Instrumentation

John Dunnicliff

Introduction

This is the fourth episode of GIN. There's not much here this time, partly because of my other commitments, and partly because my attempts to twist your arms for contributions have not been very successful. The following article by Hashash et al. is another one about electrolevels, and you'll find more in this column on that subject. This isn't by design - just that this appears to be **the** hot subject at the moment.

Letters to Editor

Somebody has asked - if I want to express an opinion on the "to name or not to name?" question, as a letter to the editor, will this be accepted? John Gadsby (Publisher) and Lynn Pugh (Managing Editor) both give an emphatic **yes,** to letters on any subject. Write it, and you will see.

More on Load Cells

Two previous issues of GIN included information on load cell calibrations, addressing in particular the measurement errors caused by a mis-match of diameters between the load cell and hydraulic jack *(Geotechnical News, September 1994, pages 65, 66 and March 1995 page 35)*. When thinking about the subject I'd forgotten about the **other** face of the load cell, which may be in contact with a surface that also creates measurement errors. Remember to address bearing surface issues at both faces!

More on Electrolevels

The Hong Kong Institute of Engineers hosted a geotechnical seminar on May 10, 1995. Four papers that describe experience with electrolevels were presented, by Chris Spalton (Soil Instruments Ltd, England, fax +44-1825-761740), Rob Weeks and Cyril Chan (Geotechnical Instruments Ltd, England and Hong Kong, Weeks' fax +44-1926-338110), Chris Rasmussen, Elton Wong and Ray Wood (Slope Indicator Co, USA; Fugro Geotechnical Services, Hong Kong, Rasmussen's fax +1-206-547-4818) and Richard Bassett (Department of Civil Engineering, University College London, Gower Street, London WC2E 6BT, England).

At the time of writing this column (April), I have only one of the papers - by Chris Spalton. This paper addresses some realistic practical issues and, in my view, deserves some publicity. The title is: "*Electrolevels. A Practical Solution or Numeric Nightmare*?"

The stated aim of the paper is to highlight the factors that affect the performance of electrolevels, and to discuss their suitability for use in a civil engineering environment. The contents include operating principle, calibration, temperature effects, long-term stability, and guidelines on acceptable environments for good performance. The paper concludes:

The concern expressed by engineers in the industry with regard to the suitability of these sensors for use in a civil engineering environment is either rooted in practical experience or misgivings based on some, or all, of the above points.

Understandably, if engineers have been given conflicting information about the performance and limitations of the sensors, they will be wary of including them in their specifications. Equally, if they have been impressed by an Original Equipment Manufacturer's (OEM's) promotional information and have specified them for installation on a site where, for one reason or another, the instruments produce unreliable data, they will be reluctant to specify them again.

Claims made by manufacturers about the performance of instruments based on the electrolevel sensor have surrounded them with too many myths and too much secrecy. In future manufacturers should provide full technical backup for their claims and engineers proposing to specify these instruments should be asking the following questions:

- *Are the sensors individually calibrated for rotation and temperature effects over their working range?*
- *How many points have been used to produce the calibration reference matrices?*
- *Will a copy of the individual calibration matrices be available to the engineer?*
- *What tests have been carried out to determine the long term stability of the sensors and their associated electronics?*
- *Will full technical support be available from the OEMs, or their agents, to assist with the proposal of locations, choice of suitable instruments and preparation of the specification?*

In summary, if engineers in the civil engineering industry are to be convinced that these sensors are "A Practical Solution" to monitoring problems, the equipment manufacturers must be prepared to have their calibration procedures scrutinized.

A Practical Solution? Potentially.

A Numeric Nightmare? Not necessarily!

This, of course, is the view of one manufacturer only. I expect there will be follow-ups in this column. If you want to read the papers, I suggest you contact the authors for copies.

Interfels News

Interfels GmbH, Bad Bentheim, Germany, have a very informative magazine "Interfels News," published about twice each year. Recent issues have included technical material describing hydraulic pressure and load cells, instrumentation for monitoring performance of tunnels, inclinometers, the borehole slotter stressmeter, the "Increx" probe extensometer, and borehole probes for in situ testing. To receive copies, contact

Interfels at P.O. Box 1265, D-48443 Bad Bentheim, Germany, Tel. +49-5922-98-98-0, fax +49-5922-98-98-98.

