

I. Construction Innovation Forum • NOVA Award Nomination

Instructions

Step 1 Enter a Descriptive Name for the Process/Method/Technique you are nominating on line A of this page.

Step 2 Complete this page.

"I. Construction Innovation Forum • NOVA Award Nomination"

- a. Be sure to provide original signatures in Section B and E on this page. Your nomination cannot be reviewed without them.
b. If you need additional space for names and addresses you may attach additional pages for names and address information.
You may attach extra pages only for sheet I.

Step 3 "II - Innovation Description" — attach one (one only) 8-1/2" X 11" page that gives a succinct written description of the innovation. Put the name of the innovation at top of page. Tell us what you think is innovative about this. You should include:

- What the innovation is
- Where and when it originated, has been used, and is expected to be used in the future
- Why it is innovative
- If the nomination is for an innovative project, specifically identify its innovations.
- What it changed or replaced

Please type, with 1" margins, 10 characters per inch, 6 lines per inch.

Step 4 "III - Innovation Illustration" — attach one (one only) 8 1/2" X 11" page that contains one or more photographs, drawings, tables, graphs, clauses, etc., that visually describe the innovation. Do not submit more than one page of visuals. The jurors will see only one sheet for review. Put the name of the innovation at top of page.

Other You must submit 12 (twelve) sets of sheets I, II and III (a total of 36 pages)

Nominations are due September 15 mailed or delivered to:

The Construction Innovation Forum, 1000 Campus Drive, Suite 100, Ann Arbor, MI, USA 48104-6792, Phone: 313-995-1855, Fax: 313-995-5002

A. Name of Innovation: JET-GROUTED CONSTRUCTED LAMINAR DIAPHRAGMS

B. Person(s) and/or Organization(s) Primarily Responsible for the Innovation (Those to whom NOVA Award should be presented.)

Name: ING. B. GEMMI

Title: VICE-PRESIDENT

Affiliation: FONDAZIONI SPECIALI S.r.l.

Address: VIA POZZUOLO DEL FRIULI 1

PARMA - ITALY

Phone: 0039-521-593441

Signature: [Signature]

(Signature(s) indicate acceptance of the nomination and consent to have CIF research and make presentations on the innovation for the purpose of jurying and publicizing awards.)

C. Other Primary Sources of Information on the Innovation: (in addition to the persons nominated above.)

Name: MAGISTRATO PER IL PO

Title: _____

Affiliation: PUBLIC WORKS MINISTRY

Address: VIA GARIBOLDI 75

PARMA - ITALY

Phone: 0039-521-772401

D. Independent Reference(s) familiar with the use of the Innovation

Name: PROF. P. LUNARDI

Title: CONSULTANT

Affiliation: ROCKSOIL S.p.A.

Address: PIAZZA S. MARCO 1

MILANO - ITALY

Phone: 0039-2-6590181

E. Person(s) making nomination:

Name: F.A. BARES

Title: _____

Affiliation: U.C.I. CONSULTANTS

Address: 68 FLETCHER ST.

WINCHESTER, MA 01890

Phone: 617 729 3656

Signature: [Signature]

(Signature(s) indicate familiarity with the innovation and signify that information contained in the nomination is correct to the best of one's knowledge.)



JET-GROUTING CONSTRUCTED LAMINAR DIAPHRAGMS A SHORT DESCRIPTION AND IDENTIFICATION OF THE INNOVATION

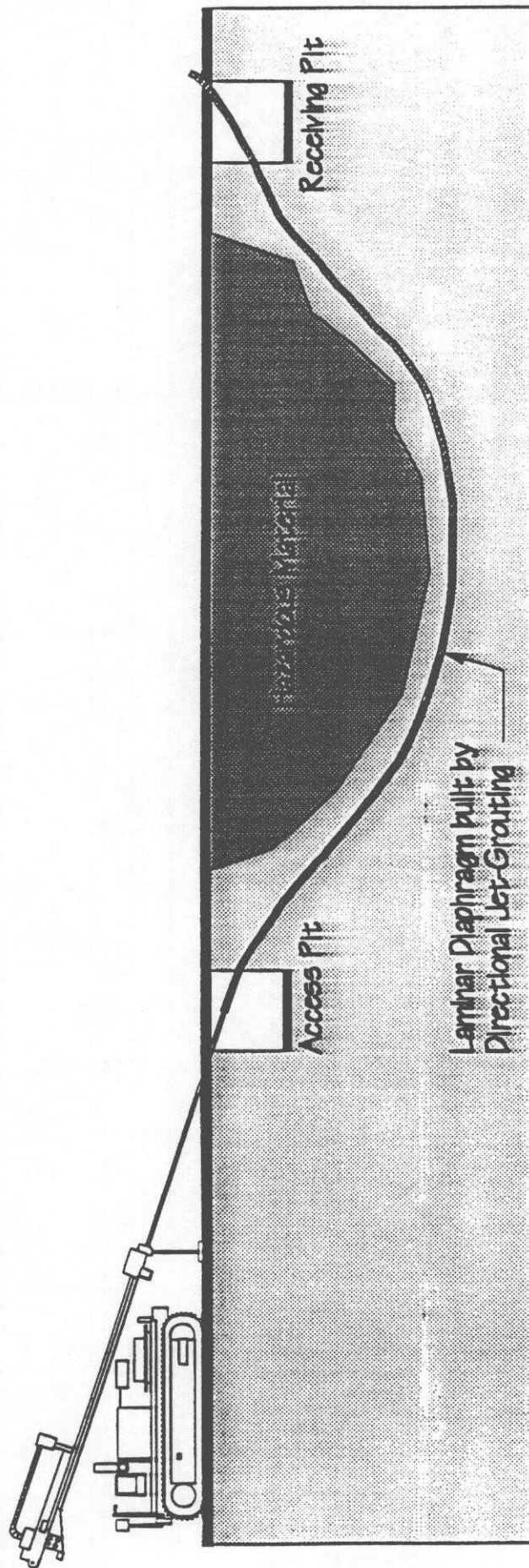
Laminar Diaphragms are thin (100 150mm thick), laminar structures constructed underground using high pressure, high volume jets of grouts. Grouts are usually a mixture of different materials in a water base. Most widely used and common are cement grouts, a mixture of normal Portland cement and water to hydrate it. Recently, grouts made of an emulsion of mineral wax in water, have been used. Jet-grouted diaphragms extend for distances of up to three meters on each side of the source of jetting. Actual lateral soil penetration is a function of the nature of the soil, the type of equipment used, the skills of the operators and other factors. By overlapping jet-grouted areas, continuous impervious barriers are constructed.

