March 24, 1942. P. BECHTNER 2,277,286

METHOD AND MEANS FOR IMPEDING THE SEEPAGE OR FLOW OF WATER

Filed Nov. 5, 1936

Fig. 1.

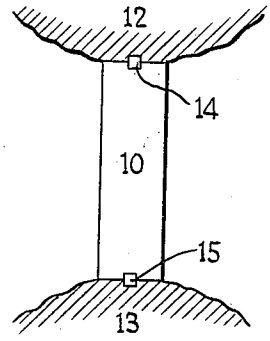


Fig. 2.

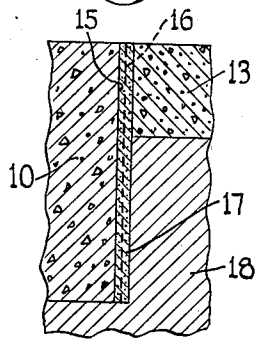


Fig. 3.

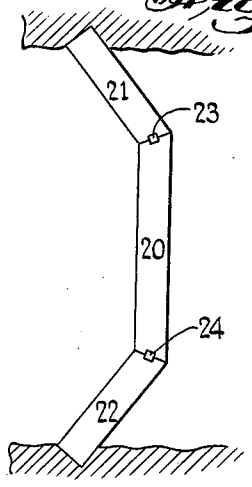


Fig. 4.

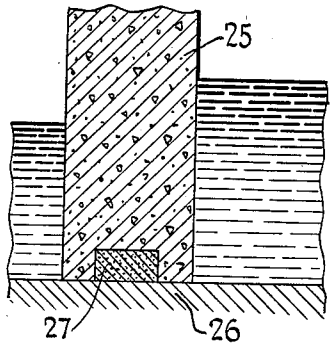


Fig. 5.

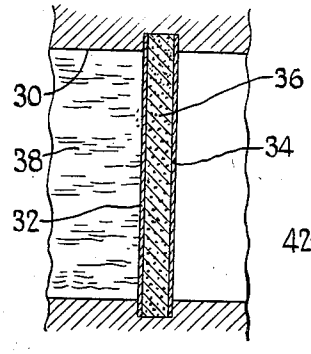


Fig. 6.

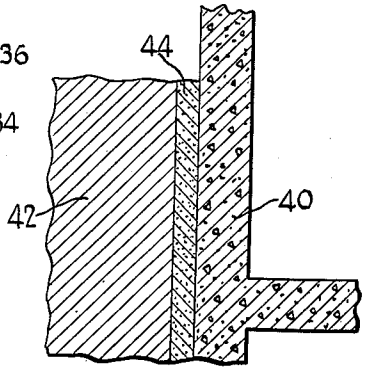


Fig. 8.

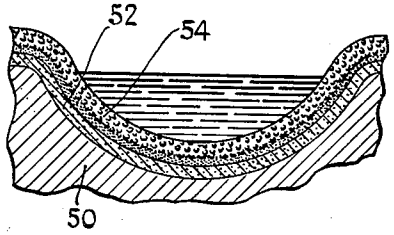


Fig. 10.

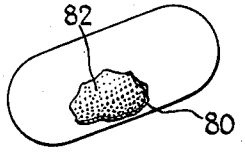


Fig. 9.

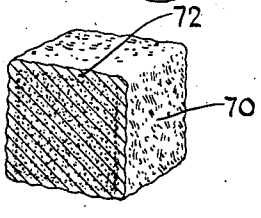
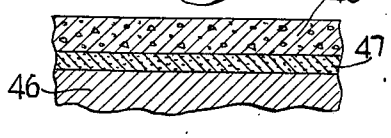


Fig. 7.



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2,277,286

METHOD AND MEANS FOR IMPEDING THE SEEPAGE OR FLOW OF WATER

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Application November 5, 1936, Serial No. 109,245

13 Claims. (Cl. 61—30)

This invention relates to improved methods and means for impeding the flow of water and for reinforcing structures to prevent the seepage of water therethrough. The seepage and flow of water through earthworks, dams, masonry constructions, water barriers and the like causes untold economical loss, much of which can be prevented by the invention herein described.

