

Aug. 4, 1942.

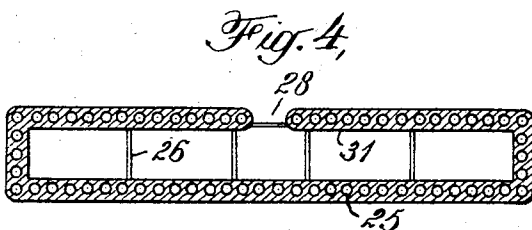
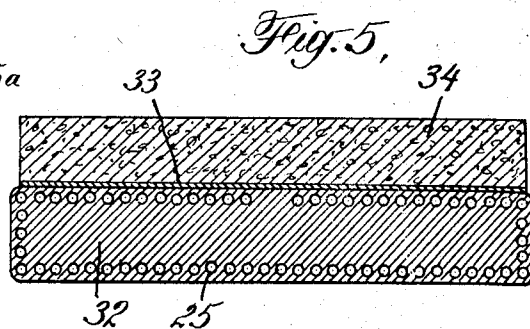
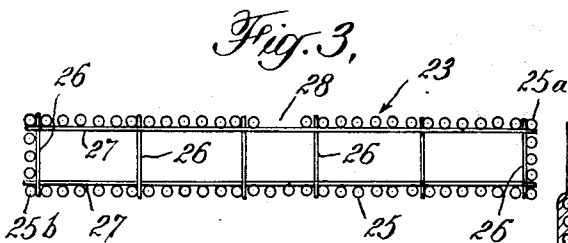
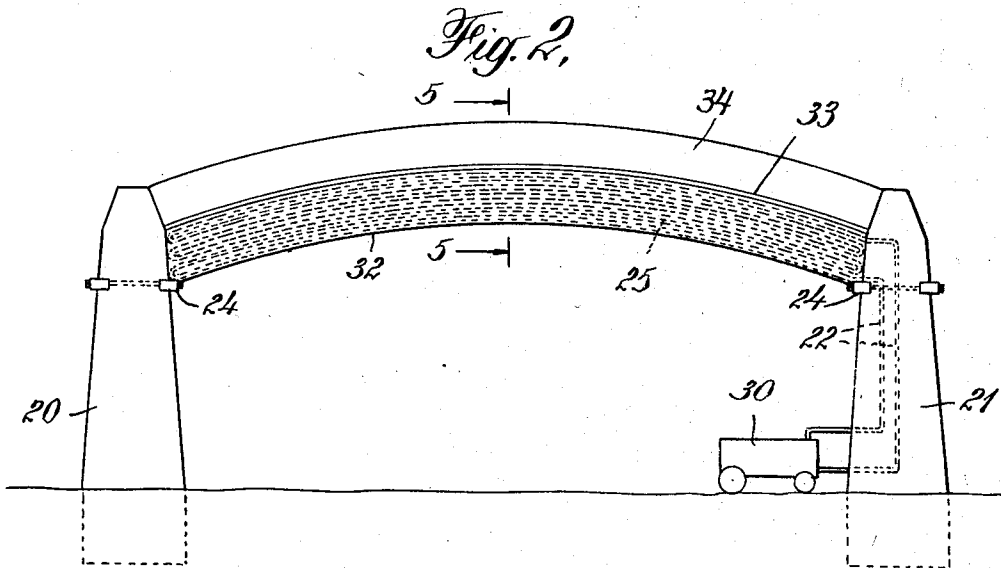
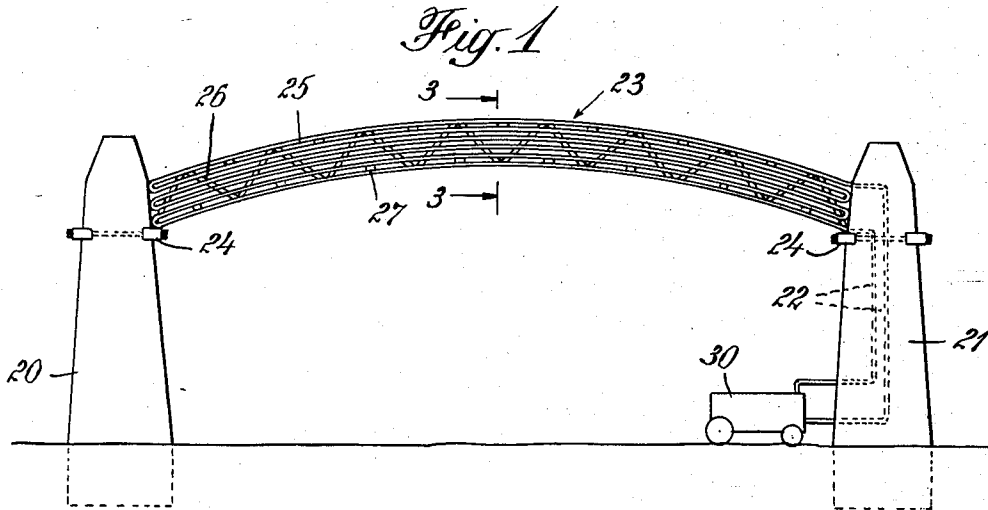
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2,291,680

