Pepper Laboratory of Clinical Medicine

711 Maloney Building

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UNIVERSITY of PENNSYLVANIA

PHILADELPHIA 19104

Associate Members
HERMAN BEERMAN, M.D., Sc.D.
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E. L. FOLTZ, M.D.

EVERGREEN 2-4600
EXTENSION 2631

20 October 1965

Arch.
Rich

Dr. Froelich Rainey
University Museum

Dear Doctor Rainey:

Following the Museum Dinner I spoke to you about the use of acrylamide as a water barrier in permeable soils. This material is a water soluble powder which is made up in a dilute solution and pumped into the water-bearing soil through well points. After a few hours it solidifies forming a completely impermeable water barrier. The solid acrylamide gel is, however, soft and can easily be cut with a shovel. I would think there is at least some possibility that it might be useful in digging on locations such as Sybaris.

You can obtain further information about this material from Dr. J.L. Fedrick at the American Cyanamid Company, Pearl River, N.Y. 10965. Dr. Fedrick is technical director of the Fine Chemicals Department. If you would like to have a demonstration of the material I have a supply in my laboratory and would be glad to show you how it works at any time.

Sincerely yours,

Samuel Raymond

Samuel Raymond, M.D.
Assistant Professor

SR/rw

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2 November 1965

Techniques

Dr. Froelich Rainey
University Museum

Dear Doctor Rainey:

Supplementing my previous information on acrylamide gel the man to talk to at the Cyanamid Company is Mr. Reuben Karol at the American Cyanamid Company Mining Chemicals Plant in Princeton, N.J. His phone number is 609-799-0400, Ext. 8494. Dr. Fedrick, with whom I have discussed the project, indicated that he thought the Cyanamid Company would be willing to subsidize to some extent this use of acrylamide for its advertising value.

In talking to Mr. Karol, you should use the term AM-9 Chemical Grout.

Sincerely yours,

Samuel Raymond

Samuel Raymond, M.D.
Assistant Professor

SR/rw

Techniques

did not get for November 4, 1965

retyped on Nov 11th

Dear Dr. Raymond:

This is the memorandum which I promised you, about the physical conditions of the plain of Sybaris, which bear upon our experiment with chemical grouting which we hope may be carried out during the early spring months of next year.

A hydrologist, Mr. Robert Raikes, who has been working with us, studying the drill records, concludes that about the end of the VIth century B. C. some earthquake phenomenon caused the subsidence of the plain of the Crati about 3 meters. Then the sea rushed in over the shoresdunes to form a large lagoon into which the rivers Crati and Coscile dumped large masses of fine sediments and thus buried the remains of Sybaris to a depth of some 6 meters. With our drills and in the test excavations we made, we find about 1 meter to 1 and a half meter of cultivated soil, above the water table. Below this, there are 2, 3 or 4 meters of very fine, dense clay with some bands of sand through it. Below the clay, at 4, 5 and 6 meters (depending upon the section of the plain) there is coarse sand going on down as far as we have drilled, that is at least 25 meters. In the test excavations, we found relatively little water flowing into our excavations, so long as we were working in the clay. But as soon as we broke through the clay into the sand, the water would rush in at a terrific rate and if our pumps failed, kit would fill the whole excavation to within 50 centimeters of the surface in a matter of a few hours. In other words, the blue clay acts as a seal, holding the water in the very wet sands until perforated, and then the water springs up in what the Italians call "sorgenti". Moreover, we know that there is considerable flow of water through the sands below the surface, because surface vegetation washed down some of our drill holes, would pass under ground and come out again in our nearby excavation.

I do not know the amount of flow in actual gallons per minute, but excavating a hole about 30 meters in diameter, we had to use one large gasoline pump, and three electric pumps, to keep the excavation from flooding. The surface of the plain where we are working is only about 3 meters above sea level, and the ruins are about 3 meters below sea level. Which means that we are going to have to dig at least 6 or 7 meters below the surface, into the sands. We already know that the buildings were originally built on or within the sands. The site lies near the Crati river which now flows above the level of the plain, at that point between levies, and about 2 kilometers from the present shore.

With the cesium magnetometer, we have now located structures measuring 100 meters in length, lying between about 5 and 7 meters deep. We should now make a test excavation at least 50 meters in diameter, and we may want to extend this by another 50 meters. Drilling in that area indicates that there are no ruins above 5 meters deep and hence we could use a drag-line to excavate the hole down to 5 meters. And thereafter work by hand with shovels, uncovering ruins to a maximum of 7 meters deep. Probably, one or two meters into the fluid sand. I should think we would treat the whole area to be excavated with a considerable margin around to act as a dyke, and then to excavate the treated soils both with the drag-line and with the shovels. We have a McCullough screw drill on the site, which will penetrate to at least 8 meters with a bore of about 3 inches diameter. But this is fairly slow drilling, because the drill's stem often gets bound by the heavy clays. For most of our drilling we use the geophysical prospecting drill mounted on a jeep, which flushed out the hole with water. This drill is now not available on the site.