Courses

A reminder: the 2-day course in Vancouver will be on September 23 and 24, 1995, immediately preceding the 48th Canadian Geotechnical Society Annual Meeting and Conference. See Geotechnical News, March 1995, page 59 for an outline, and call or fax Sandi or Lynn at BiTech for more details. A flyer with a full course description and schedule is now available from BiTech Publishers.

The 3-day course in Florida will be on November 6-8, 1995. Call or fax me for a full description and schedule.

Both courses include half-hour technical presentations by manufacturers (5 in Vancouver, 7 in Florida). All previous courses with which I've been involved have emphasized the users' views and, because I believe that "we're all in this together", I wanted to provide a better forum for manufacturers at these courses. This not only provides greater diversity in the material, but also encourages manufacturers to bring their instruments and set up demonstration tables - a very significant plus. Some of my user colleagues are concerned that this gives the courses too much of a "commercial" flavor - I'll get a consensus after we've tried it twice.

Reprints of GIN

BiTech has prepared an 8-page reprint, containing GIN-1, 2 and 3, for handing out during FMGM 95 in Italy. I have a stock of extra copies. If you want some to give to others in your office, please let me know.

It isn't Easy being an Editor

How many of you searched for "page ??" (Geotechnical News, March 1995, page 35)? The preliminary details of the course were on page 59 in that issue. If you found it, you really wanted to find it, didn't you?

How many of you found the humor on lines 13 and 14, on page 14 of the same issue?

Closure

As said before, please send me discussions, new material, whatever you think may be useful, to 16 Whitridge Road, South Natick, MA 01760, Tel. (508) 655-1775, fax (508) 655-1840. Prosit!

BART Tunnel Monitoring During MUNI Tunnel Construction

Youssef M.A. Hashash, Birger Schmidt and Lee W. Abramson

Project Description

The Bay Area Rapid Transit (BART) system is a commuter rail system that is used daily by thousands of riders to commute from the East Bay to downtown San Francisco. Along Market street the San Francisco Municipal MUNI Metro (light rail) twin tunnels run parallel and above the BART twin tunnels. The two systems were completed in the early 1970's.

As part of the plan to expand the capacity of the MUNI system, the MUNI Metro Turnback project is currently under construction in downtown San Francisco, Figure 1. The project entails extending the MUNI subway rail line at Embarcadero Station to an at-grade rail on 'The Embarcadero'. The new tunnels run parallel and above BART tunnels for about 500 ft with a vertical separation distance ranging between 4 and 17 feet, Figure 1.

Ground Conditions and Construction Constraints

Site geology consists of miscellaneous fill over dune sand underlain by soft Bay Mud. The BART and MUNI tunnels intersect over 500 abandoned wooden piles that were part of foundations of old buildings and wharves. Some of these piles were encountered during previous BART tunnel construction and were cut just above the BART tunnel crown.

Given the proximity of the proposed MUNI tunnels to the existing BART tunnels and the soft ground conditions, measures were adopted to maintain continuous BART operations during MUNI tunnel construction.

The BART tunnels in this area provide the only access to the immersed tube tunnel that crosses the bay to Oakland. Tunnel excavation for the MUNI tunnel had the following constraints:

1. Maintain the integrity of BART tunnels underneath.
2. Limit deformations of BART tunnels to maintain continuous train operations and minimize distress to BART tunnel lining.
3. Limit surface settlements to avoid damage to surface streets and utilities

Excavation of the MUNI tunnels was conducted under compressed air to maintain face stability. The soils over the BART tunnels were pregrouted to improve response to MUNI tunnel excavation. Hand mining methods in conjunction with careful cutting of wood piles were adopted to minimize soil disturbance. An instrumentation program was implemented to verify the adequacy of the mining techniques and monitor deformations in and around BART tunnels.