STRUCTURE AND METHOD OF MAKING THE SAME

Filed Dec. 14, 1939

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 6,

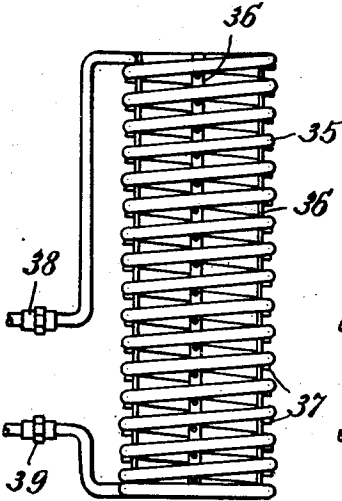


Fig. 7,

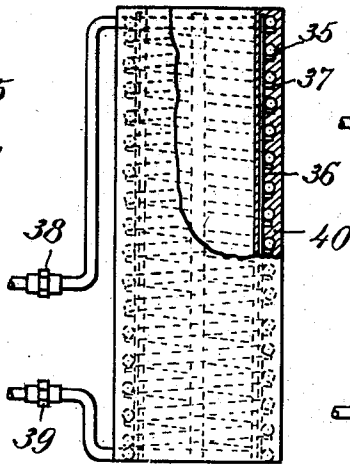


Fig. 8,

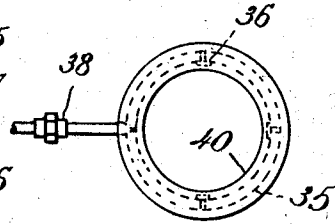


Fig. 9,

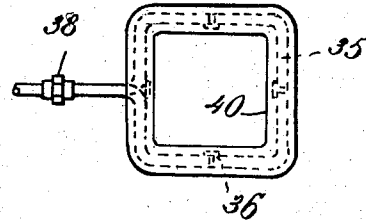


Fig. 10,

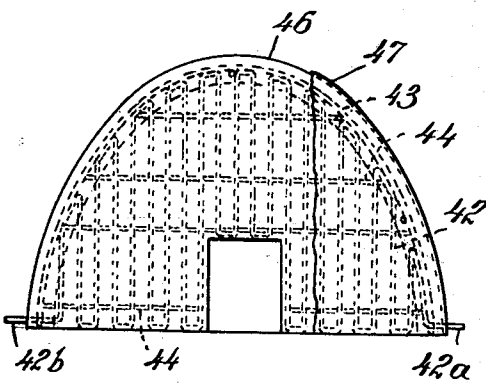


Fig. 11,

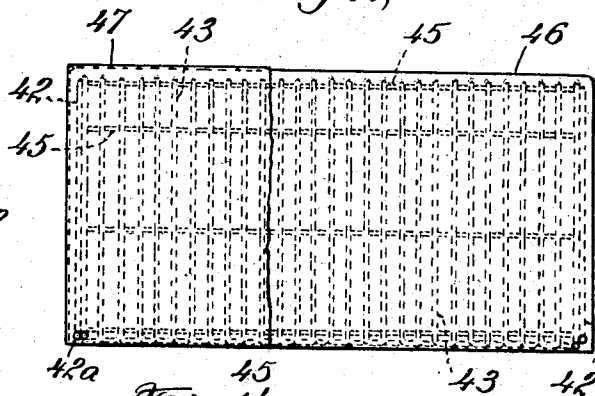


Fig. 12,

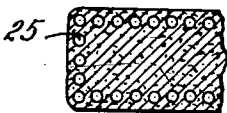


Fig. 13,

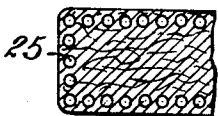
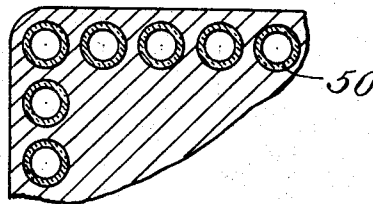


Fig. 14.



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2,291,680

STRUCTURE AND METHOD OF MAKING
THE SAME

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Application December 14, 1939, Serial No. 309,269

4 Claims. (Cl. 62—1)

This invention relates to structural objects, such as supporting columns, arches, building walls, and the like, and has particular reference to a novel reinforced structure which is comparable in strength with a similar structure made of high grade concrete but which affords certain advantages over concrete structures by reason of its inclusion of ice as a principal constituent. The new structure is easy to assemble and disassemble and may be made at low cost by the practice of a novel method which also forms part of the invention.

The use of concrete in construction work is not entirely satisfactory for some purposes because concrete when poured cannot retain its form without support and has very little strength in tension and compression until it has set. Accordingly, it is necessary to provide a mold for retaining the concrete in its soft condition, and when the structure includes an arch or other part which is normally supported from below only at remote points, the mold itself has to be braced by a temporary framework. Also, the chemical reaction of the cement and water known as the setting is retarded or stopped altogether when the temperature of the concrete mass gets near to freezing. Consequently, suitable provision must be made to prevent the formation of ice within the mass of concrete.

