United States Patent

Paramore et al.

[15] **3,672,173**

[45] **June 27, 1972**

[54] FORMING SELF-SUPPORTING BARRIERS IN MINE PASSAGES AND THE LIKE

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[22] Filed: **May 13, 1969**

[21] Appl. No.: **824,157**

[52] **U.S. Cl.** **61/36,** 61/39, 166/293

[51] **Int. Cl.** **E02b 3/16,** E02d 29/00

[58] **Field of Search** 61/35, 36, 39; 106/76; 166/293, 292

[56] **References Cited**

UNITED STATES PATENTS

1,547,189	7/1925	Wilson	61/36 UX
2,210,545	8/1940	Hamilton	61/36 X
2,233,872	3/1941	Proctor	61/36
2,876,123	3/1959	Drummond	106/76
2,985,239	5/1961	Shell	166/293
3,227,213	1/1966	Smith	166/292
3,335,018	8/1967	Peeler, Jr. et al.	106/76
3,433,657	3/1969	Pickering	106/76 X
3,469,405	9/1969	Reinhold	61/35

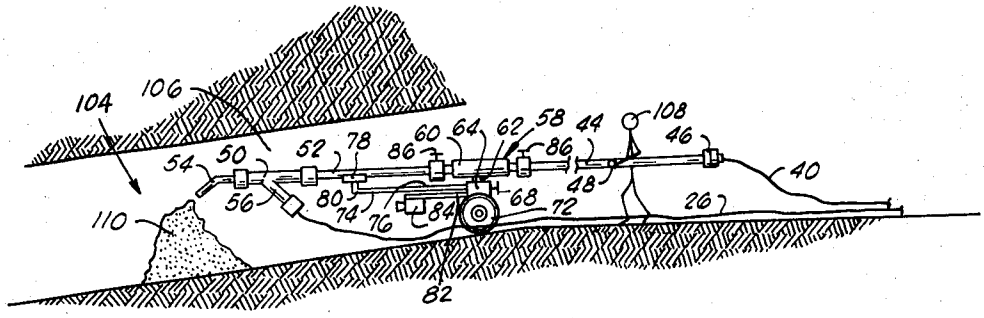
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[57] **ABSTRACT**

The present invention relates to methods and apparatus for remotely forming self-supporting water impermeable barriers in mine passages and the like. A fast setting cementitious composition is formed by combining an aqueous slurry of cement with an aqueous silicate solution. The cementitious composition thus formed is continuously deposited transversely on the floor and walls of a mine passage by apparatus extending into the mine passage through the mine opening, or through a bore drilled into the passage from the ground surface. The cementitious composition sets into a firm impermeable mass as it is being deposited thereby forming a firm self-supporting barrier in said passage.