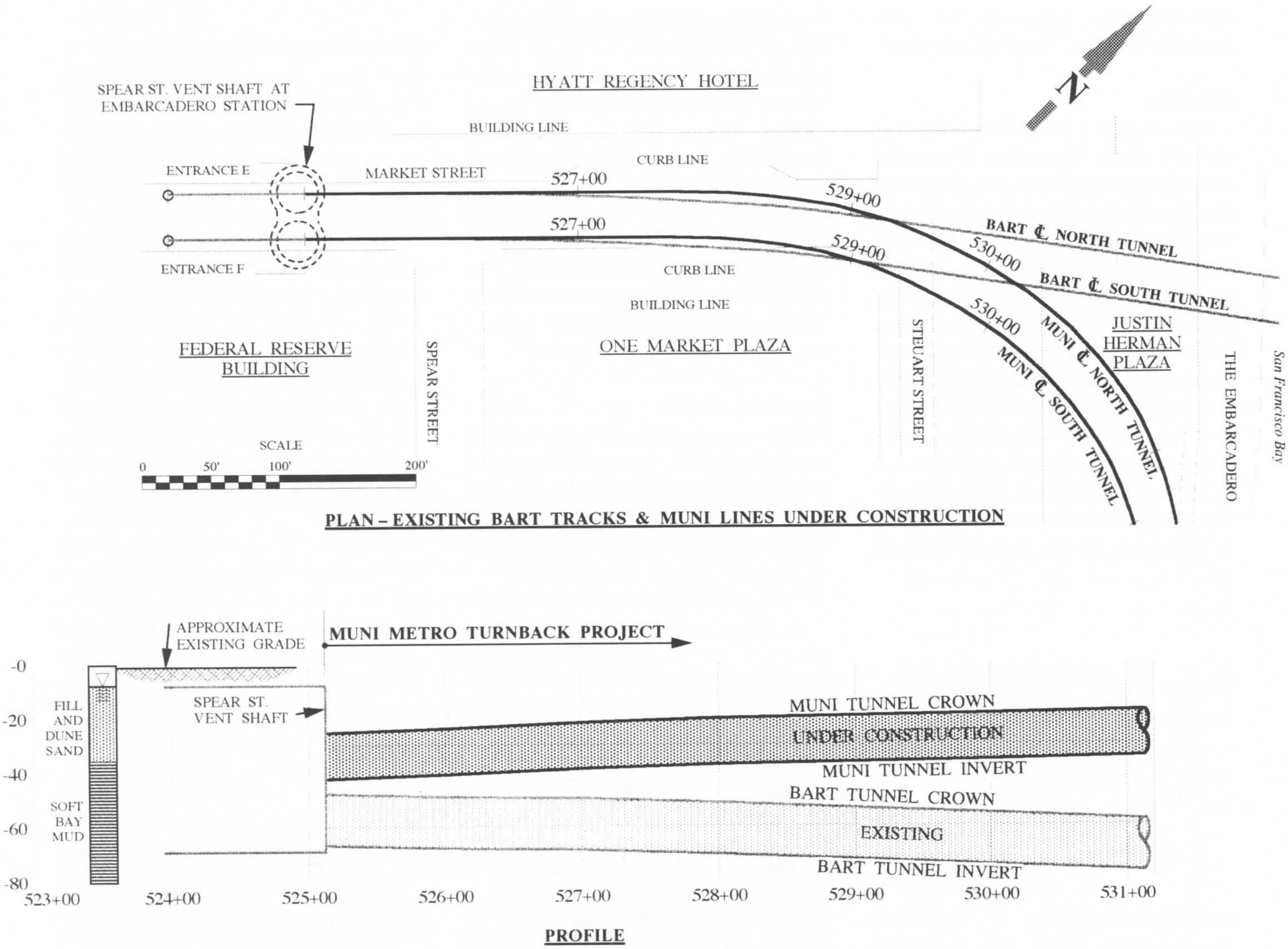


Figure 1 Plan and Section View of the Project

Instrumentation for BART Tunnels

During construction of the MUNI North tunnel the following monitoring program for BART tunnels was followed:

1. Nightly surveys of tunnel invert and crown elevations at 25 ft intervals in both tunnels.
2. Nightly springline convergence measurements using a tape extensometer in both tunnels.
3. Nightly measurement of rail track offset in both tunnels.
4. Continuous, 24-hr monitoring of tunnel vertical displacement using an electrolevel settlement monitoring (EL-Beam) system. The system was used in the BART North tunnel directly underneath the MUNI North tunnel under construction only.