4 enclosures

Enclosed are photographs of our last test excavation made on the plain last June. Also copies of two articles which appeared in the Illustrated London News on December 8th and 15th, 1962, respectively.

Very best wishes,

Froelich Rainey
Director

Dr. Samuel Raymond, 746 Gates, U. of P. Hospital

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EVERGREEN 2-4600
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15 November 1965

Dr. Froelich Rainey
University Museum
University of Pennsylvania Re: AM-9 Chemical Grout

Dear Doctor Rainey:

I have arranged with Mr. Reuben Karol of the American Cyanamid Company, Princeton, N.Y. for a demonstration of AM-9 Chemical Grout in their experimental laboratory later this week. I suggest that we put our heads together and decide what soil structure we would like him to use and when we want to see the demonstration. His experimental facilities include a demonstration chamber three feet deep which can be packed with any type of soil. The demonstration will take probably a whole day. We could leave Philadelphia in the morning, see the demonstration and be back the same day.

Mr. Karol also offered a full-scale field trial but his schedule is such that this cannot be carried out until the middle of January or later. He can furnish equipment, chemicals and two men for the field trial.

Please let me know how this program appeals to you.

Sincerely yours,

Samuel Raymond

Samuel Raymond, M.D.
Assistant Professor

SR/rw

February 18, 1966

Dear Dr. Raymond:

Many thanks for your very thoughtful and detailed summary on chemical grouting. This reminds me that I should bring you up to day with our negotiations with American Cyanamid. Mr. Bullitt and I had a long conference with the President and two Vice Presidents of the company about a month ago. After that, Reuben Karol was instructed to make a detailed study of the Sybaris proposition with the idea that they might finance the whole operation with Karol in charge in the field. Now I have a report from Karol, and a call from the President's office saying that after complete studies by their chemists and engineers, that concluded that chemical grouting is a much more expensive process than dewatering with deep wells and well points. Hence, they did not wish to carry out the work at Sybaris since it was not economically feasible. Karol estimated the cost of the chemical alone at something over $14,000.

Under these circumstances, Mr. Bullitt and I decided to get bids from the Italian firms on the dewatering process and to go ahead on that basis. However, I have been suggesting to Karol that he come out and experiment a bit anyway, if he can convince his bosses that it is worthwhile. I am very sorry that things have worked out this way, because I really did want to experiment with chemical grouting, but it certainly is not economically feasible for us if American Cyanamic does not pay the bill.

In any case, I do hope that you and your wife can come out to Sybaris sometime in the spring to see what we are doing there, even thought

it is not chemical grouting. Frankly, I dread the business of pumps again. But it seems the only alternative.

Sincerely,

Froelich Rainey
Director

Dr. Samuel Raymond
746 Gates Building
H. U. P.

FGR/vg

16 November 1965

To: Dr. Froelich Rainey, University Museum
From: Dr. Samuel Raymond, Pepper Laboratory
Subj: A. Methods of excavation in watery sands

B. Other applications of AM-9 Chemical Grout

This report summarizes my investigations into the use AM-9 Chemical Grout for excavation in watery soils such as are encountered in Sybaris. The following persons were consulted:

Dr. J.L. Fedrick, Technical Director of Fine Chemicals Department, Pearl River, N.Y.

Mr. George Schobinger, Consulting Engineer, Swarthmore, Pennsylvania

Mr. Reuben Karol, Supervisor, Development Laboratory, American Cyanamid Co., Princeton, N.J.

Mr. J.P. Welsh, District Manager, Intrusion-Prepakt, Inc., Phila., Pa.

Mr. L.J. Walton, Chief Engineer, Eastern Gunite Company, Bala-Cynwyd, Pa.

Basic Theory.

The usual approach to the problem of water in excavations is to "pump out, not keep out," that is, it is usually much easier to pump water out of a hole than it is to make the walls of the hole completely impervious to water. It is relatively feasible to surround a given excavation with a curtain wall of impervious material but unless the curtain wall extends down to a completely solid impervious sub-stratum the water will flow in through the bottom of the hole. It is not feasible in most cases to construct a floor across the bottom which will be strong enough to withstand the hydrostatic pressures involved. For example, at the bottom of the 20 foot depth the upward pressure will amount to some 1200 lbs. per sq. ft.