52 Claims, 4 Drawing Figures



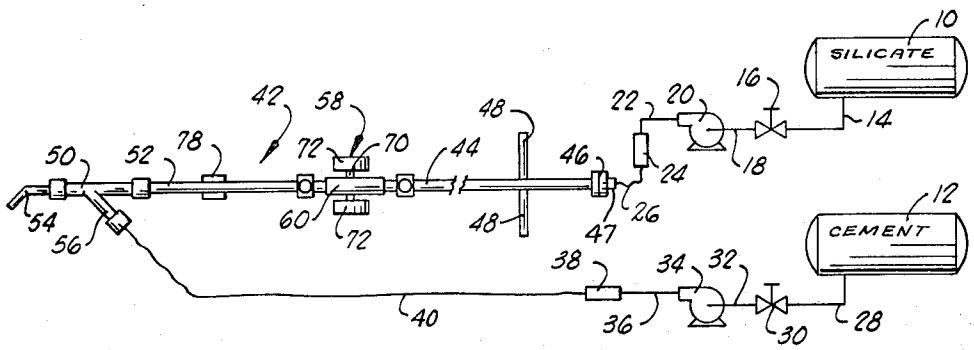


Fig. 1

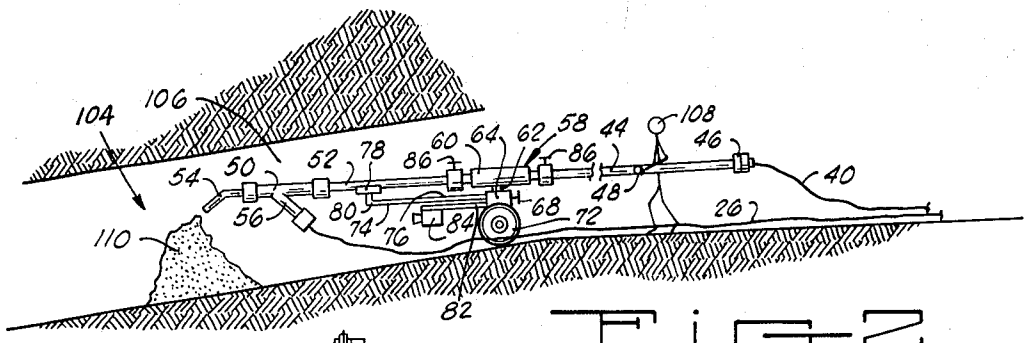


Fig. 2

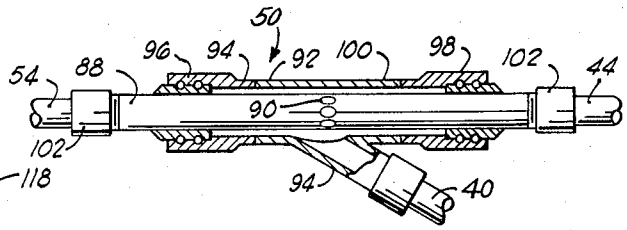


Fig. 3

Fig. 4

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FORMING SELF-SUPPORTING BARRIERS IN MINE PASSAGES AND THE LIKE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to methods and apparatus for forming self-supporting barriers in mine passages and the like, and more particularly, but not by way of limitation, to methods and apparatus for remotely forming self-supporting water impermeable barriers in mine passages and the like wherein a fast setting cementitious composition is remotely deposited in a portion of said passage until a firm impermeable self-supporting barrier is formed therein.

2. Description of the Prior Art

In certain areas water emanating from either active or abandoned underground mines finds its way into streams and rivers. Because such mine water is usually acid from reacting with the materials contained within the mines, pollution of the streams and rivers results. Many processes and apparatus have been proposed for purifying such acid mine water before it is allowed to enter the streams and rivers. However, since a given mine commonly includes many openings through which acid water can escape, collection of the water for purification presents a substantial problem.

In addition, since abandoned mines are often the greatest sources of pollution, many methods for sealing the openings or passages in the mines have been proposed. However, abandoned mines are hazardous to enter, and therefore, placement of barriers within the mine passages is a dangerous undertaking if in placing such barriers personnel must enter the mine passages. The present invention provides methods and apparatus for forming such barriers remotely thereby not requiring the entering of mine passages by personnel.

SUMMARY OF THE INVENTION

The present invention relates to methods of remotely forming self-supporting barriers in mine passages and the like which comprises remotely depositing a fast setting cementitious composition in a portion of said passage until a firm self-supporting impermeable structure is formed therein. Apparatus for remotely depositing said composition within said passage is also provided.

It is, therefore, a general object of the present invention to provide methods and apparatus for forming self-supporting barriers in mine passages and the like.

A further object of the present invention is the provision of methods and apparatus for forming barriers in mine passages and the like which do not require forms.

Still a further object of the present invention is the provision of methods and apparatus for forming water impermeable barriers in mine passages and the like wherein personnel are not required to enter the mine passages.

It is still a further object of the present invention to provide methods and apparatus for forming barriers in mine passages using cementitious compositions which are relatively inexpensive to prepare.

Another object of the present invention is the provision of methods and apparatus for remotely forming self-supporting, water impermeable barriers in mine passages and the like wherein the barrier formed has sufficient strength to support overburden pressures as well as hydrostatic pressures to be encountered within said passage after said barrier is formed.

Yet another object of the present invention is the provision of methods of remotely forming barriers in mine passages and the like with a cementitious composition wherein the setting time, viscosity and thixotropic properties of the cementitious composition may be continuously changed as said barrier is being formed.

Other objects and advantages of the invention will be evident from the following detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top view of one form of mixing and depositing apparatus which may be used to carry out the method of the present invention, and a view of auxiliary apparatus used to carry out the method of the present invention in diagrammatic form,

FIG. 2 is a side view of the mixing and depositing apparatus of FIG. 1, and

FIG. 3 is a view of the mixer of FIGS. 1 and 2 in cross section,

FIG. 4 is a cross-sectional view of a mine passage below the ground surface with an alternate form of apparatus for carrying out the method of the present invention illustrated.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It has been found that compositions prepared by combining aqueous slurries of cement with aqueous silicate solutions result in superior cementitious compositions particularly useful in forming self-supporting barriers in mine passages and the like. Additionally, it has been found that such cementitious compositions are quick setting and obtain high strength rapidly so that they may be continuously deposited on portions of the floor and walls of remote mine passages to form water impermeable barriers therein. Furthermore, it has been found that an aqueous slurry of cement and an aqueous silicate solution may be prepared and stored in separate storage containers. When it is desired to remotely form a barrier in a mine passage, the cement slurry and silicate solution may be mixed and the resulting cementitious composition continuously deposited in the mine passage by apparatus of the present invention. Due to the properties of the cementitious compositions thus mixed and deposited, a structure may be formed in the passage having a high angle of repose and which will have sufficient strength to withstand overburden and hydrostatic pressures encountered within the mine passage thereby providing a barrier which will effectively shut-off the mine passage.