Access to BART tunnels was limited to a four hour period in the early morning when the system was not in operation. A remote monitoring system, such as the EL-beam system, was needed to monitor deformation when the BART system was in operation. All measurements were performed within segments of the BART tunnels 50 ft ahead and 200 ft behind the heading of the MUNI tunnel above.

Description of the Electrolevel Settlement Monitoring (EL-Beam) System

The El-Beam sensor is a rigid metal beam fitted with an electrolytic tilt sensor. The 5 ft beams used on the project were mounted on brackets firmly attached to flanges in BART steel liner, Figure 2. A total of 48 beams (240 ft) were used in three clusters of 16 beams connected to multiplexer units for electronic readout of data. The readout units were connected to a data logger that was read via a laptop computer on site or remotely via a modem. The clusters were leapfrogged one at a time as the MUNI tunnel heading advanced above the BART tunnel. The EL-Beam system used was manufactured by the Slope Indicator Company, Seattle, Washington.

Originally a water level system was chosen to monitor the tunnel. However, it was replaced by the El-Beam system because:

1. The water level system was deemed to be complex requiring elaborate water pipe connections. The system would have interfered with emergency walkways in the BART tunnel and required extensive maintenance.
2. The passage of trains through the tunnels would result in rapid changes in air pressure due to piston effects of a train going through a tunnel. There was concern that changes in air pressure would adversely affect the water level system.
3. The EL-Beam system would be easily leapfrogged forward as the tunnel heading above progresses. A water level system would be very cumbersome to move.

