April 3, 1951 R. E. DAVIS 2,546,982

CONCRETE STRUCTURE AND METHOD OF MAKING SAME

Filed Dec. 20, 1947 2 Sheets-Sheet 1

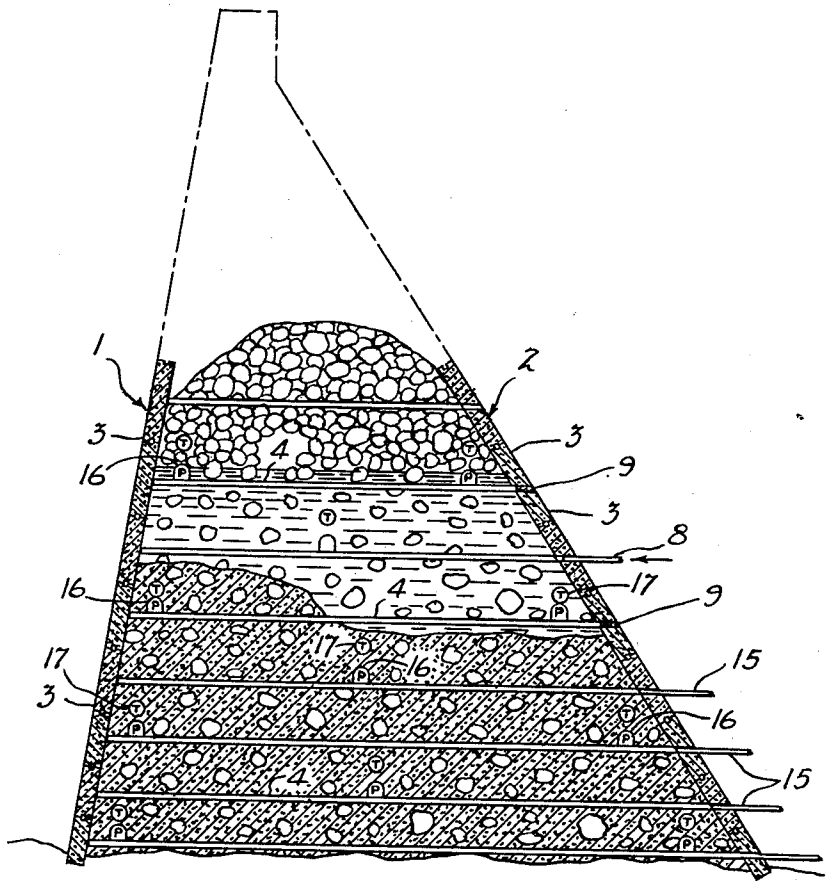


Fig. 1

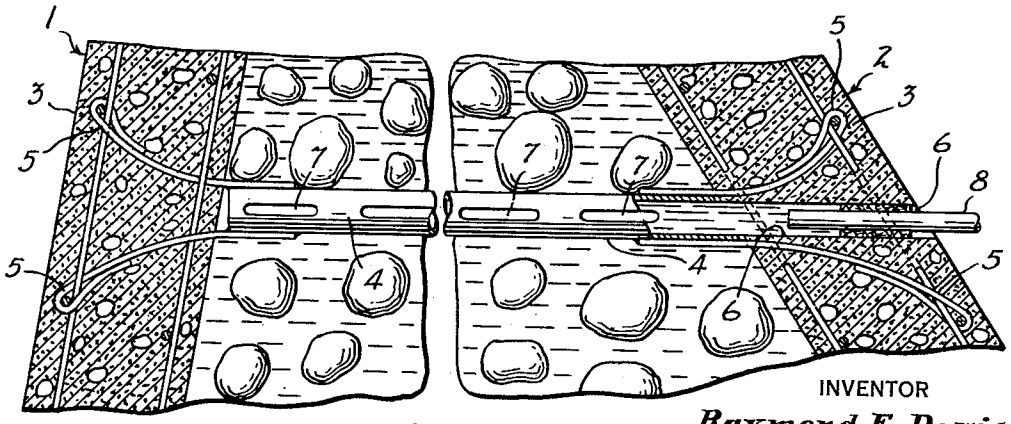


Fig. 2

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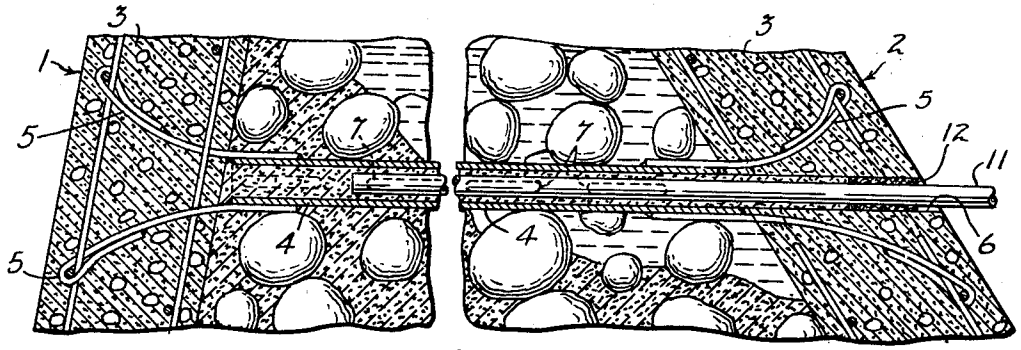


Fig. 3

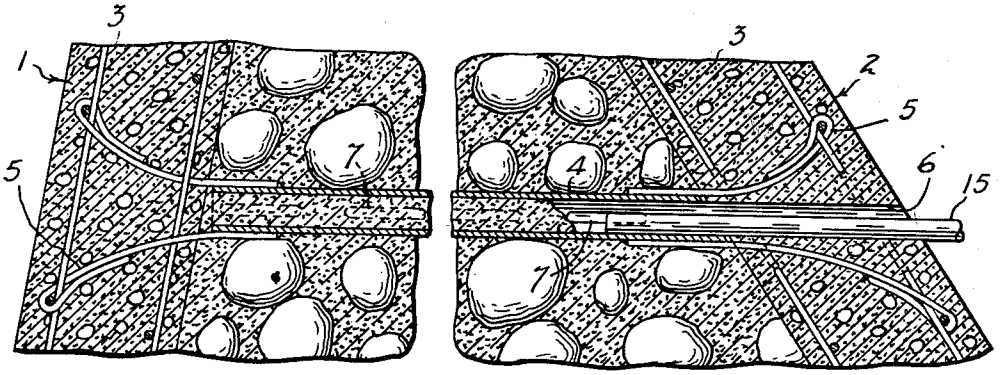


Fig. 4

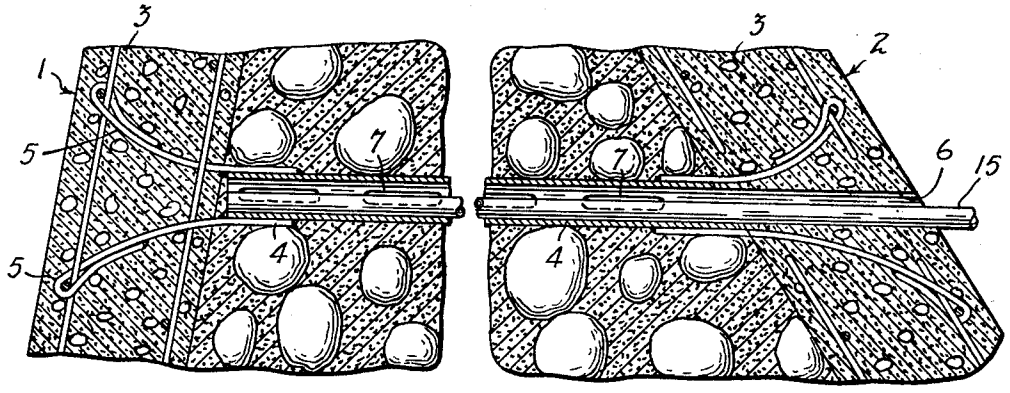


Fig. 5

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UNITED STATES PATENT OFFICE

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CONCRETE STRUCTURE AND METHOD OF MAKING SAME

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Application December 20, 1947, Serial No. 792,972

8 Claims. (Cl. 61—30)

1

This invention relates to construction of large monolithic concrete structures such as dams, piers and the like, and is an improvement upon the invention disclosed in Patent No. 2,331,311, granted to me October 12, 1943.