Referring to FIGS. 1 and 2, one form of apparatus of the present invention is illustrated. Two containers 10 and 12 are provided which may be any form of portable tank movable from one location to another. An aqueous silicate solution, which will be described further herein, is prepared and stored in container 10. An aqueous cement slurry, which will also be described further herein, is prepared and stored in container 12. A conduit 14 is connected to container 10 and is connected to a flow control valve 16. A conduit 18 connects valve 16 to a fluid pump 20. Conduit 22 connects fluid pump 20 to a liquid flow meter 24, and a flexible hose 26 is connected to flow meter 24.

A conduit 28 is connected to container 12 and to flow control valve 30 which is in turn connected to fluid pump 34 by conduit 32. Conduit 36 is connected to fluid pump 34 and to a flow meter 38. A flexible hose 40 is connected to flow meter 38.

Fluid pumps 20 and 34 and flow meters 24 and 38 may be of conventional design of sufficient size to pump and measure the required flows of aqueous silicate solution and aqueous cement slurry respectively. Containers 10 and 12, valves 16 and 30, fluid pumps 20 and 34 and flow meters 24 and 38 may all be mounted on one or more trucks so that they may conveniently be moved from one location to another.

Flexible hoses 26 and 40 are connected to a mixing and depositing apparatus generally designated by the numeral 42. Apparatus 42 basically comprises an elongated conduit 44 having a conventional rotary joint 46 connected to the rearward end 47 thereof to which hose 40 is connected. A pair of handles 48 are attached to opposite sides of conduit 44 near the rearward end 47 for manually turning conduit 44. A mixer 50 is attached to the forward end 52 of conduit 44, and a spray nozzle 54 is attached to mixer 50. Mixer 50 which will be described further herein includes a swivel connection 56 to which hose 40 is connected. A carriage 58 is slidably disposed on conduit 44 between handles 48 and mixer 50.

Carriage 58 is comprised of a sleeve 60 slidably disposed over conduit 44. A shaft 62 positioned perpendicularly to the axis of sleeve 60 is attached to sleeve 60, and is slidably secured within a second sleeve 64. A hand bolt 68 is threadedly secured in a bore in the upper end of sleeve 64 for securing shaft 62 in a desired position. The lower end of sleeve 64 is attached to an axle 70 having a pair of wheels 72 rotatably attached thereto. An elongated member 74, positioned parallel with the axis of sleeve 60, is attached to sleeve 64 at the rearward end 76 of member 74. A support member 78, formed in the shape of a half cylinder for slidably supporting conduit 44 is attached to the forward end 80 of member 74. A member 82 is attached to sleeve 64 below member 74 for supporting conventional closed circuit television camera and light apparatus 84. A pair of adjustable stops 86 are slidably disposed on conduit 44 for securing sleeve 60 in a desired position on conduit 44.

Referring now to FIG. 3, mixer 50 is shown in cross section. Mixer 50 comprises a conduit 88, threaded at both ends, having a plurality of openings 90 through the walls thereof. Openings 90 are positioned in the middle portion of conduit 88, and are spaced around the periphery thereof. A second conduit 92 of larger internal diameter than the outside diameter of conduit 88 is disposed over the middle portion of conduit 88 and openings 90. Conduit 92 includes a threaded nozzle 94 attached thereto for receiving hose 40 described above. A conventional rotary joint 96 is attached to conduit 92 at the forward end 94 thereof and to conduit 88. A second conventional rotary joint 98 is attached to the rearward end 100 of conduit 92 and to conduit 88. Thus, conduit 94 is free to rotate on conduit 88. Conduit 88 is attached to conduit 44 and spray nozzle 54 by conventional collars 102.

Referring now particularly to FIG. 2, let it be assumed that it is desired to form a barrier at point 104 inside mine passage 106. The apparatus 42 is positioned in the opening of passage 106, as illustrated, with conduit 44, carriage 58, mixer 50 and spray nozzle 54 extending within the passage so that nozzle 54 is adjacent to the point 104 of passage 106. Assuming that container 10 (FIG. 1) contains a quantity of the cement slurry, and container 12 contains a quantity of the silicate solution, pumps 20 and 34 are started and valves 16 and 30 opened so that the desired flow rates of silicate solution and cement slurry pass through flow meters 24 and 38 and flexible hoses 26 and 40 into apparatus 42. As will be understood, the flow rates of silicate solution and cement slurry may be varied by adjusting valves 16 and 30 respectively. Flow meters 24 and 38 serve to indicate the actual flow of materials passing into apparatus 42.