Seepage through water barriers, such as dams, cofferdams, and water-retaining walls may be caused by any of several conditions. The bedrock may not be impervious to flow. The circumstances may require that the barrier be placed on porous bodies of materials such as sand or gravel. Barriers formed of concrete or of any of the usual materials are likely to crack or develop minute openings which allow seepage, or they may be formed of aggregate, sheet, planks or the like, which are inherently susceptible to leakage through seams or crevices in the structure.

In the sealing of mines against the flow of underground water it is common practice to provide a wall of concrete across the mine shaft, yet such an expedient often fails to accomplish its purpose because of the leakage allowed by shrinkage of the setting concrete away from the walls against which it is cast. Such leakage, once started, sometimes results in destruction of the wall and complete release of the backed-up water.

Similar problems are encountered in efforts to exclude water from core trenches, excavations and foundation walls of buildings and to confine water to prescribed ditches or channels. In fact, these are but a few of the many circumstances under which it is highly desirable yet difficult effectively to prevent the flow or seepage of water.

An object of my invention is to provide improved methods and means for inhibiting the seepage of water through pervious structures and for safeguarding against seepage or flow through structures that are normally impervious but capable of developing leaks.

Another object is to provide improved barriers which are constructed better to insure against water seepage or flow.

Another object of my invention is to provide such methods and means which are permanently effective regardless of shrinkage, cracks, or shocks and distortions caused by subsidence, earth movements and the like.

Another object is to provide special methods and means by which it is possible to correct existing conditions of seepage or flow without requiring freedom from contact with the water.

Still further objects and advantages of the invention will be apparent from the following description.

I have discovered that water seepage may be prevented and that structures of various types may be safeguarded against leakage by blocking the path of flow of the water with bentonitic or highly colloidal clay which possesses the capacity to swell and gelatinize upon contact with water. The type of clay best suited for the present purposes is the true bentonite obtained in regions of Wyoming and South Dakota, although other highly colloidal, or bentonitic clays which possess the property of swelling and gelatinizing in water to a substantial degree are also useful. The degree of their effectiveness depends upon the closeness with which this swelling property corresponds to that of true bentonite.

True bentonite is a material consisting principally of the mineral "Montmorillonite" and occurring naturally in combination with about 25 to 45% water. For commercial use this material is dug, dried to contain about 9% moisture, and then granulated or powdered. Some physical characteristics which distinguish bentonite from other clays are its permeable texture and its extremely small grain size. From 65 to 70% of the grains of a Wyoming bentonite are finer than .2 micron; over 85% are finer than 2 microns. These grains or particles, when wetted, adsorb films of water that are thicker than the films which form on other clay-like materials, and after the bentonite has been wetted the water cannot be expelled, even at high pressures. The strong adsorptive power of commercial bentonite, which will adsorb almost five times its weight of water, is therefore partially attributable to the preponderance of extremely small grains or particles, providing tremendous surface area for the exertion of adsorptive powers, and the film retaining capacity of these particles.

Commercial bentonite swells, when contacted with water, as much as 10 to 20 times its dry volume. One factor which causes this swelling is the separation of the small particles by the water films adsorbed thereon. Another is the distinctive nature of the particles themselves, which are composed of minute plate-like structures that possess the peculiar property of allowing water molecules to penetrate their crystal lattice. The crystal structure itself is thus expanded. A third factor is the mutual repulsion of the particles, due to like negative polarity.