Well Points.

The previous considerations suggest the desirability of using a pumping system comprising a series of well points driven around the periphery of the proposed excavation. Suction pressure applied to all of the well points simultaneously results in a lowering of the water table locally around the well points. Provided the pumping rate exceeds the flow of water through the porous strata the area enclosed by the well points can be maintained completely dry down to the depth of the points as long as the pumping is continued. This is usually the most convenient and most satisfactory method for de-watering and excavation.

Note that the same effect is not necessarily obtained by first digging a hole and then dropping the suction end of a pump connection into the hole. In the well point technique the water flowing through the porous strata to the well point undergoes a filtering action so that only clean water is pumped out of the hole leaving the soil in place. Furthermore, fine silt suspended in the water tends to clog the pores of the porous strata resulting in a reduction in the rate of water flow through the strata, thereby decreasing the load on the pumps. Neither of these effects operates in an open excavation since the water flowing into the open hole continually causes cave-ins of the sides of the hole.

A standard procedure for the use of well points is to excavate an area five or six feet deep with sides sloping at a two to one ratio, leaving a terrace three feet wide at the bottom of the excavation. This terrace is technically called a berm. The points are then sunk into the berm five feet. At the inner edge of the berm another slope is excavated under dry conditions until a second berm is required. The process is repeated until the desired depth is reached. The difficulty with this type of construction is that the top layer excavation must be very much wider than the desired width of the excavation at the bottom because of the sloping sides and the cumulative width of all of the berms which surround the hole.

Grout Wall.

Some of the massive excavation required by the previous method can be eliminated by sinking an impermeable curtain wall vertically around the desired excavation. The curtain wall is put in place by driving pipes through the soil to the desired depth and pumping in a grout mixture under pressure, withdrawing the pipe gradually as the mixture is pumped in. A grout plug, approximately 12 inches in diameter to any depth, can be placed by this method. In order to form an impervious curtain wall the grout holes have to be placed closely spaced, i.e. one-half the diameter of the resulting grout plug to secure adequate overlap.

The disadvantage of this technique is the cost both in labor and materials. The labor of sinking a grout curtain 20 feet deep around a circle 20 feet in diameter has been estimated by the Eastern Gunite Corp. as costing approximately $1200 in the vicinity of Philadelphia. Their estimate includes the services of a four-man crew and all of the necessary equipment for the period of three days which they estimate will be required to produce such a grout curtain. Materials on this basis are extra. Assuming perfect placement of the grout wall, the total volume of grout required would amount to approximately 1200 cubic feet. Cement grout costs $1 to $2 per cubic foot, whereas AM-9 Chemical Grout costs $2 to $4 per cubic foot. Because of the greater technical difficulty in applying cement grout and the resulting indestructable structure of the cement in place, I suggest that AM-9 Chemical Grout will prove more satisfactory for archeological purposes.

In any grout wall construction it will be necessary for safety to provide extensive shoring across the diameters of the excavation.

Trench Excavation.

In order to reduce the costs of materials and labor a trench excavation rather than a round hole may prove desirable. A trench three or four feet wide and 20 feet deep could probably be excavated at a cost of some $100 to $200 per running foot of trench, including grouting materials and the necessary shoring. In this type of excavation two parallel grout curtains can be put in place three or four feet apart and the excavation dug between them. Shoring would be simple and strong and pumping would probably be required at the two ends of the trench. This construction will illustrate one of the advantages of chemical grout as compared to a cement grout. In the event that an artifact is found embedded in the grout wall it would be very easy using hand tools to cut through the grout wall for the removal of the object as required.

Core Samples.

In addition to the drill sample technique devised by Donald Brown, I suggest the use of core samples. Equipment is available for driving a hollow drill

down through almost any depth of soil. The core contained within the hollow drill can afterward be removed for detailed examination. It is possible to obtain cores as much as 12 inches in diameter. For this to be effective in loose water-bearing sandy soils the soil must be stabilized in some manner. This can be done by laying down a single column of AM-9 Chemical Grout before following up with the core drill. The AM-9 Chemical Grout would provide a core which can be easily broken apart for examination of any artifacts contained in it.

Dry Walls.

In many archeological excavations it is necessary to use a terrace structure in order to support the sides of the trenches properly. However, by impregnating the soil with the chemical grout before doing the digging it is possible to obtain a trench face of almost any height which can be cut smooth to leave the strata easily visible.

Preservation of mud bricks.

AM-9 Chemical Grout as a one-shot solution treatment should be ideal for the preservation of mud bricks.

SR/rw