No other system exists that can install thin, continuous, waterproof diaphragms without vibrations and open excavations, even in very difficult, obstruction-rich soils. The stability and the integrity of the structures treated is never jeopardized nor affected by shaking vibrations and potentially undermining excavations. The system effectively and economically replaces impervious diaphragm construction systems like conventional grouting, bentonite slurry walls, sheet piling and others. Based on an in situ ground improvement concept, the diaphragms can be constructed to considerable depths, at any angle and orientation and with positive control of final location and placement. Light construction machinery, makes the system versatile, flexible, adaptable to different and tight geometry and of faster implementation anywhere it is needed. The system was devised to quickly waterproof large earthen bodies, especially river levees subject to weakening by extensive flood water soaking. It underwent its first successful use in 1989 when it was applied to protect and strengthen 1,200m of levees along the Po river in Italy. The significant construction depth helped preventing water piping through sandy, highly pervious ground under the embankments during subsequent floods. What is more unique now is that laminar jet-grouted containment membranes were recently constructed under and around contaminated soil zones and lagoons of toxic chemicals to intercept and stop plumes of hazardous and toxic substances from further leaching into the surrounding soil. For the first time, grouts made of emulsions of mineral wax in water were used to counteract aggressive chemicals which would quickly attack and degrade any other substance customarily used in the past, like cement, bentonite and other chemical resisting compounds. The first successful use of this technique was performed in 1993, in Slesia (Germany) to prevent and contain highly toxic leachates from coal mining tailing lagoons from dispersing into the local aquifer. An additional unique feature of this novel environmental remediation application, is that it used sophisticated directional drilling systems to guide the jetting tools under bodies of fluids and around obstacles, thus further removing operators and machinery from the hazard of working within highly contaminated and toxic areas.

Jet-grouting constructed laminar diaphragms could presently be effectively used in the US to strengthen levees along the Missouri and Mississippi rivers. A presentation to the US Corps of Engineers and to affected State Department of Public Works is presently under way. A presentation of the environmental remediation process using emulsified wax has also been recently submitted to the D.O.E. for consideration and use.

Attached, please find some evidential material showing the appearance of exposed jet-grouting constructed laminar diaphragms and the application concept of the environmental remediation application.

Directional Jet-Grouting for the construction of lamihar containment tile diaphragms ©



Cross Section
Not To Scale



CONSULTANTS, INC.
98 FLETCHER STREET
WINCHESTER, MA 01890

AWARD MANAGER'S SUMMARY

AWARD MANAGER'S SUMMARY
Nomination 9411

JET-GROUTED LAMINAR DIAPHRAGMS

The Innovation

Jet-grouted laminar diaphragms are impermeable barriers constructed underground using special jet-grouting techniques. By jetting grout into the soil through properly spaced drill holes, a continuous diaphragm, or membrane, may be constructed to prevent the passage of water or other fluids which may contain toxic or hazardous chemicals.

Drill holes are spaced according to the plans of the project. If the grout diaphragm is to be vertical, commonly used drilling equipment is used. If the drill holes are to follow a particular shape, such as would be the case if the membrane is to be placed beneath a hazardous waste site, then directional drilling equipment is needed.

The nominated jet-grouting method uses special grout nozzles to create a grout sheet of controlled width and thickness from each drilled grout hole. This sheet is commonly 100mm to 150mm in thickness, two to three meters in width, and of any desired length. According to the nomination, the width of the sheet in one pass can go up to six meters. Actual lateral soil penetration of the grout jets is a function of the nature of the soil, the type of equipment used, the skill of the operator, and other factors.

The grout is injected into the soil from opposing high pressure jets that are at an angle to each other. Grouting begins at the far extremity of the drilled hole, and as the jetting pipe is withdrawn, the jet nozzles are not rotated. The grout therefore forms a sheet with a slight vee shape when viewed from the end of the grout pipe. The minimum width of the grout sheet that can be achieved in given soil conditions is either measured or predicted. Then, the distance to the next drill hole is set such that the edge of the new grout sheet intersects the edge of the previous sheet. In this way, the overlapping sheets form a continuous membrane with an undulating surface and gaps between the adjacent grout sheets are eliminated.

Grouts that can be used with the method are usually a mixture of different materials in a water base. The most commonly used grouts are made by mixing normal Portland cement in water. More recently, grouts made of an emulsion of mineral wax in water have been used.

It is claimed that the diaphragms can be constructed to considerable depths, at any angle and orientation, and with positive control of final location and placement. Light construction machinery makes the system versatile, flexible, and

adaptable to different and tight geometries. Speed of implementation is also cited as an advantage of the system.

The nominators claim that no other system exists that can install thin, continuous, waterproof diaphragms without creating vibrations nor without the need for open excavations, even in very difficult, obstruction rich soils. The stability and the integrity of nearby structures is never jeopardized by shaking vibrations and potentially undermining excavations. The system may effectively and economically replace impervious diaphragm construction systems, such as conventional grouting, bentonite slurry walls, sheet piling, and others.

Background of Innovation

The inventors of Jet-Grouted Laminar Diaphragms are Bruno Gemmi, of Fondazioni Speciali, and Andrea Perelli, of Rodio Company, both from Italy. Dr. Gemmi is the leader and the spokesman for the method.

The system was devised to protect river levees from weakening owing to high flood waters. It was first successfully used in 1989 when it was applied to protect and strengthen 1200 meters of levees along the Po river in Italy. The levees were constructed of quite uniform sandy soil, and the width and thickness control of the membranes was not difficult to achieve. The significant construction depth prevented water from piping through the sandy and highly pervious soil. Piezometers were set up and water seepage was measured for one and a half years. The results of these tests showed that there was a good seal against the waters of the Po river.

There is an Italian patent for the process under the names of Gemmi and Perelli. (No. 21499 A/88)

Application

The method for constructing jet-grouted laminar diaphragms has been extended to construct containment membranes under and around contaminated soil zones and toxic chemical lagoons. Grouts made of emulsions of mineral wax in water are used to counteract aggressive chemicals which have quickly attacked and degraded other grouts used in the past.

Directional drilling is used for toxic lagoon containment membranes. An access pit is first built at one side of the contaminated area and a corresponding receiving pit is built on the opposite side of the area. Directional drilling using high pressure jets begins at the access pit and ends in the receiving pit. The jet drill is electronically controlled for speed and direction. After the receiving pit is reached, the jet nozzle is pulled back to the access pit without rotation. It is during this backward pass that the jet produces the membrane sheet that

is four to six inches in thickness and 10 to 20 feet in width, depending upon soil conditions.

The first successful use of this technique was performed in 1993 in Slesia, Germany, to prevent highly toxic leachates originating in coal mine tailing lagoons from dispersing into the local aquifer. This remediation application used sophisticated directional drilling systems to guide the jetting tools under the site and around obstacles.

It has been proposed that jet-grouted laminar diaphragms could be effectively used in the United States to strengthen levees along the Missouri and Mississippi rivers. A presentation to the US Army Corps of Engineers and to the affected State Departments of Public Works is being planned. A request for a presentation of the environmental remediation process using emulsified wax has also been recently submitted to the U.S. Department of Energy for consideration and use.

Notes on Nominated Persons

Dr. Bruno Gemmi

Dr. Bruno Gemmi is Vice President of Fondazioni Speciali s.r.l. of Parma, Italy. The company specializes in geotechnical and environmental engineering with particular interest in jet grouting.

Dr. Gemmi says that the main innovation is the speedy and economical construction of jet grouted membranes. Some membrane jet grouting has probably been done before, but Gemmi has come up with a method which controls thickness and width and can place continuous membranes. The first application of the idea was for the stabilization of levees along the River Po.

Opinions of Outside Persons

Mr. F. A. Bares

Mr. F. A. Bares is the Nominator of Jet Grouted Laminar Diaphragms. He is Principal of the firm UCI Consultants, Inc. located in Winchester, Massachusetts, and represents Dr. Gemmi and his firm Fondazioni Speciali s.r.l. of Parma, Italy.

Mr. Bares became interested in the process and brought it to the USA. He studied it in detail and thinks the process has a good future. He thinks that the US Army Corps of Engineers is going to use the method extensively.