In its swollen condition bentonite has several advantageous properties; it will carry materials in suspension; it exerts a cohesive effect; when left quiescent it forms a permanent gel the viscosity of which increases upon aging. An important aspect of the swelling of bentonite which I have discovered is that it will swell only to the extent necessary to fill available space, without

exerting substantial pressure when confined against further swelling. Another important quality is that repeated drying and contraction of swollen bentonite in no way impairs its capacity to swell again upon renewed contact with water. These properties make it an ideal material for incorporation in a dry or slightly moist state into dams and other water barriers, at points where leakage possibilities occur, so that in case cracks or other leakage develop the bentonite will come into contact with the leaking water and swell to stop the leak but will not create pressure which might cause further breaks.

I have discovered that a blanket or wall of bentonite which possesses the capacity to swell upon contact with water will permanently resist seepage or flow of water therethrough. When the bentonite is contacted with water it swells to fill available voids or spaces. Thereafter it is impervious, and it remains impervious to water as long as water is present. If water is not continuously present the bentonite may contract as it dries, but its resistance to seepage is immediately restored upon renewed contact with water.

I have found also that bentonite confined within masonry structures or the like, when wet, does not exert swelling pressures sufficient to harm the structures in any way, yet it forms an impervious seal with the confining surfaces. Furthermore, the bentonite, either in dry or wet swollen condition, may be subjected to shocks, earth movements or subsidence without destroying its sealing power. The swelling capacity of the material is completely exhausted only when it is suspended freely in many times its volume of water. Accordingly, by utilizing a blanket or wall of bentonite to block the flow or seepage of water I am able to effect permanent impedence of such flow or seepage under many difficult conditions. Appropriate combinations of bentonite and strength giving structure produce barriers that are resistant to water under great pressure.

Several preferred modes of practicing my invention are illustrated diagrammatically in the drawing, wherein

Fig. 1 is a diagrammatical plan view of an embodiment of my invention in which inserts of bentonite are employed to reinforce a dam against water seepage.

Fig. 2 is a diagrammatical vertical section through a portion of a dam at a joint between the main wall of the dam and the abutment.

Fig. 3 shows an application of my invention similar to Fig. 1 in which the bentonite is placed in wells adjacent the connection of the main portion of a dam with the wings thereof.

Fig. 4 represents a vertical cross section of another type of dam construction, in which a blanket of bentonite is interposed between the bedrock and the bottom of the dam.

Fig. 5 illustrates the application of the invention to the closing of a mine or conduit against the flow of water therethrough.

Fig. 6 illustrates the use of a blanket of bentonite to protect the foundation wall of a building against water seepage.

Fig. 7 is a partial view, in vertical section, of a floor provided with an underlying layer of bentonite.

Fig. 8 represents, in cross section, a trench or ditch bordered by a blanket of bentonite in such manner as to prevent the seepage of water from the ditch through pervious earth adjacent thereto.

Fig. 9 is a cross section of a structural unit of bentonitic clay, constituting a special feature of the invention.

Fig. 10 shows another embodiment of a structural unit.

In Figures 1 to 4, inclusive, I illustrate improved dam constructions utilizing the principles of my invention. Within the dam structure at points likely to be affected by seepage, cracks or the like, I provide inserts of bentonite so that water seeping through the structure will contact the bentonite.

For example, in the construction of Figure 1, the dam **10** faces against abutment walls **12** and **13**, and at the meeting surfaces of these members wells **14** and **15**, extending for the height of the dam into the concrete or other material of which the dam is formed, are provided. The wells are filled with a dry bentonitic clay having the capacity to swell and gelatinize upon contact with water. Figure 2 may be considered as a section taken vertically along the axis of the dam and through the well **15**. The abutment **13** is illustrated as comprising a concrete portion positioned on rock at **18**. Well **15** extends, for the height of the dam, across the joint **16** between the main wall **10** and the abutment, and it is filled with bentonite as indicated at **17**.

Figure 3 represents an arch-like dam having a central wall **20**, wings **21** and **22**, and, at the joints between the wall **20** and the wings, wells which confine masses **23** and **24** of bentonitic clay. In Figure 4, a dam **25** positioned on bedrock **26** is provided with an insert of bentonitic clay at **27**, bridging the seam between the dam and the rock.