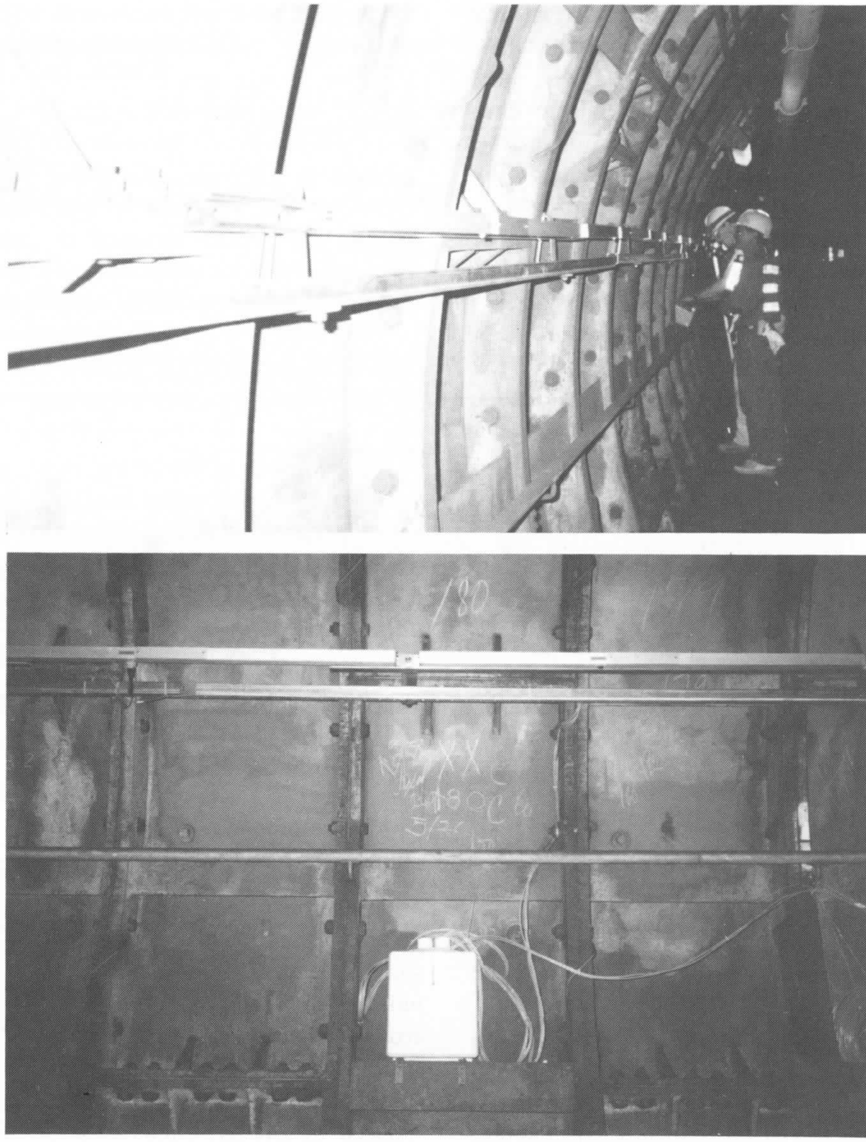


Figure 2 Installed EL-Beams in BART North Tunnel

Verification of EL-Beam System

The EL-Beam system was installed several months ahead of the scheduled tunneling to verify system operation. Several issues had to be addressed :

1. Effect of power lines and electric fields on the performance of the system. The BART tunnels contain a 1,000 volts third rail in addition to electric conduits for light fixtures and sump pumps. There was no detectable interference with the system operation. During tunneling some noise was detected in the system. However, it only occurred over a short period of time. Noise problems were reduced by adjusting the data collection algorithm and the method for reporting and averaging data.
2. The reliability of remote data transmission via modem over a phone line was important to allow access to the system remotely at any time of the day.
3. The software package allowed for data collection at the data logger, data processing and plotting, and activation of an automatic alarm system at the instrumentation engineer's office. The system was designed such that the data logger was accessed remotely every half hour via a computer in the instrumentation engineer's office. The total displacements are then automatically calculated and checked to see if they exceeded a predetermined threshold value. If the threshold value was exceeded, an alarm/ beeper was automatically activated to notify the instrumentation engineer on duty. The system was setup such that any of the parties involved in the monitoring could access the data from their desktop or laptop computers in their office or home 24 hours a day.

Small movements were recorded by the EL-Beam system prior to tunneling. This movement was confirmed by survey and tape extensometer measurements of tunnel deformations. The tunnels were undergoing continuous movement. Several suggestions were made as to the source of this movement including temperature changes related to ventilation fan operations and tidal movement. However, a definite cause of these movements has yet to be determined.

These deformations were on the order of 0.05 inches, less than movements anticipated from tunneling. The EL-Beam system recorded the movement of the BART North tunnel during an offshore earthquake along the northern California coast.

Practical problems encountered during monitoring included accidental power supply interruption. The system had a battery backup and was read manually on site until power was restored.

