Showed To Cotte

CYANAMID

AMERICAN CYANAMID COMPANY
POST OFFICE BOX 672, PRINCETON, N. J.
AREA CODE 609—SWINBURNE 9-0400

February 7, 1966

Dr. F. Rainey
University of Pennsylvania Museum
Philadelphia
Pennsylvania

Dear Dr. Rainey:

The entire problem of the use of AM-9* for archeological excavation in Italy has been studied and has resulted in the report which is attached.

This report is, of course, based on rather limited data. However, the conclusion reached is that AM-9 is not the least expensive way of excavating the test section. If you have any data which would enable us to estimate costs more accurately, or if you would like to discuss this problem in further detail with me, I would be very happy to do so.

Sincerely

R. H. Karol

R. H. Karol, P. E.

RHK:dek
Attachment
*Trademark

FEASIBILITY STUDIES OF THE USE OF AM-9 IN ARCHEOLOGICAL EXCAVATIONS

Submitted by
R. H. Karol, P. E.
Engineering Chemicals Research Center
American Cyanamid Company
Princeton, New Jersey
January 18, 1966

INDEX

SUMMARY

An economic and engineering feasibility study has been made to evaluate the use of AM-9 in southern Italy as an aid to archeological excavation in areas below the water table.

Based on exceedingly limited data, it is concluded that deep wells represent the most economical solution to obtain dry excavation of a proposed test section. Drying of the area could also be accomplished by a chemical grout curtain. Equipment, materials and supervision for this project if provided by Cyanamid, would total about $22,000. Dollar breakdown for chemicals alone is $14,915.

INTRODUCTION

On November 15, 1965, Dr. S. Raymond of Pennsylvania University visited the ECRC at Princeton to discuss the possible use of AM-9 for archeological excavations. In particular, the project that he had in mind was a trial section in an area located in southern Italy. At this location, ruins of the ancient Greek city of Sybaris are thought to be located about 20 feet below grade. The water table at the location is about 3 feet below grade, making excavation an extremely difficult and hazardous operation. University personnel feel that it is necessary to identify a small portion of the ruins visually prior to estimating the cost and worth of excavation for the entire city. Cyanamid was approached for information regarding the technical and economical feasibility of the use of ECRC products on such a project.

Preliminary discussion led to the conclusion that the use of AM-9 for establishing cut-off walls around very large areas was not feasible economically. However, there are types of exploratory excavations for which the use of AM-9 is technically feasible, and appears to be a better approach economically than standard methods. Specifically, one of these is the in-situ stabilization of a relatively small diameter vertical cylinder of soil to virtually any depth which would permit recovery of an undisturbed, stabilized core of 10 inches to 12 inches in diameter. The other possibility is the establishment of a relatively short single line curtain which would permit visual examination of all the strata and relics in their actual position in the ground. Interest in these two end uses was great enough so that a laboratory experiment was programmed. This was witnessed on November 24 by Dr. S. Raymond, Dr. F. Rainey and Dr. D. Crownover all from the University of Pennsylvania.

Following the laboratory demonstration and its verification of the potential of AM-9, members from the Pennsylvania University staff had a meeting with officials from Cyanamid, including Vice President G. W. Russell. During this meeting, it was suggested that Cyanamid consider providing equipment, supervision and sufficient chemicals to stabilize an area approximately 100 feet by 200 feet in extent. Such an area would permit complete excavation of a temple floor and the ruins of its walls.

At a meeting on January 10, 1966, in Mr. Russell's office, attended by M. C. Behre of E & MC and R. H. Karol of ECRC, a very cursory study of the amount of chemicals required to permit excavation of the temple indicated 75,000 to 125,000 pounds would be needed. In view of this large number, Engineering Chemicals Research Center was asked to furnish a complete report on the exact nature of the problem, its possible reduction in scale, and the engineering and economic feasibility of grout curtains.

The problem was discussed over the phone with Dr. Rainey. He stated that in his opinion the use of AM-9 was definitely an economic feasibility for the initial exploration of small areas, and he further indicated that for the specific problem at hand, an area of approximately 50 feet by 50 feet in extent would serve very well to prove the utility of AM-9 Chemical Grout.

Dr. Rainey also stated that discussions he has had with local officials indicate that if the ruins are authentic, the chances are that funds available through the Italian government and private industry will result in excavation of the entire city as a tourist attraction. He felt that there would be a significant use of AM-9, providing its utility can be verified.