Professor Donald H. Gray

Professor Donald H. Gray is a professor of Geotechnical Engineering at the University of Michigan. He is an expert on slope stability and the effect of water in saturated soils.

Professor Gray says that there does not seem to be enough documentation, references, or supporting analyses to back up the concept and its claims. For example, inadequate information is given about problems of hydraulic lifting at shallow injection depths, the control of shape and direction of the laminations, and the elimination of "windows" or openings in the laminar diaphragms.

He says that "I wouldn't invest any money in it based on the information and particulars submitted."

Professor Thomas Iseley

Professor Thomas Iseley is well known for his expertise in microdrilling and microtunneling. He has experience in all kinds of drilling techniques, especially directional drilling.

Professor Iseley says that he does not know of any jet grouted membrane installations in the United States. He has heard about this process being applied in Europe (Italy), but he does not have any case studies or installation reports in his file.

Professor Iseley says that for the case where a straight-line (no curves) microtunnel is to be made, there is no problem with microtunneling because the boring machine can be guided by a laser beam. As a result of this experience, he sees no difficulty in installing membranes in a levee. For the curved membranes under a contaminated pond area, horizontal directional drilling methods are expected to be used. It can be done, but the process is more complicated and needs improvement in accuracy.

Professor Walter J. Weber

Professor Walter J. Weber is Professor of Environmental Engineering at the University of Michigan. Professor Weber is one of the leading environmental engineering authorities in the United States. He has had extensive experience in site remediation problems.

Professor Weber says that directional drilling is nothing new. He has not seen a method for the construction of a membrane under a contaminated pool without disturbing the pool. There may be a problem with boulders and other obstacles to construction. If such a membrane is constructed it has to be impermeable; it must have no holes.

Professor Weber believes that a membrane under a contaminated area or pool has a limited usefulness. Usually, you do not want to keep that pool with an open surface. You want to eliminate it. Further, such membranes would probably not last a long time.

He sees the usefulness of such a membrane in cases where there is a spillage or where the contaminant can not be picked up immediately. In situations like that, a fast membrane application could be useful if it is to serve for about a year before final remedial action is taken.

Award Managers' Comments

The innovation appears to be in the way that jet grouting is used. By injecting grout with nozzles that have controlled positions it is possible to create a sheet-like form of grout in the soil. The opposing jet nozzles are set at an angle on the injection tool so that the sheet of grout that is formed assumes the shape of a shallow vee trough. This geometry insures that the grout sheets of adjacent holes will intersect and a continuous barrier results.

The use of this technique is expected to save material and drilling expense. Installation takes less time than for conventional grout barriers. The concept appears to be adaptable for uses in the environmental area where impermeable barriers may be needed for a limited period of time.

SELECTED INTERVIEW SUMMARIES

Phone Interviewer: Tons
Date: 12/01/93

#9411
No. 1

Name: Mr. F. A. Bares
Title: Principal
Affiliation: UCI Consultants, Inc.
68 Fletcher Street
Winchester, MA 01890

1. Mr. Bares says that the original idea was to come up with a quick method to improve the stability of a levee without disturbing the levee material (soil). In floods and emergencies this is very important. The work can be done from barges or the top of the levee. This system of membrane application is unique and applications other than levees are being developed.
2. The jet grouting idea, as such, is not new. Around 1972 the Japanese started to use jet grouting using the columnar procedure for underpinning, support of excavation, and other applications. Their procedures, however, were rather cumbersome. They were not in the thin membrane applications area.
3. Mr. Gemmi uses two types of drilling: (a) rotary type with a rotary bit for rock, hard material with a rotary bit which makes the initial hole, and (b) directional drilling where the initial hole is blasted (sheared) out by advancing high pressure water-bentonite jet.
4. The directional drilling is the most frequently used and it works with all kinds of soils. For toxic lagoon containment membranes, first, an access trench (pit) is built, then a receiving trench. The directional drill jetting starts at the access pit and ends in the receiving pit. The jet drill is directed electronically by x-y-z control. After the receiving pit is reached, the jet nozzle is pulled backwards to the access pit. During this time, the jet is set to produce a laminar membrane 4-6 inches thick and up to 20 feet wide (depends on soil and other factors). Each individual membrane strip is slightly tilted so that an impermeable joint is established with the next membrane strip application.

Sometimes a tractor is placed in the access trench with a rig to pull the drill jet backwards through the soil. The grout pressure during the pull-back is in the area of 5000 to 6000 psi. Jetting is done using special nozzles. In silty-sandy soils, each membrane strip width can go up to 20 feet. For tough soils the boring holes are closer and the membrane strip width is less.
5. Mr. Gemmi is the main inventor; no others at this level.
6. Mr. Bares got interested in bringing the process to the USA. He studied it in detail and thinks the process has a good future. He thinks that the US Army Corps of Engineers is going to use the

method extensively.

7. There are no other reference people in the USA. He says that we should talk to Gemmi who speaks English and is in his office between 6-8 pm (best time) which is 12-2 pm our time.

8. There is an Italian patent for the process. Ask Gemmi.

9. Bares will send us further information on Po River and Slesia projects and possibly some Corps of Engineers proposal literature.

NOTE:

Lunardi is a professor working also on various design projects in Italy. He may not speak English. Gemmi will give us a specific name for the Magistrato per Il Po.

Phone Interviewer: Tons
Date: 12/02/93

#9411
No. 2

Name: Walter J. Weber, Jr.
Title: Professor
Affiliation: Department of Civil and
Environmental Engineering
University of Michigan
Ann Arbor, MI 48109-2125

1. Professor Weber thinks that directional drilling is nothing new. He has not seen a method for construction of a membrane under a contaminated pool without disturbing it. There may be a problem with boulders and other obstacles. If such a membrane is constructed it has to be impermeable (no holes).
2. Professor Weber says that a membrane under a contaminated area or pool has a limited usefulness. Usually you do not want to keep that pool with an open surface. You want to eliminate it. Also, such membranes would probably not last a long time.
3. He sees the usefulness of this membrane where there is a spillage or where the contaminant can not be picked up immediately. In cases like that, a fast membrane application to serve for about a year before final remedial action is taken could be useful.
4. Professor Weber is organizing a demonstration workshop for gadgets like this at Wurtsmith Air Base in Michigan. He is thinking about inviting Bares to demonstrate his equipment.
5. Professor Weber also has a visitor coming next week from an Italian pollution agency. He will ask him some questions.