The aim of the present invention is to provide an improved method of construction which reduces labor and material costs and that also produces an improved monolithic concrete structure in which the pipes originally used for introduction of grout into the aggregate provide a drainage system for draining water from all portions of the interior of the monolithic structure, a feature that is particularly desirable in dams.

I have found that in regions where the mean annual temperature is low, the cooling of graded aggregate prior to grouting, as disclosed in my above-mentioned patent, is insufficient to prevent large concrete masses from acquiring a temperature during the hardening period which is undesirably higher than the mean annual. By experiment I have found that this condition may be overcome, even in regions where the mean annual temperature is as low as 45° F., by first following the practice disclosed in my above-mentioned patent with respect to cooling the graded aggregate with cold water and grouting the aggregate mass, after which I circulate through the grout pipes a supply of cold water which acts to remove the heat of hydration of the cement substantially as fast as it is developed. By following this improved method, I am able to keep the maximum hardening temperature of massive concrete structures such as dams and bridge piers to only a few degrees above that of the cooled mass of graded aggregate at the time of grouting. As applied to dams, I have also discovered that uplift pressures which decrease the stability of the structure and are caused by waters permeating from the upstream face along the foundation contact or through the concrete of the dam itself, may be virtually eliminated by a system of horizontal drain pipes open at their downstream ends and extending through the dam, to the slabs at the upstream face. The use of such a system of drains removes all possibility of appreciable pore pressure beneath or within the dam and therefore makes safely possible a substantial reduction in the size of the mass over that customarily required, and makes unnecessary the use of water stops or seals at any of the joints between slabs in the upstream face of the dam.

With the above and other objects in view, the invention may be said to comprise the method

2

of forming concrete structures and the improved concrete structure as illustrated in the accompanying drawings, hereinafter described and particularly set forth in the appended claims, together with such variations and modifications thereof as will be apparent to one skilled in the art to which the invention pertains.

Reference should be had to the accompanying drawings forming a part of this specification, in which:

Figure 1 is a vertical section through a dam in the process of construction;

Fig. 2 is a fragmentary vertical section on an enlarged scale showing one of the tie pipes connected to a pipe for delivering water or air under pressure into the aggregate to cool the same;

Fig. 3 is a fragmentary vertical section on an enlarged scale showing the manner of introducing the grout into the aggregate;

Fig. 4 is a fragmentary vertical section on an enlarged scale, showing the washing of partially set grout from one of the tie pipes; and

Fig. 5 is a fragmentary vertical section on an enlarged scale showing the manner in which water is circulated through the pipes to cool the concrete while it is hardening.

In the accompanying drawings the invention is shown applied to the construction of a dam. As in the method of my earlier patent above referred to, an outer shell is first built and filled with graded aggregate which is cooled by circulating water or air through the aggregate, after which a grout of high fluidity is introduced under pressure, first at the bottom of the structure and then progressively at higher levels so as to displace the water and fill the voids of the aggregate.

In the accompanying drawings the invention is shown applied to the construction of a dam in which the shell has an upstream wall 1 and a downstream wall 2. The shell which may be of a temporary or permanent nature serves as a form to retain the aggregates and grout until after the grout has set.

The shell is preferably composed of relatively thin articulated slabs of highly impervious weather-resistant reinforced concrete precast and cured and then placed in position to serve as a form. The joints between the face slabs 3 may be filled by grouting or if extreme water tightness is desired the slabs may be joined together with flexible strips of rubber or copper or other ductile and corrosion-resistant metal so that there can be small movements of one slab with

respect to adjacent slabs without breaking the seal between the slabs.