As a background on the ruins themselves, these are alleged to be those of the ancient Greek city of Sybaris. This city was founded by the Athenians about 800 B. C. By 600 B. C., Sybaris had grown to be the most wealthy city in the Greek Empire. Some 90 years later, it was overrun during a war with a neighboring city, and according to legend, the sea was let over it. If the ruins are authentic and in the shape anticipated, they would undoubtedly be the tourist attraction that is anticipated.

ENGINEERING CONSIDERATIONS

For any dewatering problem, it is necessary to consider the soil conditions (including profile, permeability and ground water supply), the areal and volume extent of the construction site, and whether the dewatering is to be temporary or permanent.

In general, for open excavation, chemical grouting is best suited for small projects (either temporary or permanent), wells and well point systems for small and moderate size temporary shallow projects, cement grout cut-offs reinforced by chemicals and slurry trenches for large size permanent projects, and suspended solids grouting for treatment of large volumes of soil.

In this specific problem, the final solution must be for a large area and volume and must be permanent in nature. The test section proposed, however, is for a small area, and the dewatering required is temporary. Thus, a method suitable for the test section need not necessarily be technically or economically applicable to the main problem.

PARAMETERS OF THE TEST SECTION

The site of the alleged ruins of ancient Sybaris is approximately in the middle of the "instep of the boot" in southern Italy, some 100 kilometers west of the city of Taranto.

Borings in the proposed test section have been interpreted to indicate a solid stone floor about 100 feet wide by 165 feet long, supporting in some places remnants of stone walls along the floor perimeter. The ruins are located 21 to 22 feet below the ground surface.

The average soil profile is reported to consist of 2 to 2 1/2 meters of dense clay with pockets of sand, underlain by 3 to 4 1/2 meters of mixed sand and clay, then medium to coarse sands down to substantial depths below the ruins. Ground water is one meter below ground surface.

PURPOSE OF THE TEST SECTION

The purpose of the test section is to permit visual inspection of a large enough portion of the ruins to permit positive identification, to determine the value of the entire site as a tourist attraction, and to evaluate dewatering procedures for the site.

EXTENT OF THE TEST SECTION

University of Pennsylvania officials have agreed that an open excavation of 50 feet in extent is sufficient for these purposes. By preference, the excavation should expose a portion of the floor along two intersecting perimeter lines.

CHEMICAL GROUT CURTAIN

To fulfill the requirements, a chemical grout curtain, circular in shape, centered 15 feet away from each of two intersecting floor edges, will suffice. The diameter inside the curtain will be approximately 50 feet, with about half of the curtain on the floor slab. The curtain may be formed by grouting two concentric circles of grout holes. These will be spaced 5 feet apart in each circle. The circles will have diameters of 54 1/2 and 52 1/2 feet. Holes in the inner row will be centered between holes in the outer row, and grouted last.

For computation purposes, the profile is assumed to be:

0-6 feet, dense clay with sand pockets, 5% voids
6-15 feet, mixed sand and clay, 15% voids
15-50 feet, medium to coarse sand, 30% voids.

Those grout holes which do not touch the floor slab must be carried to about 18 feet below the floor slab, in order to preclude the occurrence of quick conditions.

Based on a 20 inch radial spread of grout from each hole and the assumed soil profile and properties, the total grout volume required is about 30,000 gallons. At 7% AM-9 solution concentration, this is equivalent to 17,500 pounds of AM-9. Approximately 1,000 pounds of activator DMAPN and 1,250 pounds of catalyst AP will also be required. It should be anticipated that quick conditions requiring additional grouting

will develop where the curtain meets the floor slab, as excavation proceeds. The quantity estimate should be increased by about 10% to cover this contingency.

Chemical	Quantity
AM-9	20,000 lbs.
DMAPN	1,100 lbs.
AP	1,400 lbs.

In addition to chemicals, drilling and pumping equipment must be supplied. Chemical grout proportioning pumps are an absolute necessity. Adequate pumps are probably not available in Italy, but could be shipped from the Engineering Chemicals Research Center at Princeton. The success of such a project is directly related to the accuracy with which the grout pipes are placed. A mobile drill with trained crew will be required for as long as 30 working days, at a cost estimated at about $225 per day. This cost should also cover the rental of dewatering pumps, which will be necessary to keep the excavation dry,* and an air compressor to operate the grout pumps.

The grouting itself should be closely supervised for two to three weeks, to train the crew, establish exact field procedures, and set up the necessary field records. Supervision of the final closure stages is also desirable, so that anticipated zones of weakness, as revealed by the project records, may be corrected. Costs of supervision of grouting, and costs of local labor for grouting, excavating, etc, have not been included in this report.

As the grout curtain is exposed during excavation, it will be necessary to shore the stabilized soil to prevent a structural failure due to creep. Such shoring should be placed as soon as practical after exposure of the curtain. Costs of the labor and material for shoring have not been included.