Phone Interviewer: Tons
Date: 12/07/93

#9411
No. 3

Name: Donald H. Gray
Title: Professor
Affiliation: Department of Civil and
Environmental Engineering
University of Michigan
Ann Arbor, MI 48109-2125

1. Professor Gray says that there are not enough documentations, references, supporting analyses, etc. to support claims and concept. Problems of hydraulic lifting at shallow injection depths, control of shape and direction of laminations, and elimination of "windows" or openings in the laminar diaphragms are not addressed. I wouldn't invest any money based on information and particulars submitted,

Phone Interviewer: Tons
Date: 12/09/93

#9411
No. 4

Name: ing. B. Gemmi
Title: Vice President
Affiliation: Fondazioni Speciali s.r.l.
Via Pozzuolo Del Friuli 1
Parma, Italy

1. Dr. Gemmi says that the main innovation is the speedy and economical construction of jet grout membranes. Some membrane jet grouting has probably been done before, but Gemmi has come up with a method which controls thickness and width and can lay continuous membranes. The first application of the idea was for river levee sealing. They also want to get into hazardous waste containment.
2. The first major application was for the Po River levees in Italy. The levees were constructed of quite uniform sandy soil and the width and thickness control of the membranes was not difficult. The result was a good seal against the waters of the Po River. They set up some piezometers and measured the water seepage for one and a half years. They concluded that the seal was very good.
3. The thickness of the membrane is usually 10-15 cm (4-6 inches) but at the far ends of the jets there is a tendency to spread out and one can get up to 20 cm or even more thickness.
4. The width of the one-pass membrane also varies according to soil and other conditions. Usually, each pass produces a two to three meter wide membrane. It is important to know or predict the minimum width that can be achieved for given soil conditions. Then, the spacing of the next drill hole is set based on this minimum spray width. In this way, no gaps between one pass and the next will be left and the membrane will be "continuous."
5. There are some instances where the membrane has been contaminated with the soil during the jetting operations. This results in local pockets of weakness as far as permeability is concerned. Gemmi does not think that this is important from a practical point of view.
6. In soils containing boulders and obstacles, some problems may develop. They do not have extensive knowledge as yet. Limited field observations show that the nozzle spray tends to go around boulders to a great extent.
7. The membrane should be at least 50-80 cm below the surface to avoid "hydraulic lifting."
8. The main inventors of this technique are: Bruno Gemmi, of Fondazioni Speciali, and Andrea Perelli, of Rodio Company. Dr.

Gemmi appears to be the leader and the spokesman.

9. There is an Italian patent for the process under the names of Gemmi and Perelli. (No. 21499 A/88)

10. Dr. Gemmi says we can call Professor Lunardi, but he does not speak English. The Po River magistrate is Mr. Sanguanini who speaks only Italian.

NOTE:

Dr. Gemmi's English was quite good, but there were times where I had to repeat my questions several times using different words and expressions to get the information.

Phone Interviewer: Tons
Date: 12/13/93

#9411
No. 5

Name: Dr. Thomas Iseley
Title: Professor
Affiliation: Department of Civil Engineering
P.O. Box 10348
Louisiana Tech University
Ruston, LA 71272-0046

1. Professor Iseley says that he does not know of any jet grouted membrane installations in the United States. He has heard about this process being applied in Europe (Italy), but he does not have any case studies or installation reports in his file.
2. Jet grouting, in general, has been used in a variety of applications for a long time. Another person we could try to contact is Dr. Joe Kauschinger with the firm of Law Engineering in Georgia. Telephone 404-499-6716. But as far as membrane applications are concerned, he may not know much. He has some experience with directional drilling and microtunneling.
3. Professor Iseley is an expert in microtunneling. For the case where a straight-line (no curves) tunnel is made, there is no problem with microtunneling. It can be guided by a laser beam, so installing of membranes in a levee should not be difficult. For curved membranes under a contaminated pond area, horizontal directional drilling methods must be used. It can be done, but the process is more complicated and the accuracy needs improvement. Professor Iseley is working on improvements in accuracy.

CONTACTS MADE

Contacts Made

Name: Mr. F. A. Bares
Title: Principal
Affiliation: UCI Consultants, Inc.
 68 Fletcher Street
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Name: Ing. B. Gemmi
Title: Vice President
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 Via Pozzuolo Del Friuli 1
 Parma, Italy

Name: Donald H. Gray
Title: Professor
Affiliation: Department of Civil and
 Environmental Engineering
 University of Michigan
 Ann Arbor, MI 48109-2125

Name: Dr. Thomas Iseley
Title: Professor
Affiliation: Department of Civil Engineering
 P.O. Box 10348
 Louisiana Tech University
 Ruston, LA 71272-0046

Name: Walter J. Weber, Jr.
Title: Professor
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PRIMARY EXHIBITS



Re: JET-GROUTING CONSTRUCTED LAMINAR DIAPHRAGMS FOR THE PROTECTION OF RIVER EMBANKMENTS

Let's first briefly introduce U.C.I. Consultants. We are a Construction consulting firm with offices in many States, staffed by engineers with extensive and diversified practical construction experience. To cover the many disciplines which make the construction industry so interesting, we rely on Associates. One of them is Fondazioni Speciali, an Italian firm which has developed, perfected and successfully implemented a process by which river levees are quickly strengthened by the use of jet-grouting at relatively low cost.

We assume you have some familiarity with the basics of jet-grouting, a ground modification process which transforms a soil into a stronger substance by replacing portions of it with adequate compounds, the most commonly used being grouts made of water and cement. As shown in one of the attached brochures, the process can be effectively used to construct thin, continuos, rectilinear, impervious diaphragms in the body of earthen structures.

The most visible and significant advantages of the system are:

1. The constitution of a continuos, impervious apron to help preventing the weakening of levees when extensively soaked by long lasting flood periods as it recently happened along the Mississippi and Missouri rivers.
2. The cutting-off and/or reduction of uplift pressures and of piping on the dry side of the levees.
3. Ease of construction with high flexibility and adaptability to differing geometry and soil conditions.
4. Quicker and cheaper construction than other similar, but not as effective structures. Note that construction is not affected by weather or season and that the relatively small equipment used, makes mobilization easy and fast.
5. The absence of potentially destabilizing excavations and cuts. Probably one of the most important features of using jet-grouting for the strengthening of levees, because it avoids and prevents the opening up or the starting of new piping channels both vertically as well as horizontally. Practically speaking, a jet-grouted

diaphragm, is the only structure that can be efficiently and quickly constructed within the body of a levee, without cutting or breaching it. In fact, jet-grouting would immediately strengthen and waterproof any earthen body exactly when needed, i.e. at flood stage, with river water levels at or less than 1 meter below the top of the levee.

6. ***The ability of heaving levees by using modified jet-grouting techniques.***
This feature, a by product of the technique, is a much more effective and faster device than sand bagging.

Basically, the construction sequences are the following:

A. Construction by sub horizontal jet-grouting of laminar diaphragms, two to three feet below existing ground level or deeper according to the nature of the soil, starting from (generally), the top of the levee and extending to well below the level of the existing water table. The laminar diaphragms are obtained by a gradual pull-out without rotation of the jetting tool, thereby cutting the soil along two flat planes. The jets are slightly angled in order to intersect the next wing and provide structural continuity. The process is repeated at predetermined intervals until necessary. From each jetting location, is possible to achieve the construction of laminar diaphragms with wings extending up to 3m (10ft) or more, on each side. The width of the wings is controlled by factors, like nature of the soil treated, skills of the operators, thickness of overburden, efficiency and power of equipment and more. The final result, as it is visible in the pictures, is a continuous laminar tile diaphragm with thickness varying from 100 to 150mm (4 to 6 inch).

B. Construction of another deep, vertical jet-grouted laminar diaphragm using the same procedure (rods withdrawn without rotation), from the tip of the inclined laminar diaphragm to a depth determined by hydrological design.

C. Construction of a short stretch of conventional jet-grouting to provide an anchoring capping beam for the lower diaphragm, a stabilizing footing for the upper one and an overlapping connection between the two.

Let's try and answer some of the most frequently asked questions on the system.

The most significant construction of Laminar Diaphragms was performed in 1988-89, along the levees of the Po river in Northern Italy, under contract with the Magistrato del Po, the Italian equivalent to the Army Corps of Engineers for the control of waterways.