The walls 1 and 2 of the shell are held together by a large number of substantially horizontal tie members in the form of pipes 4 which are attached at their ends to slabs 3 of the two walls. The pipes 4 are arranged in horizontal rows which are superposed one upon another throughout the height of the structure. The pipes 4 are anchored by suitable means such as welding to steel straps, rods or bars 5 anchored in the slabs 3 and protruding from the upstream and downstream walls. Appropriate openings 6 are formed in the downstream slabs with which the downstream ends of the pipes 4 are alined and these openings permit connection of water and grout supply pipes to the pipes 4. The downstream ends of the pipes 4 are open and the pipes are provided with openings that permit lateral flow from or into the pipes substantially throughout their length. The particular form of the openings is unimportant but for purposes of illustration the pipes 4 are shown provided with spaced slots 7. The pipes 4 are utilized for cooling the aggregate, for introducing grout under pressure into the aggregate to displace the water and fill the voids of the aggregate, for circulating cold water to cool the concrete while it is hardening and, in the case of dams, for the drainage of any water which may find its way through the upstream face or beneath the dam.

In building the dam the graded aggregate is deposited in layers, the pipes are placed in position, and the slabs are erected and connected to the pipes. Thus walls 1 and 2 act as forms which are prevented from collapsing by the pipes 4 and by the intervening mass of graded aggregate. The pipes act as tension members to withstand the lateral pressures produced by the coarse aggregate, and later by the cooling water and freshly injected grout; and also the pipes are used for the circulation of cooling water through the voids in the graded aggregate prior to grouting, for the introduction of grout to fill these voids, for the circulation of cooling water after the introduction of grout into the surrounding aggregate mass, and in the case of dams for the removal of any water which may find its way through or beneath the upstream face. The operations of aggregate cooling, grouting and cooling of the grouted mass may be started in the lower portions of the structure while the shell construction and placing of aggregate is proceeding at a higher level.

For cooling the aggregate, water may be introduced into the aggregate in any suitable manner, draining the water out through pipes 4 to maintain the desired level of water. However, it is preferred to utilize the pipes 4 both for introducing the cooling water and maintaining the level thereof. Smaller pipes or hose 8 may be inserted for any desired distance in pipes 4, as shown in Fig. 2, to introduce at desired points water under pressure, which may be allowed to drain out through other of the pipes 4. The flow of water through the aggregate may be regulated by valves as desired, and the water level may be controlled by plugging the outlet ends of some of the pipes 4, as indicated at 9 in Fig. 1. Where atmospheric humidity is low the cooling may be effected by first thoroughly wetting the aggregate and then blowing air under pressure through the aggregate. Air under pressure may be introduced into certain of the pipes 4 through

pipes such as the pipes 8 to cause evaporation of the water and cooling of the aggregate.

After the aggregate is properly cooled the grouting operation is commenced at the bottom of the structure by introducing the grout under pressure through the lowermost pipes 4 to displace water and fill the voids of the aggregate. The grouting may be done as illustrated in Fig. 3 by inserting pipes 11 of smaller diameter than the pipes 4 into the pipes 4 and forcing the grout under pressure through the pipes 11. The space between the exterior of each pipe 11 and the interior of the pipe 4 into which the pipe 11 extends is preferably sealed at the downstream end by any suitable device such as the packing ring 12 shown in Fig. 3. The pipes 11 are first inserted until their discharge ends are near the upstream end of the pipes 4 and the pipes 11 are gradually retracted as the grout is filled in around the pipes 4. Grout is successively introduced into horizontal rows of pipes 4 from the bottom to the top of the structure to completely fill the voids of the aggregate with grout.

After the grout pipes 11 are withdrawn from the pipes 4, the pipes will remain filled with grout. After the grout in the pipes 4 has partially set so that it will no longer flow it is removed from the pipes 4 to permit use of the pipes for circulating water to cool the concrete mass during hardening. The removal of the partially set grout from the pipes 4 may be accomplished by suitable pipe cleaning tools but it is preferred to wash it out by inserting a small pipe 15 into the downstream end of the pipe 4 and forcing a jet of water or air and water under pressure through the pipe 15 against the soft grout, which will loosen and wash out through the space between the exterior of the pipe 15 and the interior of the pipe 4. The pipe 15 is gradually advanced in the pipe 4 as the grout is washed out, until its inner end is disposed adjacent the closed end of the pipe 4, as shown in Fig. 5 of the drawing, after which cold water under suitable pressure flows through the pipe 15 to the upstream end of the pipe 4 and back through the space between the exterior of the pipe 15 and the interior of the pipe 4 to the downstream end of the pipe 4. Water so circulated through the pipes 4 serves to keep the body of the surrounding concrete cool while it is hardening.

