansive force, is used inside the pipe so that the distribution of prestress is higher on the inside. Arrangement of reinforcing bars is such that a part or all of the reinforcing bars may be in the inner concrete having a larger expansive force, the remaining being in the outer concrete. Furthermore, the quality and quantity of the reinforcing bars is determined similarly to the foregoing (1) or (2).

The method of producing the high strength concrete pipe of the present invention will hereinafter be illustrated.

The usual Portland cement, aggregate and CSA are adequately blended with water, charged into a molding flask in which reinforcing bars are assembled (in the case of foregoing molding method (1), CSA is not blended), subjected to revolving for a predetermined time, for example, in the centrifugal molding method and then the revolving of the molding flask is lowered (in the case of foregoing molding method (2), the revolving may be continued to a predetermined thickness) thereby forming a part corresponding to the layer B. Then, a mixture in which more CSA is blended than in the layer B is

charged into the molding flask and subjected to revolving, thereby forming another part corresponding to layer A. In the case of foregoing molding method (2), the same compound is used as in layer B. The CSA used herein is one capable of forming a hydrated product having a most remarkable expanding effect of concrete, that is, cement bacillus of high sulfate type, which is prepared by firing a raw material having a CaO/Al_2O_3 ratio of 2/6 and a $CaSO_4/Al_2O_3$ ratio of 2/4 and pulverizing the sintered product to a grain size distribution of particles of less than 44 microns representing less than 10 percent, particles of 44—250 microns representing more than 70 percent and particles of more than 250 microns representing less than 20 percent and which has, for example, the following chemical composition.

TABLE 1.—CHEMICAL COMPOSITION OF CSA (PERCENT)

Ignition loss	Insoluble	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	SO_3	Total
0.5	2.4	1.7	12.2	0.6	48.8	0.3	0.3	32.2	99.0

stress to the concrete through its reaction force.

The following examples are set forth in order to more fully illustrate the present invention and are not intended to be limiting in nature.

Example 1 (Molding method (1))

The reinforced concrete pipe to be made is 1200 mm. in inner diameter, 95 mm. in pipe thickness and 2430 mm. in length. Twenty-four iron wires (Φ =5 mm.) were used as the straight reinforcing bar and an iron wire (pitch 35 mm., Φ 4 mm.) was used as the spiral reinforcing bar. The pipe was molded by the centrifugal method, and comprises two layers, the inside layer having a thickness of 30 mm. and consisting of a blend of Portland cement and CSA (87:13), and the outside layer having a thickness of 65 mm. and consisting of only cement. The molded pipe was allowed to stand at room temperature for 3 hours after the molding, cured by steam in the molding flask for 5 hours (maximum temperature 65° C, 2 hours), released from the mold and cured in water for 13 days. Results of external pressure tests are tabulated in table 2.

TABLE 2.—EXTERNAL PRESSURE TEST RESULTS

	Thickness (mm.)		Inner layer (percent)		Outer layer (percent)		Initial crack load (T/m.)	Crack load, crack width 0.25 mm. (T/m.)	Break load (T/m.)
	Inner layer	Outer layer	Portland cement	CSA	Portland cement	CSA			
Our method	30	65	87	13	100	0	6.2	8.0	16.0
Known method	30	65	100	0	100	0	3.0	4.0	15.3

The pipe is shown in Fig. 2A.

Example 2 (Molding method (2))

It has been found by various experiments that a suitable blending ratio of the CSA in cement is within a range of 4—20 percent (cement: CSA=96:4—80:20by weight) for obtaining a sufficient compressive stress and sufficient bending tensile strength by expansion. By employing a blend ratio less than this range, the expansive force of concrete is so small that the compressive stress is scarcely given, whereas by employing a blend ratio greater than this range, there occur crackings due to expansion at parts where the binding either does not extend to or is hardly affected, for example, at the end parts.

In the foregoing molding methods (1), (2) and (3), the CSA is preferably blended in a proportion of 4—20 percent in a cement. In particular, in the case of the molding method (3), a layer A should be blended therewith 1 percent more than layer B in order to achieve the object of the present invention. As a curing method, a high temperature curing, at normal temperature or higher, is carried out in the molding flask after molding. Preferably, the temperature should not exceed 90° C since, when the CSA is blended, the evaporation of water from the concrete o,curs to such an extent that the water required for hydration is wanted.