The construction extended to over 2,100m of levees with a vertical design depth of 20m, (measured from the base of the levees) for an equivalent cost of \$1.6 mil. The trapezoidal shaped levees were 8-9m high, with an upper platform 6m wide and slopes varying

between 1/2.5 to 1/3. The levees were made of fine sand and silty sand, with permeability of the order of 10^{-2} to 10^{-3} . The thickness of the laminar diaphragm varied between 80 and 120mm. Jet-grouting was performed with a bentonite-cement mixture injected at 3m intervals to assure ample overlapping. All the work was performed on the river side of the levees in a period of low waters, using single pass injections with strict verticality and rod-torsion controls. A field test was performed prior to actual construction to ascertain thickness, continuity and lateral wing extension of jet-grouting at each jetting position. The test diaphragm was exposed and the results are shown in the enclosed brochure.

The diaphragm did not reach any impervious strata: none existed within reasonable depth. For practical reasons it terminated in deep, slightly denser layers of sand. The success of the construction was monitored by piezometer readings during subsequent flood periods and found to work well within expectations. No strengthened levee was lost nor impaired during floods.

The rate of construction achieved was an average of 6 vertical jet penetrations per day (10 hrs), 20m deep at 3m intervals per rig. Angled jetting and rotating jetting for the connection, progressed at 2/3 of the above rate. Presently, due to the development (since 1989) of larger pumping units capable of generating up to 800 hp, a productivity of 300m of completed jet-grouted diaphragm, using three rigs in series, is feasible. This would correspond to 300sqm of diaphragm completed per 10 hour shift. Obviously, this production would be increased by working multiple shifts.

The system is most suited to medium height levees (8-10m). However, theoretically, there are no depth limitations, except than economical. For angled jetting there are some limitations imposed by the work space necessary to accommodate rigs supported by wide-spaced stabilizing pads, working with 10 to 15m long booms at 45 degree angles.

The system is very suitable to work in emergency situations. First of all, jet-grouting is not affected by the presence and position of water table. It is easily installed at or below water table as well as under standing or flowing water. Second, by using the right type of grout, it is possible to install jet-grouting even in the presence of flowing water with velocity of up to 10^{-2} cm/sec. Faster flows have been successfully tackled by adding compounds to either speed up the set time or to increase the viscosity of the grout.

Many different construction designs have been devised to suite existing conditions. The one illustrated in the attached literature, would not necessarily be the chosen one if the situation would not grant it. Actual conditions would suggest or dictate the use of the most appropriate designs/solutions. Like, for instance in the case of the leaky levee successfully waterproofed by a combination of explosive charges and jet-grouting (please see the attached "Explosive Waterproofing of an Emergency River Embankment", a report presented in October 1992 at the annual meeting of the Deep Foundation Institute).

These laminar diaphragms can be constructed both when river water levels are low or at flood stages. While work is less expensive if done from the dry, it can be equally well performed from barges and other floating devices as it is commonly done, for instance, for the construction of underwater portions of marine and river jetties. Additionally, if and when necessary, jet-grouting can be successfully reinforced using different materials, including corrosion-immune, fiberglass rods.

In our belief, confirmed by experience, that the use of jet-grouting constructed laminar diaphragms constitutes a valid solution to some of the present and future levees' problems along the Mississippi and Missouri rivers, we trust we have supplied you with thought provoking information.

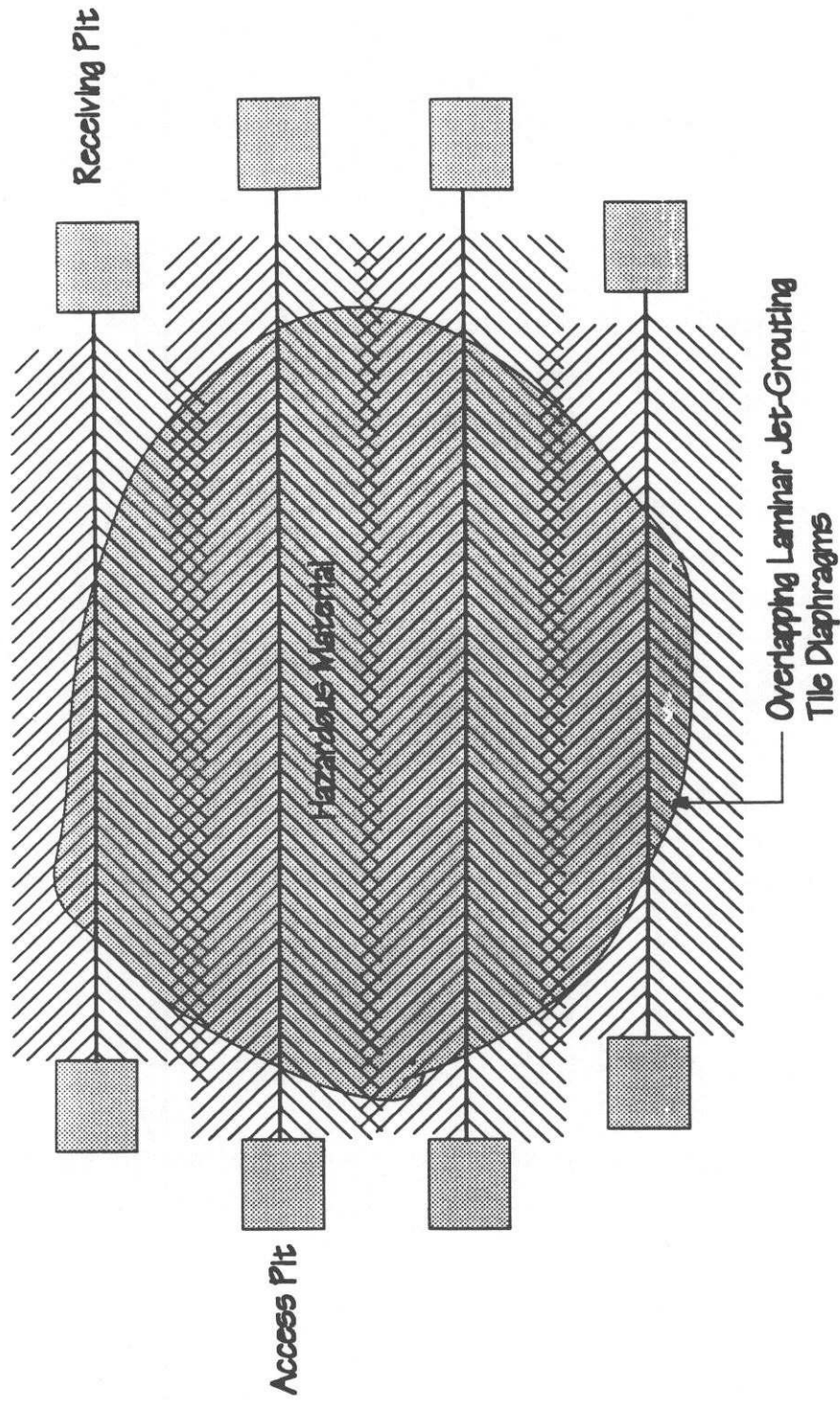
FONDAZIONI SPECIALI, is a world leader in the performance of jet-grouting: the attached illustrative material shows many other application of this versatile technique and many more are devised each year. Presently, for instance, thin laminar diaphragms are being used for the construction of containing structures around and under zones of contaminated soil. Sophisticated directional drilling techniques allow to place jet-grouted diaphragms under lagoons or under other contaminated soil masses. The same directional drilling may be used to construct continuous laminar tile diaphragms in "one pass" operations.