After the concrete has hardened and is at any desired low temperature the pipes 15 are withdrawn and in the case of dams the pipes 4 serve as a drainage system extending to all parts of the interior so that any water which may seep into any part of the interior of the structure will be drained out through the pipes 4.

In order to properly regulate pressures within the mass during the operations of placing and cooling of aggregate and grouting, a series of strain meters 16 may be attached to pipes 4 at suitable points throughout the structure, the meters 16 being designed as electrical resistance units which will indicate elastic strains in the pipes 4 from which form pressures may be calculated. Suitable electric resistance thermometers 17 may also be distributed throughout the mass to register the temperatures existing in various portions of the structure. The strain meters enable the operators to maintain suitable aggregate, water and grout levels, so that excessive pressures which might cause damage to the shell or cause excessively high tensile stresses in the pipes are avoided, and the thermometers enable the operator to establish the desired low

temperatures of the aggregate mass at the time of grouting and also to maintain suitable low temperatures in all portions of the mass during the hardening of the concrete, by regulating the flow of cooling water.

It is to be understood that variations and modifications of the specific process and product herein shown and described for purposes of illustration may be made without departing from the spirit of the invention.

What I claim is:

1. The method of constructing a monolithic concrete dam or other hydraulic structure one face of which will be subjected to water pressure, which comprises erecting an outer shell having opposite relatively thin walls, connecting said walls by substantially parallel pipes attached at their ends to the walls and spaced apart laterally and vertically throughout the length and height of said walls, the ends of the pipes attached to the upstream wall being closed and the opposite ends of the pipes opening to the outer face of the downstream wall, said pipes having openings permitting lateral flow along the length thereof, filling the space within the shell with graded aggregate, cooling the aggregate by flowing water through the aggregate and out through certain of said pipes, progressively displacing water in the voids of the aggregate from the bottom to the top of the structure with grout introduced through said pipes, removing grout from the interior of said pipes, and cooling the concrete mass during the hardening thereof by circulating water through the pipes from which grout has been removed.

2. The method of constructing a monolithic dam structure which comprises erecting an outer shell having opposite relatively thin walls, connecting said walls by substantially parallel pipes attached at their ends to the walls and spaced apart laterally and vertically throughout the length and height of said walls, the ends of the pipes attached to the upstream wall being closed and the opposite ends of the pipes opening to the outer face of the downstream wall, said pipes having openings permitting lateral flow substantially throughout their lengths, filling the space within the shell with graded aggregate, cooling the aggregate by flowing water through the aggregate and out through certain of said pipes, feeding grout under pressure into the voids of the aggregate through said pipes first at the bottom and then at successively higher levels, removing grout from the interior of certain of said pipes after partial setting of the grout, and cooling the concrete mass during the hardening of the concrete by circulating water through said pipes.

3. The method of constructing a monolithic concrete dam or other structure one face of which will be subjected to water pressure, which comprises erecting a relatively thin outer shell having opposite walls of weather-resistant concrete slabs connected by watertight expansion and contraction joints, connecting said walls by a system of substantially horizontal fixed perforated pipes distributed throughout the length and height of said walls, said pipes being attached at their ends to said walls and having openings distributed along the length thereof, the ends of said pipes attached to one wall being closed and their opposite ends open to the exterior face of the other wall, filling the space within the shell with graded aggregate, cooling the aggregate by introducing water into the aggregate through certain of said pipes and drawing water from the aggregate through other of the pipes, displacing water in the voids of the aggregate by introducing grout through said pipes progressively from the bottom to the top of the shell, removing grout from the interior of said pipes after the grout has partially set, and circulating water through the pipes from which grout has been removed to cool the concrete mass as it hardens.