It must also be recognized that when the floor is exposed it will become subject to hydrostatic uplift pressures. Since it was undoubtedly not

* It is not considered technically or economically feasible to grout a horizontal floor at the bottom of the grout curtain. Water inflow may be of the order of 200 to 300 gallons per minute.

designed to withstand such forces, there will be a danger of structural failure of the floor slab. Adequate dewatering of the excavation will reduce this danger.

DEWATERING BY DEEP WELLS

The details of this particular problem, insofar as they are known to us, have been discussed with a competent engineer formerly employed by one of the major domestic dewatering companies. His background includes both cement and chemical grouting, deep wells and the various wellpoint dewatering systems. In his opinion, the most economical solution is by the use of wells.

It is proposed to place three deep wells, one at the corner and one along each wall about 50 feet from the corner of the floor slab. Each well, 8 to 10 inches in size could be drilled to the proper depth, cased, equipped with a screen and a 10 hp submersible electric pump and controls for an estimated $2,000 including installation and labor.

Each well, handling 300 to 500 gallons per minute will lower the water table locally below the floor level, and permit dry excavation of one corner. Additional costs, which cannot be estimated due to lack of data, are involved in placing the discharge facilities, and in the maintanence costs. These costs, however, when added to those for well installation, should total well below the total cost of a chemical grout curtain.

It is estimated that three additional wells would permit dry excavation of the entire floor.

WELLPOINTS

Estimates on the total cost of wellpointing the test site have not been obtained from domestic contractors. University of Pennsylvania personnel report, however, that a British hydrologist, familiar with the test site, had estimated the total cost of wellpointing as $25,000 for a "small pit."

CONCLUSIONS

Excavation is necessary in order to identify and evaluate certain ruins in southern Italy. To accomplish this aim, a relatively small temporary excavation will suffice. Such an excavation may be accomplished through the aid of

1. chemical grouting
2. deep wells
3. wellpointing.

All three of these methods are feasible from an engineering point of view. Deep wells appear to be the most economical way of drying the area for excavation. Chemical grouting is probably the most expensive.

It must be recognized that the cost estimates which have been made in this report are based on exceedingly limited information. Should the actual site conditions differ considerably from what has been assumed, the cost picture and possibly the engineering feasibility may be entirely different from some of the opinions now held.

It is possible that none of these three methods would serve as the major dewatering system should it be desired to expose the entire ruined city as a tourist attraction. All three methods, however, should have local application during a major dewatering operation. Chemical grouting will probably be the quickest and easiest solution to local problems during a major dewatering operation.

The total outlay in dollars for furnishing chemicals, equipment and supervision, (not including transportation charges for equipment and materials) would be approximately $22,000. These estimates include travel for two round trips to the site and living expenses for a total of 30 days. The major value of such an expenditure would seem to be that of publicity. Additional value which cannot be put into terms of dollars at the present time is the fact that as a result of this project, there will be engineers in Italy trained in the use of AM-9.

Sybaris
Techniques

February 17, 1966

Dear Dr. Karol:

With reference to our telephone conversation of the 15th, and your letter of the 16th, I would like to make the following suggestions.

Today, I have written to engineer Enrico Mueller on the plain of Sybaris, asking him to get bids from local contractors for the dewatering operations there, both for the deep well and well point system. Also, I have had a talk with Mr. Bullitt, and we agreed that we should proceed with the wells for dewatering. However, as you know, in our Applied Science Center we are experimenting with various new techniques in archaeology, and I should very much like to experiment with AM-9 chemical grouting at Sybaris, even thought it does not now appear feasible to rely entirely upon chemical grouting for that test excavation. I have in mind grouting a small cylindrical area to see if we can remove solid cores from the strata and also an experiment with solidifying the walls of an excavation for sections to be excavated by hand, in conjunction with the wells which should reduce the underground water pressure.

It seems to me that at this site we have an excellent opportunity for experimenting with AM-9 for archaeological consolidation and with relatively little time and expense we could discover how practical and economical this technique may be in archaeological research. After all of our discussions and experiments, I feel optimistic that chemical grouting can be a very useful technique under certain circumstances and from our experience with the application of other techniques, I know that we will never determine

this without actual experimentation in the field, under the direction of somebody who knows the technique. I would, therefore, like to suggest that you consider joining us at Sybaris in April or May, with a reasonable supply of AM-9 and the pumps and equipment you have there in your laboratory, so that you can determine on the site the economic feasibility of the method. It is quite possible that you will find it much more practical than you think at the moment.