The aqueous cement slurry passing into conduit 44 from hose 26 enters conduit 88 of mixer 50. Aqueous silicate solution entering nozzle 94 of mixer 50 from hose 40 passes into the annular space between conduits 92 and 88. The aqueous silicate solution then passes through openings 90 into conduit 88 whereupon it mixes with the aqueous cement slurry passing therethrough. The mixture of cement slurry and silicate solution then travels into spray nozzle 54 from conduit 88, and is sprayed into mine passage 106.

The operator 108 of apparatus 42 may rotate conduit 44 by turning handles 48 which will in turn rotate spray nozzle 54. Since conduit 92 of mixer 50 is free to swivel on mixer 50, hose 40 attached to mixer 50 will not interfere with the rotation of spray nozzle 54. Spray nozzle 54 may also be moved forwardly and rearwardly by the operator 108 by moving the apparatus 42 forwardly and rearwardly.

The cementitious composition sprayed onto the floor and walls of passage 106 will instantly set into a firm mass. The operator 108 may manipulate apparatus 42 to build structure 110 into a barrier formed of the cementitious composition extending upwardly to partially block passage 106, or a barrier completely sealing off passage 106 may be formed by extending structure 110 transversely within passage 106 to the top of passage 106. Once the barrier has been completed, the flow of silicate solution and cement slurry may be shut off, the apparatus 42 flushed out with water, and removed from the opening of passage 106.

As will be understood the sleeve 60 of carriage 58 may be raised or lowered with respect to the wheels 72 of carriage 58 by loosening hand bolt 68 and positioning shaft 62 within sleeve 64 at a desired level. Hand bolt 68 may then be tightened against shaft 62 to secure it in the desired position.

A conventional closed circuit television receiver connected to television camera and light apparatus 84 may be used by operator 108 to view structure 110 as it is being formed.

Referring now to FIG. 4, an alternate form of apparatus for carrying out the method of the present invention is illustrated. Let it be assumed that it is desirable to plug the passage 112 at a point beneath the ground surface. A pair of vertical bores 114 and 116 are drilled from the ground surface into the passage 112 at the point where passage 112 is to be plugged. A conventional portable rig apparatus 118 is positioned over bore 114 and a string of conduit 120, such as conventional drill pipe, is lowered through bore 114 into passage 112. A remote light and closed circuit television apparatus 122 is lowered through bore 116 into passage 112. Apparatus 122 may be suspended from a conventional wire line truck 124 or other convenient means. A nozzle apparatus 126 is attached to conduit 120 at its lower end and is of a design which allows nozzle 128 to be raised and lowered in a vertical plane remotely from the surface. Conduit 120 is connected to a conventional swivel 130 at its upper end which is in turn connected to a flexible hose 132. Flexible hose 132 is connected to a mixer 134 of the same design as mixer 50 described above which is in turn connected to a pair of flexible hoses 136 and 138.

In operation, a cement slurry is pumped into hose 136 and a silicate solution is pumped into hose 138 in the same manner as described above. The cement slurry and silicate solution are intimately mixed in mixer 134 and the resulting cementitious composition is conducted through hose 132, swivel 130 and conduit 120 into nozzle apparatus 126. The cementitious composition passes through nozzle 128 and is sprayed transversely on a portion of the floor and walls of passage 112. As will be understood, conduit 120 may be rotated to move nozzle 128 transversely back and forth across passage 112 and nozzle 128 moved vertically up and down as the cementitious composition is sprayed thereby forming structure 140. Structure 140 may be viewed through closed circuit television apparatus 122 as it is being formed, and nozzle 128 may be raised and rotated until a barrier is formed within passage 112. Once the barrier is completed, conduit 120 and apparatus 126 may be flushed with water and removed from bore 114, and closed circuit television apparatus 122 may be removed from bore 116. Bores 114 and 116 may then be plugged in a conventional manner.

Grade 40 sodium silicate solution having the approximate analysis and properties given below is commercially available, and is a preferred silicate for use in the present invention:

Component	Approximate Analysis (weight per cent)
Na_2O	9.1
SiO_2	29.2
H_2O	61.7
Gravity, Degrees Baume'	41.5
Viscosity, Centipoises	206.25

In addition to sodium silicate, other silicates having the above approximate analysis may be used in the present invention such as those where potassium, guanidine, or tetramethyl ammonium are substituted for sodium.

A preferred cement for use in the present invention is a cement of the Portland cement type.

A preferred silicate solution of the present invention is comprised of grade 40 sodium silicate present in an amount of from about 6 per cent by weight to about 100 per cent by weight and water present in an amount from about 0 per cent by weight to about 94 per cent by weight.

A preferred aqueous slurry of cement for use in the present invention is comprised of cement of the Portland Cement type present in an amount of from about 7 per cent by weight to about 75 per cent by weight and water present in an amount of from about 25 per cent by weight to about 93 per cent by weight.