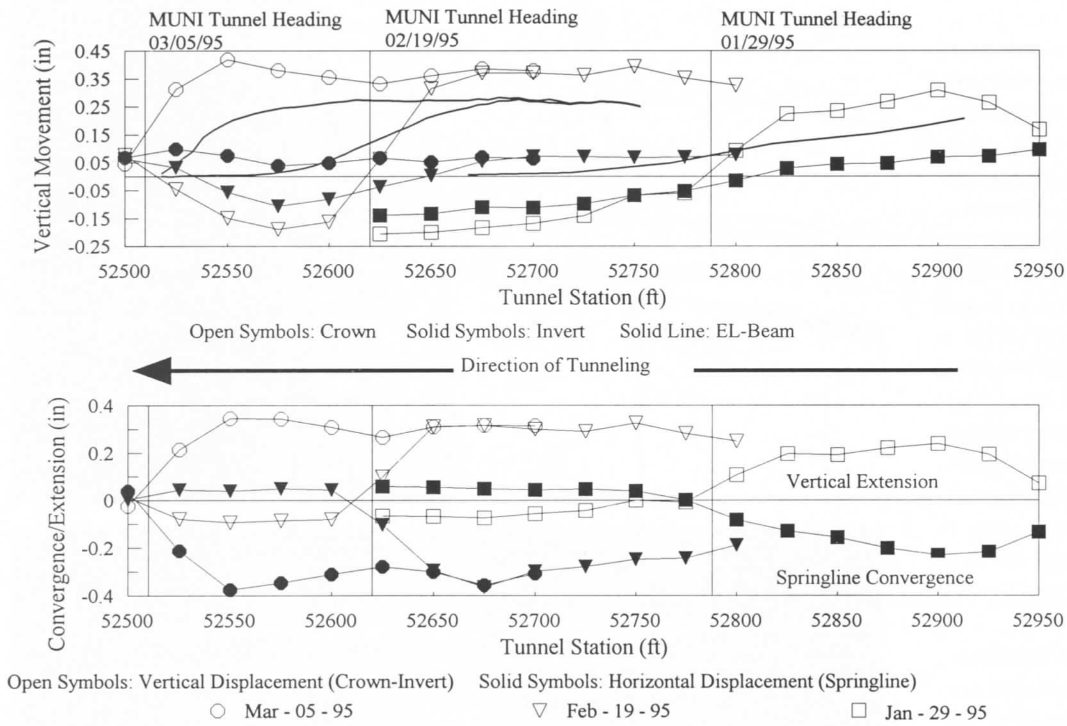


Figure 3 BART North Tunnel Deformations due to MUNI North Tunnel Excavation

Monitoring During Tunnel Excavation

As the MUNI North tunnel excavation progressed towards BART tunnels the monitoring plan was put into action. Periodic inspection of BART tunnels was conducted to detect any distress in the liner and liner joints. Observed distress was correlated with measured tunnel deformations. Data collection was handled by different groups, but transmitted on a daily basis to the instrumentation engineer's office who issued daily reports on tunnel movements.

Figure 3 is a plot of tunnel deformations when the MUNI North tunnel heading was at stations 527+88, 526+20 and 525+10 corresponding to the following dates 01/29/95, 02/19/95 and 03/05/95 respectively. These are deformations in the BART North tunnel due to MUNI North tunnel excavation. The plots include tunnel invert and crown vertical deformations which were measured by conventional survey methods and vertical displacement at the springline measured using the EL-Beam system.

The trend and magnitude of tunnel displacements at the springline obtained using the EL-Beam system were similar to the crown and invert movement data obtained from independent surveys. The vertical displacement magnitudes at the spring line were in between the magnitudes of vertical displacements at the crown and invert. This is expected given the ovalling deformation of the BART tunnel due to overburden stress relief induced by MUNI Tunnel excavation above. The EL-Beams were also surveyed at selected time intervals and movements of the EL-Beams were within 0.02-0.05 inches of the electronic readouts obtained from the system. Tape extensometer data showed that the spring line convergence was almost equal to crown-invert extension survey data, confirming the ovalling deformation of the tunnel. The convergence/extension measurements in the tunnel did not exceed 0.37 inches. Net maximum vertical movements were 0.41 inches in the crown, 0.27 inches at the spring line, and 0.07 inches in the invert. From a train operation point of view the most critical deformation was that of the invert, which showed minimal heave.

Discussion and Conclusion

The monitoring program for the BART tunnels during MUNI tunnels construction called for a system for monitoring deformation continuously. The use of the EL-Beam system in the tunnel satisfied that objective. Measurements from the EL-Beam system were confirmed by independent surveys. Some problems were encountered in the system, especially signal noise over limited duration. Such problems could be avoided in the future by taking extra measures to isolate the system electrically. This must be evaluated project by project and can be anticipated by installing the system for a period of time prior to construction. The system did not eliminate the need for physical access to the tunnels but helped to minimize it. Periodic inspection of the BART tunnel liner, which showed very limited water and compressed air leakage into the tunnel, was still needed. Overall, the use of the EL-Beam system proved to be successful.

Acknowledgments

Parsons Brinckerhoff Quade & Douglas, Inc., San Francisco, CA provided technical support to BART during project design and construction. Bechtel provided engineering and construction management service to the project owner, the City of San Francisco. Dames & Moore was responsible for monitoring the EL-Beam system and other project instrumentation. Towill, Inc provided surveying services to the EM and CM. Tudor-Saliba-Perini, J.V. was the construction contractor for the project.

Youssef M.A. Hashash, Birger Schmidt and Lee W. Abramson, Parsons Brinckerhoff Quade & Douglas, Inc., San Francisco, California, USA

Dear Colleague:

I am writing this letter to inform you of some important developments which have taken place over the past few months in the organization of rock mechanics and rock engineering activities in our country.