One feature of the present invention, therefore, resides in the provision of a novel reinforced supporting structure which may be erected without the molds or temporary frameworks required in certain concrete structures and which is favorably affected by low temperatures. I have found that ice has tensional and compressional strengths comparable to the corresponding strengths of a high grade concrete and adheres readily to metal or wood, and I make use of these properties of ice in the new structure. A structure made in accordance with the invention comprises a framework including a pipe or a nest of pipes, and a mass of ice enclosing the framework so that the pipes are embedded in the ice. Preferably, the frame includes several lengths of pipe arranged in closely adjacent relation whereby the pipes serve the dual function of binding and reinforcing the ice and, when necessary, circulating a refrigerant through it to prevent melting of the ice. In any of its various forms, the structure is capable of withstanding substantially the same tensional or compressional forces as a similar structure made of concrete. If desired, the ice may contain sand, sawdust, straw or some other inert material to make it tougher and less brittle.

Another feature of the invention resides in the provision of a novel method by which the structure may be made expeditiously and at low cost. According to the new method, a framework of pipes is constructed in the form which it is to take in the completed structure, and a refrigerant, such as brine, is circulated through the pipes. Water is then frozen around the pipes by the action of the refrigerant to form a solid mass of ice which is built up gradually around the pipes so that the strength of the structure increases as the weight of the ice on it increases. The water to be frozen may be placed in a mold built around the framework or it may be sprayed or sprinkled on the pipes. When the latter procedure is employed, the pipes may be arranged in such a manner that a shell of ice is first formed having an opening at the top through which water may be poured to build up the ice on the inside of the shell. In order to reduce any tendency of the surface of the ice to crack due to contraction resulting from sudden heating, I prefer to chill the water to be frozen to a freezing temperature before it is poured into the molds or sprinkled on the pipes. The structure thus formed may be maintained permanently by circulating the refrigerant through the pipes, or it may be disassembled when desired by passing a warm liquid through the pipes to melt the ice, and then removing the pipes.