FONDAZIONI SPECIALI, is available through us, for consulting on the feasibility and cost of any type of jet-grouting, for the supplying of know-how, of specialized jet-grouting equipment, and for the monitoring of operations. Last but not least, they are available to perform field jet-grouting demonstration tests in your area.

Should your Department be interested in pursuing this matter further, we would be very glad to discuss with you the best form of supplying you with the necessary consulting support. We believe that initially, only people like us, possessing the intimate knowledge and practical know-how of the construction, design and use of laminar diaphragms and of jet-grouting in general, can effectively help an organization like yours to perform feasibility studies, design of solutions, cost estimates and the eventual writing of correct construction specifications including those for a "demonstration test", if required. To contain costs, the test, could be performed to benefit you and other States' Agencies willing to share the knowledge acquired from it. A field test would be highly recommendable to further study features, ways of implementation, feasibility and cost of the system and, above all, to obtain a factual assessment of the results achievable locally with it.

If we can be of any help with any additional information or explanations or if you would like to discuss the features of a project including jet-grouting, please do not hesitate in calling us. We are as far as your telephone. In any case, the undersigned will call you in the next few days to be sure that you have received this presentation.

Directional Jet-Grouting for the construction of laminar containment tile diaphragms



Plan View
Not To Scale



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BOSTON, MA 02108

SECONDARY EXHIBITS

Jet set style

There is a strong tradition of craft in all aspects of Italian life. Combined in the engineering world with flair for innovation and a tendering system that permits the use of alternative designs, this may explain why an empirical technique like jet grouting has achieved fairly wide acceptance.

It is also a peculiarity of the Italian market that small companies can develop products to an exceptional level. One such company that has taken this route is Fondazioni Speciali which was set up in 1987 as a contractor specialising in geomechanical and hydrogeological engineering.

In addition to some sophisticated work, the company has also actively pursued and developed its own technologies, most notably in jet grouting. Manufacturing is by an associate company Elletari Geotecnica, which designs and manufactures drilling and 'consolidation' equipment for the construction market.

Jet grouting is essentially a ground improvement technique that increases both the consolidation and cementation of the host material. The basis of the system is that high pressure grout is injected through a rotating drilling rod, forming mixed soil and grout columns as the rod is withdrawn from a drilled pilot hole.

There are two major variations on this system. The Japanese developed the triple jet system during the early 1980s.

This uses an air shrouded high pressure water jet to erode a cylinder of soil, while simultaneously grout is pumped through a separate aperture, set about 300mm below the jetting nozzle, to form a grout/soil column.

Italians were quick to adopt the method, but soon found a major limitation for what is probably their most widespread application – pretreatment of tunnel crowns in advance of excavation. Stress relief and loosening of the ground can occur because a void is created before the grout is injected.

To overcome this the Italians removed the water erosion jet and relied upon direct displacement injection. In the one fluid version only grout is injected and for the two fluid variation grout is shrouded in an air stream which concentrates the jet's force.

The three jet type will produce a 'cleaner' column, with more soil replacement by grout, so that what is left more or less approximates to an unreinforced concrete pile. In the Italian system the resulting columns have higher soil contamination and hence a lower material strength. But there is less de-stressing around the column, the friction between the column and the soil is higher and there is greater consolidation in the surrounding soil.

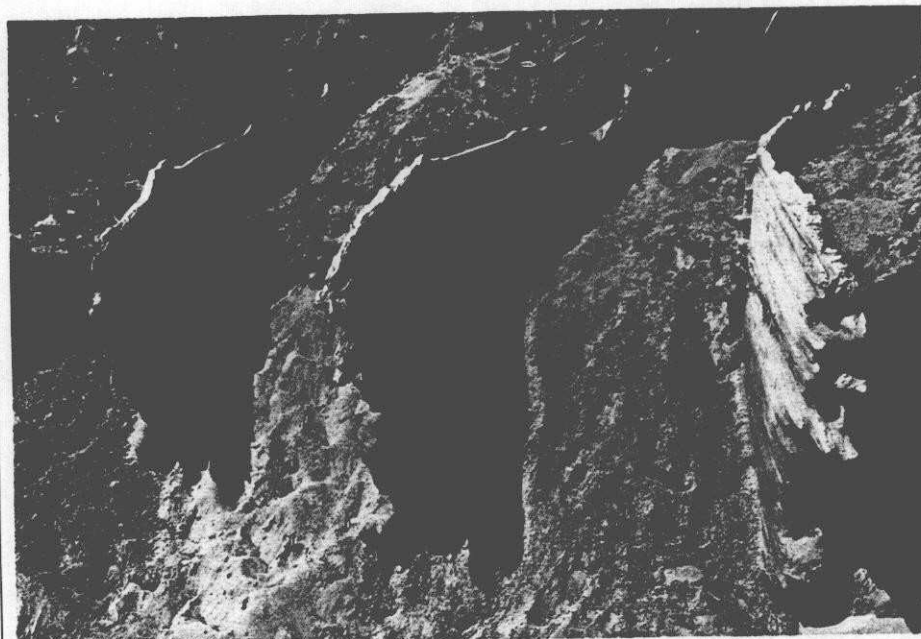
Fondazioni Speciali co-founder Bruno Gemmi has sought ways of extending the application of jet grouting and has

identified the need to increase production as one of the primary requirements.

The company has experimented with different nozzle configurations and grouting pressures at its test field near to Parma. It has even devised and patented a new installation technique – reverse injection.

'The Italian one and two fluid systems rely on displacement rather than cutting' explains Gemmi. 'One way of getting a more effective impact is to introduce sand into the grout mixture.' That requires bigger nozzles and more robust rods as more abrasion occurs, but the real limiting factor is the pump capacity. Typically pumps of around 300kW are used which, operating through two 3mm diameter nozzles, typically provide a maximum capacity of 200 litres/min at 50 000kN/m². Increase the size of the nozzle and more energy is required to maintain the pressure.

Gemmi looked for high performance pumps but not within the civil engineering market. Instead he went to Halliburton, of Dallas, which has a strong reputation in the oil industry sector. As it happens Gemmi's enquiry coincided with



The diaphragms have been used to seal a 3km section of the River Po.



Trial jet grouted diaphragms: a system for stabilising river banks.

Halliburton's search for new markets during the downturn in the petroleum sector. Gemmi has since struck a deal giving Fondazioni Speciali exclusive use of Halliburton's pumps for civil engineering applications in Italy.

The pumps have eight times the power of conventional units. For jet grouting purposes a single 2000kW pump can maintain a pressure of 50 000kN/m² through two 8mm diameter nozzles injecting up to 1500 litres of grout/min. 'The pumps are very expensive, but the productivity justifies the cost' says Gemmi.

It is now possible to jet grout in clay, and to add reinforcing fibres to the mixture. Use of the Halliburton pumps also led to the evolution of the reverse grouting process in which the grouting is carried out as the rod is 'drilled' into the ground – conventionally grouting is undertaken as the jetting rod is withdrawn so installation is a two stage operation as the circulation system has to be changed over from drilling flush to grout mix.

In Gemmi's reverse grouting technique the nozzles are inclined downwards so that the jet has both horizontal and

vertical components. Provided the soil conditions are suitable it is possible to form the grout column directly using the vertical component of the high energy jet to displace the soil at the nose of the rod.