It has been found that the addition of a particular quantity of filler, such as fly ash or silica flour, to the aqueous cement slurry will retard the setting time of the resulting cementitious composition. A preferred aqueous cement slurry with fly ash added is comprised of cement of the Portland Cement type present in an amount of from about 10 per cent by weight to about 55 per cent by weight, fly ash present in the amount of about 10 per cent by weight to about 55 per cent by weight and water present in an amount of from about 25 per cent by weight to about 35 per cent by weight.

In addition, it has been found that a suitable thixotropy inducing agent, such as bentonite, may be added to the aqueous silicate solution in order to form a cementitious composition of the desired thixotropic properties. A preferred aqueous silicate solution with thixotropy inducing agent added is comprised of grade 40 sodium silicate present in an amount of from about 12 per cent by weight to about 70 per cent by weight, bentonite present in an amount of from about 1 per cent by weight to about 10 per cent by weight and water present in an amount of from about 25 per cent by weight to about 80 per cent by weight.

When a particular quantity of an aqueous slurry of cement is mixed with a particular quantity of a silicate solution, a cementitious composition is formed having a particular setting time and viscosity. The setting time and viscosity will vary both with the compositions of the aqueous cement slurry and aqueous silicate solution used, and the volume ratio of aqueous cement slurry to aqueous silicate solution mixed. Thus, for a particular application an aqueous slurry of cement and aqueous silicate solution may be used which when mixed will form a cementitious composition having the desired setting time and viscosity. Additionally, however, the ratio of aqueous cement slurry to aqueous silicate solution may be varied to change the setting time and other properties of the cementitious composition while a barrier is being formed using the apparatus of the present invention.

The aqueous silicate solution may be prepared by adding a desired quantity of grade 40 silicate to a desired quantity of water and mixing thoroughly. The aqueous slurry of cement may be prepared by adding the desired quantity of Portland cement to the desired quantity of water and mixing thoroughly. If used, fly ash or silica flour may be added to the aqueous cement slurry when it is prepared, and bentonite may be added to the aqueous silicate solution when it is prepared.

The aqueous silicate solution may be mixed with the aqueous cement slurry in any convenient manner just prior to use. However, the cementitious composition is preferably formed by continuously mixing a stream of the silicate solution with a stream of the aqueous cement slurry as described above. The flow rates of the silicate solution, cement slurry, and resulting cementitious composition will be varied according to the size of the passage to be sealed and the particular portion of the barrier being formed. If desirable, additional fillers such as sand may be added to either or both of the aqueous cement slurry and the silicate solution.

A number of laboratory tests were performed using the cementitious compositions described above. The results of these tests are recorded hereinbelow:

PROCEDURE

The compositions listed in Tables I through III were made up in two parts, an aqueous slurry of cement designated as Solution A, and a sodium silicate solution designated as Solution B. Equal portions of the two solutions were then mixed to form the particular cementitious compositions tested. The time required for the resulting cementitious compositions to set was noted.

TABLE I

Cementitious Composition Setting Times

Solution A		Solution B		
Portland Cement, Weight %	Water, Weight %	Grade 40 Sodium Silicate, Weight %	Water, Weight %	Fluid Time, Seconds
42.86	57.14	52.63	47.37	15.0
68.49	31.51	52.53	47.47	22.7
71.43	28.57	52.63	47.37	20.9

The compositions listed above set into firm impermeable masses in the times noted.

TABLE II

Cementitious Composition Setting Times With Retarding Agent Added

Solution A			Solution B		
Portland Cement, Weight %	Water, Weight %	Fly ash, Weight %	Grade 40 Sodium Silicate, Weight %	Water Weight %	Fluid Time, Seconds
17.86	28.57	53.57	52.63	47.37	50.6
35.71	28.58	35.71	52.63	47.37	29.7
53.57	28.57	17.86	52.63	47.37	21.2
17.86	28.57	53.57	27.98	72.02	50.6
7.14	28.57	64.29	56.64	43.36	140.0
7.14	28.57	64.29	25.00	75.00	198.0
35.71	28.58	35.71	61.94	38.06	29.7

As can be seen from the above table, the setting times of the cementitious compositions of the present invention may be varied by varying the quantity of filler in Solution A and varying the quantities of sodium silicate and water in Solution B. This can also be accomplished by varying the volume ratio of Solution A to Solution B.