The invention outlined above has numerous applications. Since the new structure is self-supporting even in its formative stage and may be readily removed, it may be used to great advantage in the building of concrete or other structures requiring temporary supports, as for example, arch structures for bridges. In building concrete bridges arches according to the usual practice, it is necessary to construct a temporary trestle between the main supports to sustain the weight of the concrete before it sets, and the cost of erecting the trestle and removing it on completion of the arch involves a considerable item of expense, especially when the arch extends over a deep gully or a body of water. With the present invention, however, the framework of pipes may be constructed in any convenient place and hoisted into position between the main supports, after which the ice is frozen around the pipes to form a strong, solid support on which the concrete may be poured. Also, since the new structure may serve both as a cooling medium and an insulator, it is admirably suited for use in refrigerating compartments, storage tanks, etc., to form the walls or the roof, or both. Additionally, the structure of the invention does not ex-

pand and contract appreciably in response to temperature changes of the surrounding atmosphere, as in metal structures, because the pipes are maintained at a substantially constant temperature by the ice in which they are embedded, and therefore it may be used to advantage as a supporting column, or the like, in constructions where slight dimensional changes are undesirable.

For a better understanding of the invention, reference may be had to the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a side view of a framework of pipes arranged in the form of a temporary arch between two columns;

Fig. 2 is a similar view showing the framework encased in a mass of ice to lend temporary support to a concrete arch;

Fig. 3 is a sectional view on the line 3—3 in Fig. 1;

Fig. 4 is a view similar to Fig. 3 showing a shell of ice formed over the pipes;

Fig. 5 is a sectional view on the line 5—5 in Fig. 2;

Fig. 6 is a side view of a framework of pipes for a reinforced supporting column;

Fig. 7 is a similar view showing the framework encased in a mass of ice;

Fig. 8 is a plan view of the column shown in Fig. 7;

Fig. 9 is a view similar to Fig. 8 showing a modified form of the column;

Fig. 10 is a front view of a building constructed in accordance with the invention with part of the building broken away;

Fig. 11 is a side view of the building shown in Fig. 10 with part of the building broken away, and

Figs. 12, 13 and 14 are sectional views of modified forms of the new structure.

I have ascertained that the tensile and compressive strengths of pure ice are greater than those of most concretes and substantially the same as the corresponding strengths of a high grade concrete. Further, I have found that the strength of ice is considerably greater when it has an inert material dispersed in it, such as sand, sawdust, straw, or the like. For example, in tests of several specimen beams of 20 deg. F. and of the standard dimension of 11¼"x4½"x1" arranged with an effective span of 10" and a height of 1", the following strengths were indicated:

Material	Ultimate tensile strength	Ultimate compressive strength
	Lbs./sq. in.	Lbs./sq. in.
Pure frozen water, plain.....	500	1,500
Pure frozen water, reinforced.....	1,000	2,500
Frozen saturated wet sand, plain.....	1,100	1,300
Frozen saturated wet sand, reinforced.....	1,300	
Frozen saturated wet sawdust.....		
Straw immersed in frozen water.....		

The above strength figures refer to values of ultimate fibre stresses of the beams tested in flexure, and the compressive strengths in the reinforced specimens were determined by the straight line theory of calculation. These tests thus indicate that the tensile strength of frozen saturated sand or frozen saturated sawdust is about twice that of a good concrete while the tensile strength of immersed frozen straw is about 2½ times that of good concrete.

It will be apparent from the foregoing that the qualities of ice as a building material are similar to or better than those of concrete except that ice has a relatively low melting point. In accordance with my invention, I provide a building material of ice containing a framework which performs the same function as the usual reinforcements in concrete but which, in addition, conducts a refrigerant through the ice to maintain the ice below its melting temperature. By simple regulation of the flow of refrigerant, the temperature of the ice may be kept constant so that the thermal expansion and contraction and the resulting internal stresses common to other building materials are avoided. Also, structures embodying my invention have the advantage that, unlike ordinary insulated structures, they cannot become heated gradually under the action of continuous heat. Accordingly, the new structure may be used to advantage in the construction of cold storage buildings, gasoline storage tanks, roofs of dwellings, decks of oil tankers, etc., and by reason of its low melting point it is admirably suited for use in temporary constructions, such as the centering for supporting the arch of a bridge until the bridge is completed.