Dams constructed with inserts of bentonite at points susceptible to leakage are surprisingly resistant to the passage of water. The shrinkage of setting concrete, earth movements, contraction and expansion due to changing temperatures, etc., are likely to result in water permeable seams and crevices. The presence of a mass of bentonite at such points, however, provides permanent protection against seepage. When the confined bentonite is contacted with water which has traversed the structure to the location of the bentonite it immediately adsorbs water, swells enormously, and forms a gelatinous mass which itself is impervious to water and provides an impervious seal with the confining walls of the structure.

Although the insert **27** of bentonite in Figure 4 is illustrated as surrounded by dam structure and bedrock, other arrangements may be followed without sacrificing results. Substantially dry bentonite is notable for its extreme density and compressive strength when packed into a compact mass. Wherever the bentonite is subject to flowing water currents which would carry away the gels as they formed this erosion may be prevented by maintaining a layer of sand or other erosion resistant material between the bentonite and the flowing water. The bentonite then forms a tight-filter-cake on the surface of the sand.

Figure 5 is a diagrammatical showing of a construction which is effective to block the flow of water through mines, or water conduits in general. A pair of spaced forms or bulkheads **32** and **34** extends across a mine shaft **30**, and a mass of bentonite or similar colloidal clay is located at **36** between these forms. The forms

may be of wood, masonry or any other suitable material. The bentonite may be in finely divided form, or in the form of blocks or bricks, or it may be combined with other material, for example, sand or gravel.

In the use of this embodiment of the invention distinct advantages are obtained as compared with concrete walls and other types of barriers heretofore employed for the same purposes. The leakage permitted by the shrinkage of concrete walls away from the walls of a mine or conduit during the setting of the concrete is completely avoided. Whenever the form **32** allows backed-up water at **38** to contact the bentonite at **36**, the bentonite first contacted adsorbs water, swells and forms a gel which is permanently resistant to seepage. The same effect is produced whether the water contacts the bentonite along the walls of the mine or conduit or remote from the walls.

A characteristic feature of this and the other embodiments of the invention is that the swelling of only a small portion of the mass of bentonite, the portion first contacted with water, is usually effective to block seepage through to other portions of the mass. Thus these other portions retain their full capacity to absorb and swell and block further flow or seepage in the event that the first gel formation should be disturbed.

Another important advantage is that the expense and care incident to the provision of barriers such as concrete walls are avoided. The forms **32** and **34** need not be impervious to water; it is sufficient that they give strength to the barrier and that form **34** include no openings permitting escape of the bentonite therethrough. The blanket or wall **36** of bentonite is formed without difficulty, and it is effective as soon as formed, in contrast to concrete which requires considerable time to set. In addition, the bentonite may be removed easily; whereas the destruction of a barrier composed of masonry is a difficult task.

My invention is also applicable to impede the seepage of water through foundation walls and floors of buildings, as illustrated in Figures 6 and 7. Between the foundation wall **40** of a building (Fig. 6) and the adjacent soil **42**, a blanket of bentonite is interposed as indicated at **44**. As in the other embodiments described above, the bentonite swells when contacted with water and forms an impervious barrier which prevents the water from seeping to and through or around the wall **40**. An arrangement such as that shown in Fig. 7 is particularly suitable for the ground floors of buildings placed in low, damp ground. A blanket **47** of bentonite is placed on the base **46** for the floor, and the floor **48**, which may be of concrete or any other suitable material, is applied over the bentonite.

Figure 8 illustrates a mode of applying the invention to the prevention of seepage from a ditch or the like formed in pervious soil. In the construction of the ditch a blanket **52** of bentonite is placed adjacent the wall of the earth **50**, and this blanket **52** is covered by erosion resistant material as indicated at **54**, forming the bottom of the ditch. A preferred type of covering material for this and similar embodiments of the invention includes a layer of fine sand next to the blanket of bentonite and a layer of gravel or the like adjacent the sand. The blanket of bentonite effectively prevents the seepage of the water at **56** from the ditch through the underlying soil. As the bentonite is contacted woth water it swells to form an impervious gelatinous barrier, one that remains impervious as long as water is present and is not destroyed by subsidence, earth movements or the like.