TABLE III

[Cementitious composition setting times with retarding agent and thixotropic inducing agent added]

Solution A			Solution B			
Portland cement, weight percent	Water, weight percent	Fly ash, weight percent	Grade 40 sodium silicate, weight percent	Water weight percent	Bentonite, weight percent	Fluid time, seconds
35.71	28.58	35.71	59.56	36.59	3.85	17.5
31.50	37.00	31.50	59.56	36.59	3.85	23.0

All of compositions listed in Tables I through III above met the following conditions: 1. Solutions A and B are easily mixed and pumped with conventional equipment. 2. The compositions flash set to rigid masses not eroded or diluted by running water. 3. The compositions, after setting, progressively hardened to the extent that they possess adequate load-bearing properties. 4. Solutions A and B are comprised of components relatively low in cost.

Resistance to the flow of water, compressive strength and build-up property laboratory tests were run using compositions of the present invention.

I. RESISTANCE TO FLOW

PROCEDURE

A rectangular sheet metal trough was made, 4 inches deep, 6 inches wide and 45 inches long, and was closed at one end. A weir, 2½ inches high by 6 inches wide, was cemented in place 6 inches from the closed end of the trough. The trough

was then positioned at 7° angle and a flow of water was provided over the weir and down the trough at a rate of 0.7 gallons per minute. A composition was prepared in two portions as follows:

Solution A:	
Portland Cement (weight %)	42.86
Water (weight %)	57.14
Solution B:	
Grade 40 Sodium Silicate (weight %)	52.63
Water (weight %)	47.37

The composition was prepared with Solution A contained in one beaker and Solution B contained in a second beaker. Equal volumes of Solution A and B were then poured into a third beaker and stirred until thickening was noted. The thickened composition was then dumped into the trough and the resistance to the flow of water noted.

RESULTS

A total weight of 1,315 grams of the thickened composition was placed in the trough. After the thickened slurry had set into a firm impermeable mass, it was recovered from the trough and weighed. The test indicated that only 48 grams or approximately 4 per cent of the composition was washed away by the flowing water.

II. BUILD-UP PROPERTIES

PROCEDURE

The purpose of this test was to estimate how readily the composition shown above would build when dumped on a flat horizontal surface. A polyethylene funnel was positioned 2 inches above a flat level surface. Solutions A and B were prepared in separate beakers as follows:

Solution A:	
Portland Cement (weight %)	35.71
Water (weight %)	28.58
Fly Ash (weight %)	35.71
Solution B:	
Grade 40 Sodium Silicate (weight %)	61.94
Water (weight %)	38.06

Solution A was poured into Solution B and stirred for approximately 5 seconds, whereupon it was poured into the funnel.

RESULTS

The composition flowed through the funnel as it thickened or set and exhibited good build-up properties.

III. COMPRESSIVE STRENGTH TEST

PROCEDURE

The composition was prepared in two solutions as follows:

Solution A:	
Portland Cement (weight %)	35.71
Water (weight %)	28.58
Fly ash (weight %)	35.71
Solution B:	
Grade 40 Sodium Silicate (weight %)	61.94
Water (weight %)	38.06

Solution A and Solution B were mixed and immediately poured into 2-inch cube molds. The composition in the molds was then allowed to cure under water at room temperature. The compressive strength of the composition was determined by crushing the resultant cubes in a Tinius-Olsen compressive strength instrument.

Results

Compressive Strength	
1 Hour	72 Hours
38 psi	2016 psi

From the above it can be seen that the compositions of the present invention are ideally suited for forming firm water impermeable barriers in mine passages and the like.

Some full scale tests were run in simulated mine passages and actual mine passages using the methods and apparatus of the present invention as follows:

EXAMPLE A

A simulated mine passage was constructed in the ground at Duncan, Okla. The opening was built to the size of an average mine opening, 7 feet high with a 10 foot wide floor and a 4 foot wide ceiling, with three shoring posts on each side, approximately 1 foot apart.

Two slurries were prepared in two separate tanks as follows:

Slurry A:	
Water	807 gallons
Portland Cement	15,800 pounds
Slurry B	
Water	1,065 gallons
Bent onite	728 pounds
Grade 40 Sodium Silicate	337 gallons

Approximately equal volumes of the two slurries were mixed in apparatus of the present invention and sprayed on the floor and walls of the simulated mine passage.

RESULTS

A firm impermeable self-supporting barrier was formed in the opening which effectively sealed the opening.

EXAMPLE B

A test was run using the methods and apparatus of the present invention in an actual mine opening in West Virginia. The mine opening was approximately 5 feet high by 11 feet wide.

PROCEDURE

Two slurries were prepared and mixed in separate tanks as follows:

Slurry A:	
Water	815 gallons
Cement	15,800 pounds
Slurry B:	
Water	1,040 gallons
Bentonite	700 pounds
Grade 40 Sodium Silicate	348 gallons

Approximately equal volumes of the two slurries were mixed in apparatus of the present invention and sprayed on the floor and walls of the mine passage.

RESULTS

A self-supporting water impermeable barrier was formed in the passage effectively sealing the passage. The barrier had an angle of repose of approximately 58°.