4. The method of constructing a monolithic concrete dam or other structure one face of which will be subjected to water pressure, which comprises erecting a relatively thin outer shell having opposite walls of weather-resistant concrete slabs having their joints filled with grouting, connecting said walls by a system of substantially horizontal fixed perforated pipes distributed throughout the length and height of said walls, said pipes being attached at their ends to said walls and having openings distributed along the length thereof, the ends of said pipes attached to one wall being closed and their opposite ends open to the exterior face of the other wall, filling the space within the shell with graded aggregate, cooling the aggregate by introducing water into the aggregate through certain of said pipes and drawing water from the aggregate through other of the pipes, displacing water in the voids of the aggregate by introducing grout through said pipes progressively from the bottom to the top of the shell, removing grout from the interior of said pipes after the grout has partially set, and circulating water through the pipes from which grout has been removed to cool the concrete mass as it hardens.

5. The method of constructing a monolithic concrete dam or other structure one face of which will be subjected to water pressure, which comprises erecting a relatively thin outer shell having opposite walls of weather-resistant concrete slabs having their joints filled with grouting, connecting said walls by a system of substantially horizontal fixed perforated pipes distributed throughout the length and height of said walls, said pipes being attached at their ends to said walls and having openings distributed along the length thereof, the ends of said pipes attached to one wall being closed and their opposite ends open to the exterior face of the other wall, filling the space within the shell with graded aggregate, cooling the aggregate by introducing water into the aggregate through certain of said pipes and drawing water from the aggregate through other of the pipes, displacing water in the voids of the aggregate by introducing grout through said pipes progressively from the bottom to the top of the shell, removing grout from the interior of said pipes after the grout has partially set, circulating water through the pipes from which group has been removed to cool the concrete mass as it hardens, and thereafter leaving the pipes open to act as drains for the removal of any water which may find its way from the upstream face into or beneath the mass of the dam.

6. The method of constructing a monolithic concrete structure which comprises erecting a relatively thin outer shell having opposite walls of weather-resistant concrete slabs connected by expansion and contraction joints, connecting said walls by a system of substantially horizontal fixed pipes distributed throughout the length and height of said walls, said pipes being attached at their ends to said walls and having openings distributed along the length thereof,

the ends of said pipes attached to one wall being closed and their opposite ends open to the exterior face of the other wall, filling the space within the shell with graded aggregate, cooling the aggregate by introducing water into the aggregate through certain of said pipes and drawing water from the aggregate through other of the pipes, displacing water in the voids of the aggregate by introducing grout through said pipes progressively from the bottom to the top of the shell, washing grout from the interior of said fixed pipes by inserting into the open end of each a smaller pipe of an external diameter materially less than the internal diameter of the fixed pipe, delivering water under pressure through the smaller pipe, and advancing the delivery end of the smaller pipe to a point near the closed end of the fixed pipe, and maintaining a flow of cold water through said smaller pipes and fixed pipes to cool the concrete mass during the hardening thereof.

7. A monolithic concrete dam or other structure one face of which is subjected to water pressure, having substantially horizontal and parallel drainage pipes opening to the opposite face of the structure, said pipes extending to near the pressure face of the structure and having openings through which water may enter along the length thereof, said pipes being spaced apart laterally and vertically substantially throughout the length and height of the structure.

8. The method of constructing a monolithic bridge pier or similar structure which comprises

erecting a relatively thin outer shell of weather-resistant concrete slabs, connecting opposite walls with a system of metal ties distributed throughout the length and height of said walls, the ties connecting two of the opposite walls consisting of substantially horizontal or nearly horizontal pipes open at each end and fastened to each of the two opposite walls and alined with openings in one of the walls, filling the space within the shell with graded aggregate, cooling the aggregate by introducing cold water into the aggregate at a higher level and drawing water from certain of said pipes at a lower level, filling the voids of the aggregate by introducing grout through said pipes progressively from the bottom to the top of the shell, removing the grout from each of said pipes after the grouting operation utilizing the pipe has been completed, maintaining a flow of cold water through the pipes from which grout has been removed to cool the concrete mass during the hardening thereof.

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REFERENCES CITED

The following references are of record in the file of this patent:

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