I have illustrated in Figs. 1 to 5, inclusive, one form of the invention and a novel method of employing it in the construction of concrete arches. The main supports for the arch are in the form of piers 20 and 21 preferably made of concrete and having pipes 22 embedded in one of them. An arched framework 23 is arranged between the piers and mounted at its ends on supports 24 secured to the piers. The framework, as shown, comprises a nest of pipes 25 made of metal or other heat conducting material and arranged to form a hollow body of rectangular cross-section. The pipes may be braced by trusses 26 and cross-pieces 27 and are arranged in any suitable manner to form a continuous conduit from an inlet 25a to an outlet 25b. As shown, the pipes are disposed in parallel, closely adjacent relation except for two pipes at the top which have a relatively large spacing between them to form an opening 28. The framework is preferably constructed in any convenient location and then hoisted in position between the piers 20 and 21.

The inlet and outlet 25a and 25b are connected to the two pipes 22, respectively, which lead from the lower part of pier 21 to a refrigerating unit 30 for circulating a refrigerant, such as brine, through the pipes of the frame 23. While the refrigerant is circulating, water is sprinkled on the pipes 25 and frozen so as to form a shell of ice 31 in which the pipes are embedded. By reason of the relatively large spacing of the pipes around the opening 28, the latter is not completely obstructed by the formation of the shell 31, and, accordingly, water may be admitted into the shell through this opening and frozen by the action of the refrigerant so as to form a solid mass of ice 32. A sheet 33 of wood or other suitable material is then placed on top of the ice arch. This sheet serves as the bottom of a form, the sides of which are not shown. A layer of concrete 34 is poured into this form which rests on the ice arch. After the concrete has set and hardened, the ice may be melted by circulating a warm liquid through the pipes 25. The frame 23 may then be removed by cutting the inlet and outlet pipes 25a and 25b, and removing the supports 24. Also, the refrigerating unit may be

detached by cutting the pipes 22 where they project from the pier.

The temporary supporting structure may be made economically by the new method with materials obtainable at low cost, and it may be readily disassembled so that the framework 23 and the refrigerating unit 30 may be used again in another construction. When the ice is frozen solidly, the structure is capable of sustaining substantially the same weight as a similar structure made of concrete, but the erection of the new structure is not affected adversely by low temperatures, as in the case of concrete, and does not require the construction of a temporary supporting trestle below the arch since the pipes 25 have sufficient strength to support the shell of ice 31 which is first formed, and thereafter the structure increases in strength as the ice builds up.

Referring to Fig. 6, I have shown another form of the invention having a framework including a pipe coil 35 supported by uprights 36, each of the uprights being provided with fingers 37 for supporting the coils of the pipe. The opposite ends of the pipe may be connected through pipe joints 38 and 39 to the inlet and outlet sides, respectively, of a suitable refrigerating unit (not shown) for circulating a refrigerant through the coil. The frame is encased in an ice shell 40 by supplying water on the outside of the coil while the refrigerant is circulating through it. Water may be supplied to the coil by building a mold around the coil and filling the mold with water, or by sprinkling water over the coil. Since the coil is open at the top, water may be poured into the initial shell of ice formed around the coil so as to build up the mass of ice within the convolutions of the coil. If desired, the pipe 35 may be bent into a form of square cross-section, as shown in Fig. 9, instead of a helical form.

In the column thus formed, the pipe 35 and standards 36 act as a binder and reinforcement for the ice and also serve to pass a refrigerant through the ice to prevent melting thereof. By reason of the strong adhesion between ice and metal, the ice will not fall away from the coil 35 and uprights 36 even when the column is supporting a heavy weight. Through proper control of the supply of refrigerant in the coil 35, the temperature of the ice may be held constant in spite of changes of temperature in the surrounding atmosphere, and, accordingly, the column may be used to particular advantage in constructions where thermal expansion and contraction are objectionable.