The drawing and the foregoing description relating thereto are illustrative of only a few of the many improved constructions resulting from the use of the invention and of only a few modes of applying the same. To the skilled engineer it will be obvious that the invention may be utilized in many different fields and in many different ways.

While strong gels and high resistance to water penetration are obtained by the use of pure bentonite or pure bentonitic clay, I have discovered also that the resistance of the mass to high water pressures may be increased by employing mixtures of bentonite or bentonitic clay and other granular materials, for example, sand. For example, when a mixture of equal parts of bentonite and beach sand is poured into a T-shaped section of 3 inch pipe to a height of 20 inches in the longer arm of the T and lightly tamped therein, the mass is not moved by continuing water pressures of 1000 lb. per square inch, and the water penetrates the mass a distance of only about 5 inches.

An important advantage of the invention results from the variety of methods which may be employed to form the seepage-resistant mass of bentonite. In one embodiment ordinary commercial powdered or granulated bentonite may be used. Even when loosely put in place as by pouring, such finely-divided material provides a permanent barrier against seepage, since the swelling power of dry bentonite is so great that voids in the mass are blocked upon contact with water. The physical strength of such a mass may be increased by tamping or packing the bentonite in place.

Under some circumstances of use it is impractical to provide temporary or permanent supporting means for the bentonite before forming the mass; i. e., the bentonite must be placed first. For example, in sealing a wall against leakage from the outside earth the most practicable procedure may be to form the mass of bentonite adjacent the wall and then fill in the earth. According to another embodiment of my invention this may be accomplished by incorporating the bentonite with from one to one and a half times as much water to form a stiff putty-like mass which is sufficiently cohesive to adhere to rough or smooth surfaces. In this form it will continue to adhere as long as it is moist; yet it retains about 70 to 80% of its potential absorbent and swelling property, to be exerted when water is brought into contact.

Still other embodiments of the invention possess special advantages for use under certain conditions. The stiff putty-like bentonite prepared as above described is improved for use where water is present by fashioning it roughly into bricks or blocks each having a quantity of dry finely-divided bentonite in its interior. Similar results may be obtained, as illustrated in Figure 9, by forming a bricklike body **70** of bentonite which has been moistened only sufficiently to produce slight coherence and then contacting the outsides of the body with water, as by dipping or spraying. The water does not penetrate far into the body but causes the bentonite at the surfaces thereof to swell and form a cohesive sheath or enclosure as indicated at **72**, which strengthens the unit so that it can be handled and placed in position. Another suitable pro-

cedure (see Figure 10) is to use a fabric enclosure, for example, a paper cartridge as indicated at 80, filled with dry bentonite 82. Still another, which is useful under circumstances prohibiting the construction of a solid blanket of bentonite, as in the prevention of seepage through water covered porous rock or gravel structures, is to force a heavy pumpable suspension of bentonite into the structure and thus build up a blanket of bentonite in the path of seepage.

The invention is not limited to the specific illustrative uses and methods of use described hereinabove, although these possess their own individual advantages. When dry or swellable bentonite is applied to expansion joints, shrinkage joints, or adjacent corners where cracks are likely to develop in concrete dams, or when used in any water barrier where, upon coming in contact with water, it will swell and stop the leakage, this is within the scope of my invention, and inasmuch as I have discovered that bentonite can be used in this manner without developing appreciable pressures on swelling, innumerable further uses for bentonite in sealing water barriers, based on the principles I have disclosed, will occur to those skilled in this art.