At the 1994 symposium (the First North American Rock Mechanics Symposium, or NARMS) held in Austin, Texas, a group of your colleagues in rock mechanics and engineering began a discussion about the future for organized activities in the U.S. We realized that we had never had a national membership-based organization devoted to the promotion of our profession.

We also realized that scientists and engineers who deal with rock materials are already members of a wide variety of existing organizations, and that any new organization would need a clear and justifiable statement of purpose which would serve the needs of the U.S. community in a way existing organizations did not.

We believe we have identified a unique sense of purpose for our new organization, and we are pleased to announce the formation of a new membership organization for rock mechanics and engineering in the United States: The American Rock Mechanics Association (ARMA).

The American Rock Mechanics Association (ARMA)

ARMA will be entirely separate from the U.S. National Committee for Rock Mechanics (USNC/RM), a standing committee within the National Academy of Sciences. which is the current parent organization for ISRM membership in the U.S. The purpose of ARMA is established as:

- to promote the development of rock mechanics and rock engineering in the U. S.;
- to act as an advocate for organizations and individuals who practice rock mechanics and rock engineering;
- to provide communications links and educational services among members and other related organizations;
- to be a repository for information on the development and use of rock mechanics and rock engineering;
- to improve the states of the art and practice and to disseminate knowledge through symposia, publications, and other means;
- to work with other professional societies and organizations which have rock mechanics interests; and
- to promote international cooperation in the development of rock mechanics and rock engineering technology, and encourage involvement of U.S. scientists and engineers in ISRM activities.

Among the services ARMA will provide are:

- Co-sponsorship of annual symposia
- Development of electronic communications - the RockNet Home Page
- Organization of specialty conferences and workshops
- Participation in ARMA committees and working groups.

The ARMA Board of Directors has prepared a constitution and by-laws, and ARMA (and its counterpart charitable organization, the ARMA Foundation) has been incorporated. The officers and first Board of Directors have been elected in January, 1995. I have been elected as Vice President, and am currently serving as President until Charles Fairhurst completes his term as President of ISRM. The current board will serve during the start-up period of the association, and new board members will gradually be rotated in through elections in accordance with the constitution and by-laws of the association. With this letter, I formally invite you to become a member of the American Rock Mechanics Association. ARMA will work closely with the USNC/RM and with related societies to place U. S. rock mechanics and engineering at the forefront of science and technology. But most of all, we want to work closely with you. There is much to be done in launching a new organization, and we welcome your participation. We believe that ARMA, as a membership organization, can serve your needs as a professional in rock mechanics and engineering.

We are now open for membership, and have established a variety of member classifications which we believe will service all levels of contributions. We also encourage direct contributions to support the start-up costs for the organization, and which will be treatable as business expenses. In addition to becoming an ARMA Member, please consider becoming, an ARMA Founder. Founder contributions, which have been in the range of $250 to $5,000, should be made to the ARMA Foundation, and are tax-deductible. We expect the list of ARMA Founders to grow quite large during the year that the Founders program will operate, and we would certainly like to see your name on this list when it is closed on June 1, 1996. Please give serious consideration to participating in the American Rock Mechanics Association. Together we can build an association that will serve your needs and the needs of our profession.

ARMA membership forms can be obtained from Peter Smeallie, Executive Director, American Rock Mechanics Association, 600 Woodland Terrace, Alexandria, VA 22302 Tel: (703)683-1808 Fax:(703)683-1815 email: psmeallie@tmn.com

FHWA Sponsored Deep Foundation Draws International Full House

On December 5-8, 1994 approximately 500 deep foundation designers, constructors, and suppliers to the industry gathered in Orlando, Florida for a state-of-the-art, state-of-the-practice conference. The FHWA provided the major impetus for the meeting which attracted speakers and attendees from around the globe.

Today, federal and state government are faced with the daunting task of refurbishing and expanding the nation's highway system. The underlying purpose of the Conference was to bring together leading experts in the field so that the nation's practitioners throughout the transportation industry could become aware of the most advanced thinking in deep foundation design, construction, and testing.

The technical program featured eleven Keynote presentations as well as over 30 breakout sessions that spanned an extremely wide range of topics. Design methods, construction parameters, quality control and quality assurance, and nondestructive testing techniques were covered in detail.