The structure of the invention may also be used to advantage in refrigerating compartments. I have shown in Figs. 10 and 11 a compartment comprising end walls each having a vertical frame of pipes 42 arranged in closely adjacent, parallel relation to form a continuous conduit. A refrigerant may be circulated through the pipes by a refrigerating unit (not shown) connected to the conduit at its opposite ends 42a and 42b. The roof and sidewalls of the structure comprise a framework of pipes 43 arranged in closely adjacent relation in the form of an arch and connected to the refrigerating unit so that a suitable refrigerant may be circulated through them. The pipes 42 and 43 may be braced by cross-pieces 44 and longitudinal members 45.

The pipes thus arranged are supplied with water on the outside to form a shell of ice 46 in which the pipes are embedded, and the shell is maintained in a solid condition by circulating

the refrigerant through the pipes whenever necessary. Perishable articles may be stored within the compartment and maintained at a low temperature by the shell 46 which, if desired, may be provided with a surface covering 47 of canvas, straw or other suitable material to prevent too rapid thawing of the ice. The cost of circulating the refrigerant through the shell is comparable with that of operating a refrigerating unit within an insulated compartment as in the present practice, but the new refrigerator may be constructed at a considerably lower cost than prior refrigerators for the reason that the shell 46 serves both as the cooling medium and the insulating material. Also, since the shell 46 is translucent, it is not necessary to insert windows for lighting purposes.

When the structure includes a finely divided inert material, such as sand or sawdust, to provide additional strength, the particles may be readily incorporated before the ice is frozen, since they mix easily with water and do not have a tendency to float. In such structures, the particles are dispersed throughout the ice, as shown in Fig. 12, and increase the strength of the structure. Also imbedded sawdust decreases the rate of melting of the ice. Straw immersed in water and frozen (Fig. 13) has a still lower rate of melting and makes a strong and tough material having excellent insulating qualities. If desired, the structure may be provided with reinforcements such as bars of steel or strips of wood. Also, when the structure is to be used for decorative purposes, the ice may be formed around refrigerating pipes 50 made of artificial glass or other transparent plastic, as shown in Fig. 14.

It is well known that the volume of ice is reduced when it melts and that sudden application of heat may cause the surface of the ice to crack due to the contraction. In order to prevent such surface cracking, it is advisable to chill the water to freezing temperature in a receptacle before it is poured into the molds around the freezing pipes or sprinkled on the pipes. During the chilling operation, the water may be stirred in the receptacle to prevent it from solidifying.

I claim:

1. In combination with a pair of main supports, a hollow nest of pipes mounted at its ends on the supports to form an arch between the supports, the pipes being arranged in generally parallel, closely adjacent relation to form a hollow frame and being adapted to conduct a refrigerant through the frame, and a mass of ice enclosing and at least partly filling the frame and having the pipes embedded therein, the frame serving as a binder and reinforcement for the ice, and the initially frozen ice being disposed adjacent the frame and outside the main body of ice within the frame.

2. A method of making reinforced building structures which comprises mounting lengths of pipe in closely adjacent relation to form a generally hollow frame, passing a refrigerant through the frame, simultaneously sprinkling a liquid on the frame to form a hollow shell of ice in which the frame is embedded, and supplying liquid through the top of the shell to build up ice within the inside of the shell.

3. A method of building an arch between a pair of main supports which comprises mounting lengths of pipe in closely adjacent relation between the supports to form an arch frame, passing a refrigerant through the frame, simultane-

ously supplying a liquid on the outside of the frame to build up an arch of ice in which the frame is embedded, and laying a concrete arch on top of the ice arch.

4. A method of building an arch between a pair of main supports which comprises mounting lengths of pipe in closely adjacent relation between the supports to form an arch frame, pass-

5 ing a refrigerant through the frame, simultaneously supplying a liquid on the outside of the frame to build up an arch of ice in which the frame is embedded, laying a concrete arch on top of the ice arch, and melting the ice when the concrete has set.

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