Thus, it may be seen that the methods and apparatus of the present invention may be used for economically forming water impermeable self-supporting barriers in mine passages and the like. Furthermore, the present invention provides methods and apparatus for remotely forming said barriers which may be economically carried out without the necessity of personnel entering the passage.

The volume ratio of the aqueous cement slurry to the aqueous silicate solution may be varied from 1:9 to 9:1 while a barrier is being formed using the apparatus of the present invention.

The present invention, therefore, is well adapted to carry out the objects and attain the ends and advantages mentioned, as well as those inherent therein. While presently preferred embodiments of the invention are given for the purpose of disclosure, numerous changes in the details of construction and the arrangement of parts can be made which will readily suggest themselves to those skilled n the art and which are encompassed within the spirit of the invention disclosed herein.

What is claimed is:

1. A method of remotely forming a self supporting, sealing barrier in a mine passage, without the use of forms, comprising:

conducting a fast setting cementitious composition into said passage; and

continuously depositing said cementious composition transversely in a portion of said passage until a firm passage sealing, self-supporting impermable barrier is formed in said passage.

2. The method of claim 1 wherein the cementitious composition comprises a mixture of an aqueous slurry of cement and an aqueous silicate solution.

3. The method of claim 2 wherein the cement is of the Portland Cement type.

4. The method of claim 3 wherein the silicate is sodium silicate.

5. The method of claim 4 wherein the aqueous slurry of cement is comprised of Portland Cement present in an amount of from about 7 percent by weight to about 75 percent by weight and water present in an amount of from about 25 percent by weight to about 93 percent by weight.

6. The method of claim 4 wherein the aqueous silicate solution is comprised of grade 40 sodium silicate present in an amount of from about 6 percent by weight to about 100 percent by weight and water present in an amount of from about 0 percent by weight to about 94 percent by weight.

7. The method of claim 3 wherein the silicate is selected from the group consisting of sodium silicate, potassium silicate, guanidine silicate and tetramethyl ammonium silicate.

8. The method of claim 2 which is further characterized to include a cement setting time retarding agent in said aqueous slurry of cement.

9. The method of claim 8 wherein the cement is of the Portland cement type.

10. The method of claim 9 wherein the silicate is grade 40 sodium silicate.

11. The method of claim 10 wherein the cement setting time retarding agent is fly ash.

12. The method of claim 11 wherein the aqueous silicate solution is comprised of grade 40 sodium silicate present in an amount of from about 6 percent by weight to about 100 percent by weight and water present in an amount of from about 0 percent by weight to about 94 percent by weight.

13. The method of claim 9 wherein the silicate is selected from the group consisting of sodium silicate, potassium silicate, guanidine silicate and tetramethyl ammonium silicate.

14. The method of claim 8 which is further characterized to include a thixotropy inducing agent in said aqueous silicate solution.

15. The method of claim 14 wherein the cement is of the Portland cement type.

16. The method of claim 15 wherein the silicate is grade 40 sodium silicate.

17. The method of claim 16 wherein the cement setting time retarding agent is fly ash.

18. The method of claim 17 wherein the thixotropy inducing agent is bentonite.

19. The method of claim 15 wherein the silicate is selected from the group consisting of sodium silicate, potassium silicate, guanidine silicate and tetramethyl ammonium silicate.

20. The method of claim 15 wherein the silicate is selected from the group consisting of sodium silicate, potassium silicate, guanidine silicate and tetramethyl ammonium silicate.

21. A method of remotely forming a self-supporting barrier in a mine passage and the like, without the use of forms, which comprises:

combining a stream of an aqueous slurry of cement with a stream of an aqueous silicate solution to form a stream of cementitious composition;

continuously remotely depositing said cementitious composition in a portion of said passage to form a firm impermeable barrier therein; and

varying the volume ratio of said stream of aqueous slurry of cement to said stream of aqueous silicate solution while said composition is being deposited thereby varying the setting time and viscosity of said composition.

22. The method of claim 21 wherein said cement is of the Portland Cement type.

23. The method of claim 21 wherein said silicate is sodium silicate.

24. A method of remotely forming a self-supporting barrier in a mine passage and the like, without the use of forms, which comprises:

combining a stream comprised of an aqueous slurry of cement and a setting time retarding agent with a stream comprised of an aqueous slurry of a silicate and a thixotropic inducing agent to form a stream of cementitious composition;

continuously remotely depositing said stream of cementitious composition transversely in a portion of said passage to form a firm impermeable barrier therein; and

varying the volume ratio of said stream of aqueous slurry of cement and setting time retarding agent to said stream of aqueous slurry of silicate and thixotropic inducing agent while said composition is being deposited thereby varying the setting time and thixotropic properties of said composition.