I claim:

1. A dam comprising a masonry wall positioned on a supporting bed and abutting against end abutments, said masonry having a compartment therein at a point susceptible to leakage, and a compact mass of swellable bentonite confined within said compartment.

2. A dam comprising a masonry wall positioned on a supporting bed and abutting against end abutments, a compartment extending along the joint between said wall and an abutment, and a compact mass of swellable bentonite filling said compartment.

3. A water dam comprising a concrete dam structure having pockets of swellable bentonite therein.

4. A self-sustaining structural unit for the formation of barriers impervious to water comprising finely divided, slightly moist swellable bentonitic clay in the interior thereof and wet bentonitic clay constituting a cohesive enclosure therefor.

5. The method of making structures resistant to seepage or flow of water therethrough which comprises positioning a mass including swellable bentonite across the path of such seepage or flow and confining said mass between spaced rigid supporting structures, said mass being of sufficient thickness and bentonite concentration to swell and form adjacent the water face, when contacted by the water, a supported, water-impervious barrier of swollen gelatinous bentonite merging into swellable bentonite.

6. The method of preventing flow or seepage from bodies of water which comprises forming and supporting and confining across the water path a compact blanket of finely-divided, substantially dry swellable bentonite of sufficient thickness and bentonite concentration to swell adjacent its face upon contact by the water and form across said path a water-impervious barrier of swollen bentonite merging into a reserve mass of substantially unswollen bentonite.

7. The method of making structures such as dams, bulkheads, masonry walls and like water barriers impervious to seepage or flow therethrough from bodies of water, which comprises providing space in the structure across the path of such seepage or flow and filling into and confining within said space a mass of substantially dry, finely-divided swellable bentonite mixed with sand, said mass being of sufficient thickness and bentonite concentration to form across said path, upon contact by the water, a water-impervious barrier of swollen bentonite adjacent its face merging into substantially unswollen bentonite within the mass.

8. A water barrier comprising rigid supporting structures having space therein in the path of water seepage or flow and a compact mass of finely-divided swellable bentonite confined across said path in said space, said mass being of sufficient thickness and bentonite concentration to swell at its face and form across said path, when contacted by water, a water-impervious barrier of swollen bentonite merging into substantially unswollen bentonite.

9. The method of blocking the flow of water under pressure through a determinate path which comprises restraining the water from a part of said path, forming across said path at said part a compact mass including substantially dry swellable bentonite of sufficient thickness and bentonite concentration to swell adjacent the water face and form across said path a water-impervious barrier of swollen bentonite merging into substantially unswollen bentonite, providing supporting structure of sufficient strength to hold said mass in place against the water pressure and confining said mass by said structure, and finally admitting the water into contact with said mass.

10. A water barrier for preventing seepage or flow from a body of water through a determinate path comprising rigid supporting structure having space therein across the water path and a compact mixture of finely-divided swellable bentonite and granular material confined across said path in said space, said mixture being of sufficient thickness and bentonite concentration to swell at its face and form across said path, where contacted by water, a water impervious barrier of swollen bentonite marging into a reserve mass of substantially unswollen bentonite.

11. The method of preventing flow or seepage of water through rigid structures susceptible to water penetration which comprises placing and supporting adjacent a side of such structure and across the path of water penetration a compact blanket including finely-divided, swellable bentonite and of sufficient thickness and bentonite concentration to swell at its face upon contact by the water and form across said path a water impervious barrier of swollen bentonite merging into swellable bentonite, and providing means adjacent the face of said blanket for holding the same in place.

12. A bulkhead or the like for preventing water flow through a determinate path comprising substantially rigid structures spaced apart and extending across the water path, said structures being susceptible to water penetration, and a compact mass of finely-divided bentonite, confined within the space between said structures.

13. A bulk head or the like for preventing water flow through a determinate path comprising substantially rigid structures spaced apart and extending across the water path, said structures being susceptible to water penetration, and a water-impervious mixture of finely-divided bentonite and sand confined within the space between said structures.

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