As is described in detail hereinbefore, the method of making a high strength reinforced concrete pipe according to the present invention provides three kinds of pipes, classified according to the foregoing CSA addition methods. That is to say, the method consists of molding (1) an outer layer consisting of only cement and an inner layer blended with CSA, (2) an outer and an inner layer blended with CSA or (3) an outer and an inner layer blended with CSA, the blending proportion being higher in the latter than in the former, curing at normal temperature, or higher, until a strength sufficient to resist the mold releasing is given and, thereafter, after mold releasing, subjecting the pipe to curing in water or by spraying, thereby to tension the reinforcing bars through the expansive force generated during the same time and to apply a compressive

The reinforced concrete pipe to be made is 1200 mm. in inner diameter, 104 mm. in thickness and 1200 mm. in length. Thirty-two PC steel wires (Φ =5 mm.) were used as a straight reinforcing bar and a PC steel wire (pitch 35 mm. Φ 4 mm.) was used as a spiral reinforcing bar. Six concrete pipes were molded by the vibration method, using Portland cement to CSA ratios of 96:4,87:13;80:20,97:3 and 75:25 and no CSA for comparison. Curing after this molding was carried out as in example 1. The results are shown in table 3.

TABLE 3.—EXTERNAL PRESSURE TEST RESULTS

	Cement composition, percent		Initial crack load (T/m.)	Crack load, crack width= 0.25 mm. (T/m.)	Break load (T/m.)
	Portland cement	CSA			
Our method	96	4	6.0	7.0	31.0
	87	13	9.0	11.0	30.5
	80	20	12.0	14.0	30.0
Comparative example	97	3	3.5	4.9	30.0
	75	25	4.1	5.0	23.5
Known method	100	0	3.0	3.5	29.0

The pipe is shown in Fig. 2B.

EXAMPLE 3 (MOLDING METHOD (3))

The reinforced concrete pipe to be made has dimensions similar to example 1,i.e., 1200 mm. in inner diameter, 95 mm. in pipe thickness and 2430 mm. in length. Thirty-two iron wires (Φ =5 mm.) were used as a straight reinforcing bar and an iron wire (pitch 35 mm. Φ 3.5 mm.) was used as a spiral reinforcing bar. The pipe was molded by the centrifugal method, and comprises two layers, the inside layer (thickness =30 mm.) being blended with CSA in a Portland cement to CSA ratio of 87:13 by weight, and the outside layer (thickness =65 mm.) being blended with CSA in a Portland cement to

CSA ratio of 92:8. Curing after the molding was carried out as in example 1.5The results are tabulated in table 4.

TABLE 4.—EXTERNAL PRESSURE TEST RESULTS

	Thickness (mm.)		Inner layer (percent)		Outer layer (percent)		Initial crack load (T/m.)	Crack load, crack width 0.25 mm. (T/m.)	Break load (T/m.)
	Inner layer	Outer layer	Portland cement	CSA	Portland cement	CSA			
Our method	35	65	87	13	92	8	8.0	10.0	16.2
Known method	35	65	100	0	100	0	3.0	4.0	15.3

The pipe is shown in FIG. 2C.

It is evident from the test results of examples 1, 2 and 3 that the initial cracking load for the pipes produced by the method of the present invention is improved 2—4 times as much as those of the prior art, that is, using only the Portland cement. Moreover, the breaking load is the same as, or more than, that of the prior art, independently of the molding method.

We claim:

1. A reinforced concrete pipe having an inner layer and an outer layer, said outer layer comprising Portland Cement and said inner layer comprising a blend of a cement expanding agent and Portland cement in a proportion of from 4:96 to 20:80 by weight, said cement expanding agent comprising a pulverized, sintered material having a molar CaO/Al_2O_3 ratio of 2/6 and molar $CaSO_4/Al_2O_3$ ratio of 2/4, said pulverized, sintered material having a grain size distribution of particles of less than 44 microns representing less than 10 percent, particles of 44—250 microns representing more than 70 percent and particles of more than 250 microns representing less than 20 percent.

2. A reinforced concrete pipe as in claim 1 wherein said outer and inner layers comprise a cement blended with said cement expanding agent in a proportion of from 4:96 to 20:80.

3. A reinforced concrete pipe as in claim 1 wherein said outer and inner layers comprise a cement blended with said cement expanding agent in a proportion of from 4:96 to 20:80, the proportion of said cement expanding agent in said inner layer being greater than in said outer layer.