25. The method of claim 24 wherein the silicate is sodium silicate.

26. The method of claim 24 wherein the cement is of the Portland Cement type.

27. The method of claim 24 wherein the setting time retarding agent is fly ash.

28. The method of claim 24 wherein the thixotropic inducing agent is bentonite.

29. A method of remotely forming a self-supporting barrier in a mine passage and the like, without the use of forms, comprising:

drilling a bore from the surface of the ground into said passage;

conducting a fast setting cementitious composition through said bore into said passage; and

continuously depositing said cementitious composition transversely in a portion of said passage until a firm impermeable barrier is formed therein.

30. The method of claim 29 wherein said cementitious composition is comprised of a mixture of an aqueous cement slurry and an aqueous silicate solution.

31. The method of claim 30 wherein the cement is of the Portland Cement type.

32. The method of claim 31 wherein said silicate is sodium silicate.

33. The method of claim 32 wherein the aqueous slurry of cement is comprised of Portland Cement present in an amount of from about 7 percent by weight to about 75 percent by weight and water present in an amount of from about 25 percent by weight to about 93 percent by weight.

34. The method of claim 32 wherein the aqueous silicate solution is comprised of grade 40 sodium silicate present in an amount of from about 6 percent by weight to about 100 percent by weight and water present in an amount of from about 0 percent by weight to about 94 percent by weight.

35. The method of claim 31 wherein the silicate is selected from the group consisting of sodium silicate, potassium silicate, guanidine silicate and tetramethyl ammonium silicate.

36. The method of claim 30 which is further characterized to include a cement setting time retarding agent in said aqueous slurry of cement.

37. The method of claim 36 wherein the cement is of the Portland cement type.

38. The method of claim 37 wherein the silicate is grade 40 sodium silicate.

39. The method of claim 38 wherein the cement setting time retarding agent is fly ash.

40. The method of claim 39 wherein the aqueous silicate solution is comprised of grade 40 sodium silicate present in an amount of from about 6 percent by weight to about 100 percent by weight and water present in an amount of from about 0 percent by weight to about 94 percent by weight.

41. The method of claim 37 wherein the silicate is selected from the group consisting of sodium silicate, potassium silicate, guanidine silicate and tetramethyl ammonium silicate.

42. The method of claim 36 which is further characterized to include a thixotropy inducing agent in said aqueous silicate solution.

43. The method of claim 42 wherein the cement is of the Portland cement type.

44. The method of claim 43 wherein the silicate is grade 40 sodium silicate.

45. The method of claim 44 wherein the cement setting time retarding agent is fly ash.

46. The method of claim 45 wherein the thixotropy inducing agent is bentonite.

47. The method of remotely forming a self-supporting barrier in a mine passage and the like, without the use of forms, which comprises the step of:

remotely depositing a fast setting slurry of water, Portland cement, Grade 40 sodium silicate and fly ash, in a portion of said passage until a firm, self-supporting impermeable structure is formed therein, said cement being present in a concentration of from about 7 percent to about 55 percent by weight, said ash being present in a concentration of from about 10 percent to about 65 percent by weight and the water being present in a concentration of from about 25 percent to about 45 percent by weight.

48. The method of claim 47 further characterized by the addition of bentonite to said silicate solution, whereby thixotropic properties are induced in said slurry.

49. The method of claim 48 wherein said sodium silicate is present in a concentration of from about 12 to about 70 percent by weight, the bentonite is present in a concentration of from about 1 to about 10 percent by weight and the water is present in a concentration of from about 25 to about 80 percent by weight.

50. The method for remotely forming a self-supporting barrier in a mine passage and the like, without the use of forms, comprising the steps of:

drilling a hole from the surface of the ground into said passage;

conducting a fast setting slurry comprising Portland cement, Grade 40 sodium silicate and fly ash, and water through said hole into said passage, said cement being present in a concentration of from about 7 to about 55 percent by weight, said ash being present in a concentration of from about 10 to about 65 percent by weight and the water being present in a concentration of from about 25 to about 45 percent by weight;

continuously depositing said cementitious composition transversely in a portion of said passage until a firm, impermeable barrier is formed therein.

51. The method of claim 50 further characterized by the addition of bentonite to said silicate solution, whereby thixotropic properties are induced into said slurry.

52. The method of claim 51 wherein said sodium silicate is present in a concentration of from about 12 to about 70 percent by weight, the bentonite is present in a concentration of from about 1 to about 10 percent by weight and the water is present in a concentration of from about 25 to about 80 percent by weight.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,672,173 Dated June 27, 1972

Inventor(s) Edwin L. Paramore, et. al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet [73] "Halliburton Company, Duncan Okla." should read -- United States of America, as represented by the Secretary of the Interior -- .

Signed and sealed this 12th day of December 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.