High energy techniques used with the one fluid system increase the maximum column diameter from 0.6m to 1.5m in optimum conditions, while with the two fluid system, grout columns up to 7m in diameter can be achieved.

The decision to undertake reverse or conventional grouting is taken on site following trial columns. As a rule of thumb, says Gemmi, there is a good chance the reverse technique will be appropriate if SPT values are less than 10. In marginal conditions a hydraulic hammer can be used to help the driving.

In addition to the development of high pressure grouting Fondazioni Speciali has also been experimenting with different nozzle configurations to get the best results for different ground conditions.

The findings indicate that a five nozzle jet (two inclined, two horizontal and one vertical) gives the most consistent results and increases production by three or four times when used in conjunction with

reverse jetting. A spiral configuration made up of nine nozzles produces a column with enormous skin friction, and, says Gemmi, very little soil contamination even when using the one fluid system.

Another application of the jet grouting process developed and patented by Fondazioni Speciali, this time in conjunction with Rodio, is thin jet-grouted diaphragms. These have been used to stabilise and seal a 3km section of the River Po by forming interlocking baffles and sheets. The inclined diaphragms are formed by a conventional jet grouting rig – but not rotating the jetting rod as it is withdrawn. Although the resulting diaphragms have a thickness between 100mm and 250mm their role is purely hydrological.

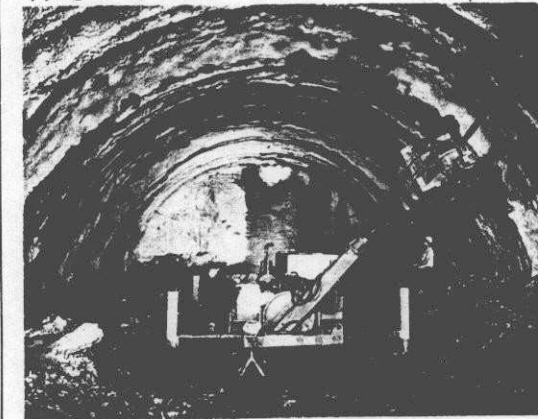
Gemmi believes there may be a number of spin-off applications for the diaphragm. Using chemical additives, for instance, makes highly impermeable barriers possible, which could be used to seal below a disused landfill, provided of course the integrity can be ensured.

This inability to quantify what has been achieved is probably the greatest obstacle to widening acceptance of jet grouting applications. 'Potential clients are reluctant to accept an empirical method where the best results are obtained by trial and error' says Gemmi.

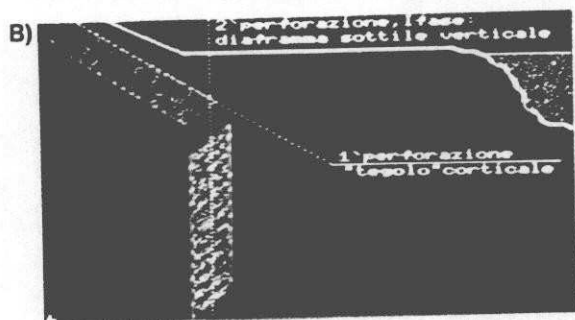
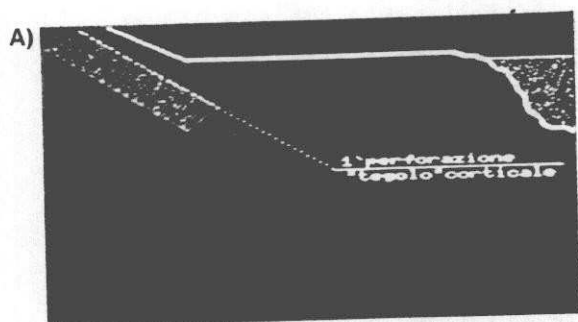
For tunnel applications and retaining walls the benefits are very clear, but suggest the method as an alternative for traditional foundations and it is very difficult to get engineers interested.

Nethertheless the company has recently undertaken a programme of pile-style static load tests on individual columns and armed with the results Gemmi believes he will get his message across.

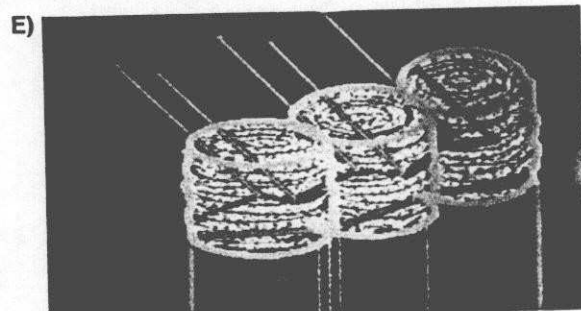
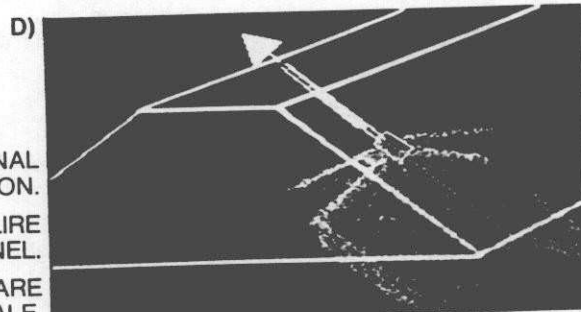
Tunnelling is one of the most common applications of jet grouting in Italy.



A), B), C), PHASES OF WORKS ON RIVER BANKS.
A), B), C), PHASES DE TRAVAIL SUR LA BERGE D'UN FLEUVE.
A), B), C), FASI DI LAVORO SULLA SPONDA DI UN FIUME.