The Conference planning process began in 1992 under the guidance of FHWA's geotechnical engineering group led by Conference Chairman, Jerry DiMaggio. Department representatives John Hooks, Al DiMillio and Chien-Tan Chang shared the leadership role. A Steering Committee representing industry, the academic community, and state departments of transportation was organized to help develop the conference program which focused on the following topics:

- Numerical Techniques
- Physical Modeling
- Integrity and Capacity Testing of Load Bearing Elements
- New and Innovative Drilled and Driven Piles Types
- Load Transfer Behavior (Single Elements & Groups)
- Deep Foundation Experiences State of Practice
- Specifications and Contracting Documents

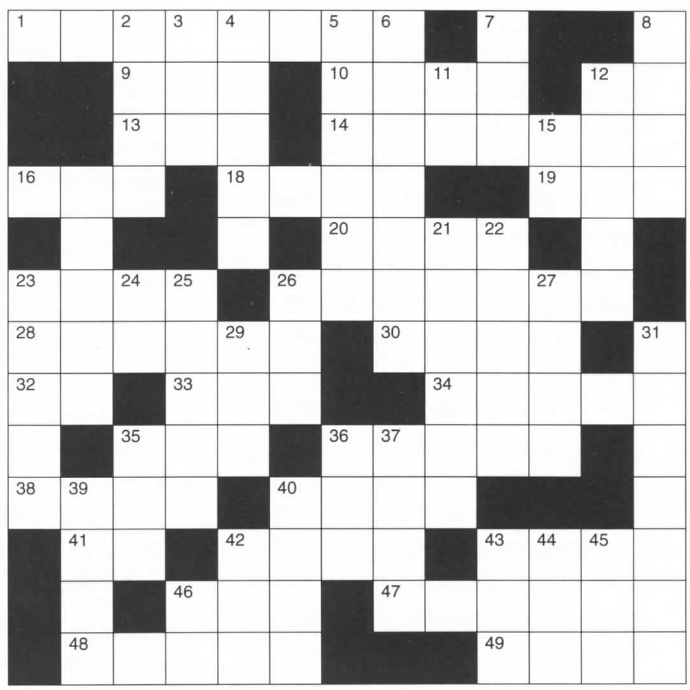
Geochallenge

ACROSS

1. earth building (8)
9. Boston great (3)
10. cropping soil (4)
12. fros' colleague (2)
13. technically renowned place (3)
14. any engineer who makes wild predictions is one (7)
16. land of the brave (3)
18. Stratford cheer (4)
19. friend from Laval (3)
20. drink to excess (4)
23. digital measurement of nanosecond? (4)
26. one can do this with students, but not samples (7)
28. modest strains might lure answers (6)
30. liver fluid (4)
32. Bob Mitchell's other job, abbr. (2)
33. plow into with force (3)
34. conveys the unwanted (5(
35. tiny killer (3)
36. usually deep, steep and coastal (5)
38. law (4)
40. common to bank and shark (4)
41. Urban map abbr. (2)
42. stability aid, sometimes (4)
43. NGI home (4)
46. hip comprehension (3)
47. taxonomy is one, as is the unified (6)
48. stems they're not (4)
49. oversatisfy (4)

DOWN

2. living death (4)
3. cycle or axial are followers (3)
4. -gonal or -clase prefix (5)
5. common mineral (6)
6. not Rankine (7)
7. US assoc'n. (3)
8. defined mathematical pathways (4)
11. one specific (2)
12. unbrave (5)
15. colloquial gratitude or cheap labour ini. (2)
17. spiritual gang (5)
21. health hazard (6)
22. column-ist? (5)
23. auger result or political ploy (5)
24. pub, en anglais (2)
25. prize, or lip configuration (5)
26. radials' mount (3)
27. sadly, some student publications are this (4)
29. luxury's sitdown offer (3)
31. bureaucratic regulations can be this (7)
35. Ht. (3)
36. pro (3)
37. even logs create these (4)
39. employer, or a sort (4)
40. supporting elements (4)
42. computer unit (3)
43. bone related (3)
44. ground location abbr. (3)
45. perform (2)
46.



This puzzle was submitted by Cam Mirza. Solution can be found on page 68