In any case, I do hope that one way or another we can collaborate in this extraordinarily interesting job in uncovering a bit of Sybaris.

Most sincerely yours,

Froelich Rainey
Director

Dr. R. H. Karol, P. E.
American Cyanamid Company
Post Office Box 672
Princeton, New Jersey

FGR/vg

cc: Mr. Bullitt
2/17/66 rr

CYANAMID

AMERICAN CYANAMID COMPANY
POST OFFICE BOX 672, PRINCETON, N. J.
AREA CODE 609—SWINBURNE 9-0400

February 16, 1966

Dr. F. Rainey
University of Pennsylvania Museum
Philadelphia, Pennsylvania

Dear Dr. Rainey:

In confirmation of our phone discussion of February 15, it is difficult for us to justify the verification of the technical feasibility of the use of AM-9* Chemical Grout in applications which do not have economic feasibility.

As noted in the report, and mentioned in our discussion, the cost estimates shown in our report are based on rather limited data and have, of necessity, included assumptions which reflect our best estimates of subsoil conditions, based on that limited data. Further, the cost data shown for well pointing and deep wells have been estimated without the benefit of in-situ pumping tests.

We both agreed that at this point, little could be gained in further discussion of the data submitted in our report. We both felt that the next logical step would be to obtain bids from local contractors for the dewatering operation, both by deep wells and by well pointing.

You indicated that you were going to arrange to obtain those bids. If the quotations you receive differ significantly from the values estimated in our report, this could make it necessary for us to review our current conclusions in regard to the economic feasibility of a chemical grout curtain.

Yours very truly,

R. H. Karol

R. H. Karol, P. E.

RHK:dek
*Trademark

copy To E. Mueller
2/17/66

C
O
P
Y

February 17, 1966

Mr. John Allegaert, President
American Cyanamid Company
Wayne, New Jersey

Dear Mr. Allegaert:

Dr. Rainey has shown me the report made by Mr. Karol on the possibility of using AM-9 at Sybaris, and the suggestion of an engineer whom he consulted that we use a system of wells.

I am writing to you in the hope that you will undertake this project in conjunction with the Museum. We have considered the use of wells and have been led to believe the cost would be about the same as quoted by Mr. Karol for AM-9. Frankly, what we most need is your experience and ability, for I am sure if your Company undertook the work it would be well done. The same cannot be said for what we have seen of the methods of the Italians. Even as a layman, I was amazed when I saw the way the work at Sybaris was done by their supposedly competent people.

Dr. Rainey has said that the discovery of Sybaris will rank with the finding of Troy and of King "Tut's" tomb. The Italians have already said he has found it, but, rightly, he wishes to be assured that the building we uncover this summer is really of the date of Sybaris. If you will be willing to help us with your knowledge and experience, you would have the satisfaction of being a participant in one of the great archaeological discoveries. In addition, Italian engineers could be brought to the site to see the practical use of AM-9 and all archaeologists would immediately know of its value to them. A small matter for a company as large as yours, but you would be making a contribution to one of the greatest and best known museums in its field in the world. In terms of money, I feel sure the $25,000. would be well spent, and in line with the many contributions you probably make to institutions of learning.

We really need your advice and your practical assistance, and I do hope you will agree to give it to us.

Sincerely yours,

O.H.B.

OHB/hg

cc: Dr. Rainey

CYANAMID

AMERICAN CYANAMID COMPANY
POST OFFICE BOX 672, PRINCETON, N. J.
AREA CODE 609—SWINBURNE 9-0400

February 21, 1966

Victoria
Send to
Mr. Bullett
2/24/1966

Dr. F. Rainey
The University Museum
University of Pennsylvania
Philadelphia, Pennsylvania 19104

Dear Dr. Rainey:

Thank you for your letter of February 17.

The application which you suggest, that is, grouting a vertical cylinder from which grouted cores can be taken, is one of the original applications which we concluded were feasible from an economic as well as an engineering point of view. We have done this thing many times in the field, since virtually all grouted cut-offs consist of overlapping vertical cylinders of stabilized soil.

From the archeological point of view, it would remain to be determined how easily stabilized cores could be used to recover and classify artifacts. This procedure must obviously be tried in the field by people such as yourself in order to obtain a realistic opinion.

Although I personnally would very much like to accept your offer to join you at Sybaris for field experimentation, the decision as to whether I can do this or not must be made elsewhere. I am therefore taking the liberty of forwarding your letter through channels to the Cyanamid executive level, where the decision must be made.

All of us appreciate your continuing interest in the use of our products.

Sincerely,

Ruth Karol

R. H. Karol, P. E.

RHK:dek