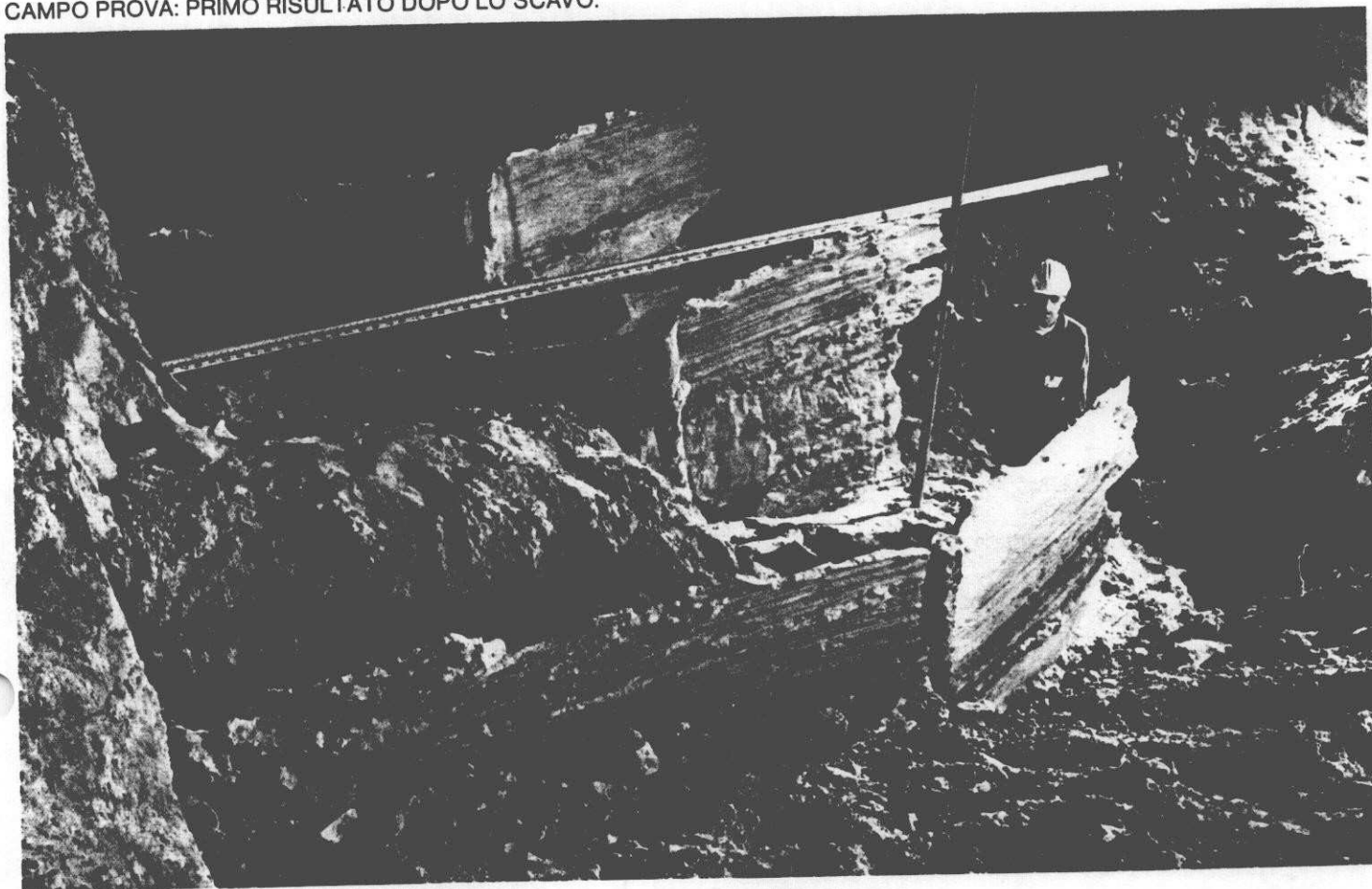


D) MONODIRECTIONAL
ANGULAR INJECTION.
D) INJECTION ANGULAIRE
MONODIRECTIONNEL.
D) INIEZIONE ANGOLARE
MONODIREZIONALE.



E) SKETCH OF FINAL RESULT.
E) CROQUIS DU RESULTAT FINAL.
E) SCHIZZO DEL RISULTATO FINALE.

TEST FIELD: EXCAVATION FIRST RESULTS.
PLOT D'ESSAI: PREMIER RESULTAT APRES L'EXCAVATION.
CAMPO PROVA: PRIMO RISULTATO DOPO LO SCAVO.

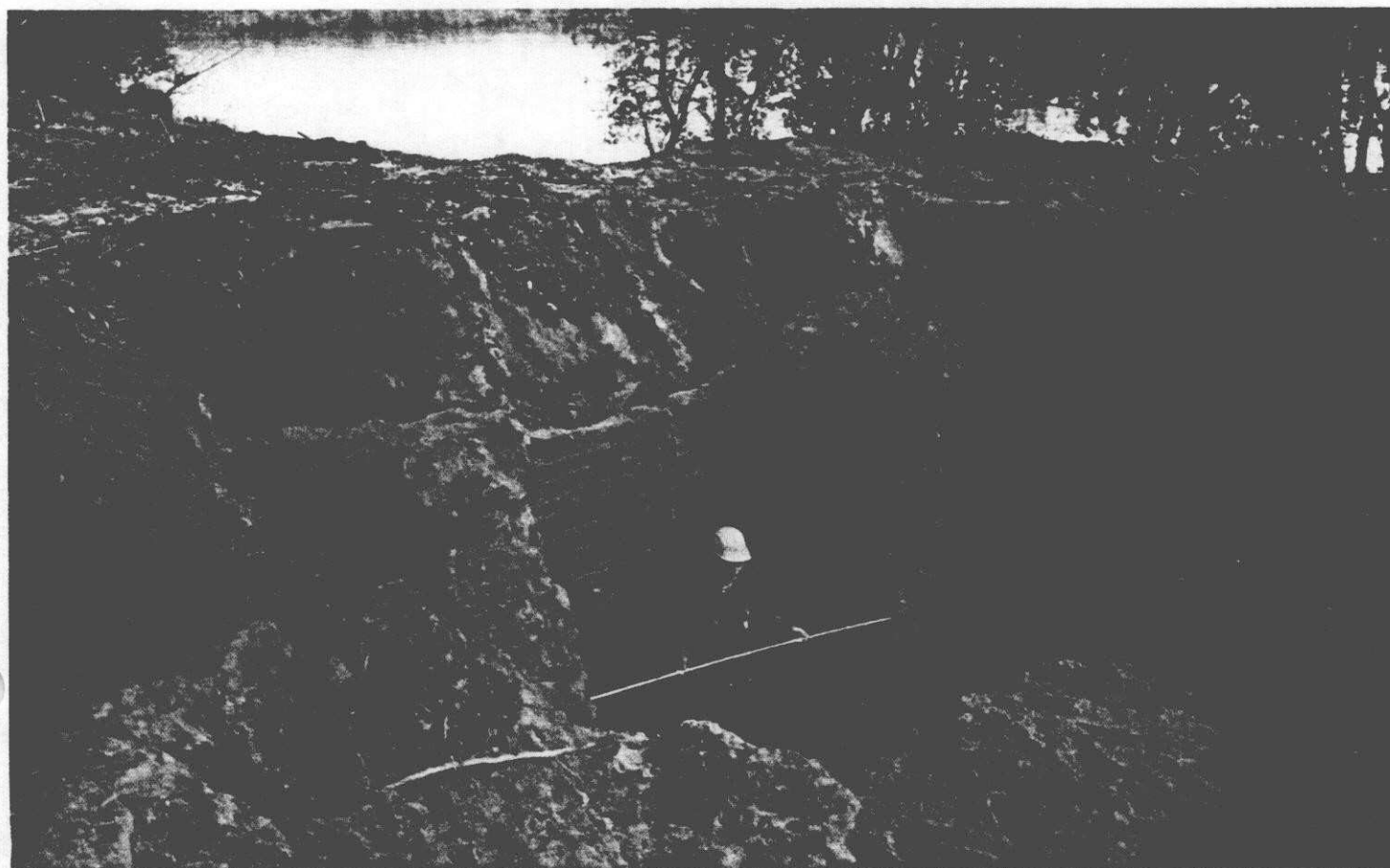




JET-GROUTED BAFFLE
AND COLUMN COPENETRATION.

COMPOSITION DE LA COMPENETRATION
DU JET-GROUTING SOIT
COLUMNNAIRE ET LAMELLAIRE.

COMPOSIZIONE DI GEOMETRIE
COLONNARI E LAMELLARI
IN JET-GROUTING.



HIGH ENERGY AND SAND-SLURRY
JET-GROUTING DEVICES.

DETAIL POUR L'EXECUTION DU
JET-GROUTING A ENERGIE ELEVE
ET AVEC L'UTILISATION DU MORTIER.

DISPOSITIVI PER JET-GROUTING
AD ALTA ENERGIA E CON IMPIEGO DI MALTE.

