FINAL REPORT

Report of the
AMERICAN PUBLIC TRANSPORTATION ASSOCIATION

PEER REVIEW PANEL

For

LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY

Los Angeles, CA

November 2005

A Service of the Safety Management Program of the
American Public Transportation Association

PEER REVIEW PANEL REPORT

On The

WILSHIRE CORRIDOR TUNNELING PROJECT

For

LOS ANGELES COUNTY MTA

PANEL MEMBERS:

John T. Christian
Jeffery C. Hewitt
Fred N. Kissell
Henry M. Nutbrown
Raymond E. Sandiford

APTA Panel Staff Advisors:
Greg Hull
Martin Schroeder

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William W. Millar, President

Peer Review Panel Report
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1 INTRODUCTION

Mr. Roger Snoble, Chief Executive Officer, Los Angeles County Metropolitan Transportation Authority (Metro), contacted the American Public Transportation Association (APTA) on behalf of the agency, Board Chairman, Mayor Antonio Villaraigosa, and the Los Angeles MTA Board to request a peer review of the agency's proposed Wilshire Corridor tunnel construction project. Los Angeles County MTA felt it would be prudent and beneficial to use the APTA peer review process to assist the organization in addressing the safety of tunneling construction and operations along Wilshire Corridor. Coordination and implementation of this review also included input and support from Congressman Henry A. Waxman (D-California).

The APTA peer review process is well established as a valuable resource to the public transportation industry for assessing all aspects of transit operations and functions. The peer reviews are conducted on-site by highly experienced transit personnel and technical professionals who are selected on the basis of their subject matter expertise. The review process included on-site interviews of agency staff, review and analysis of relevant documents, and field inspections. Following the on-site activities, the panel further reviewed its own preliminary findings and observations for accuracy and supplementary input.

The overall task objective of the peer review panel was to conduct an independent evaluation and then report on gas related safety issues associated with the proposed extension of the Metro Red Line subway along Wilshire Boulevard. The intent of the peer review panel report is to provide a conclusion as to whether tunnel and station construction and operation along Wilshire Boulevard could be implemented in a safe manner with the application of available construction and gas mitigation technologies.

During the period October 24-27, 2005, a panel of industry peers with expertise in tunnel construction and related safety concerns assembled in Los Angeles. The panel members are listed below (qualification briefs for panel members are contained in Appendix E).

John T. Christian
Prototype Engineering, Inc.
Waban, MA

Fred Kissell
Fred Kissell Mine Safety Consulting
Glenshaw, PA

Jeffery C. Hewitt
Senior Vice President, Engineering
Richmond Airport Vancouver Rapid Transit Project
Vancouver, BC, Canada

Henry M. Nutbrown
Assistant General Manager, Engineering & Construction
Port Authority of Allegheny County
Pittsburgh, PA

Raymond E. Sandiford
Chief Geotechnical Engineer
Port Authority of New York & New Jersey
Newark, NJ

Panel facilitation and support was provided by APTA Staff Advisors Greg Hull and Martin Schroeder. Mr. Rick Thorpe, Chief Capital Management Officer, provided liaison support for Los Angeles County MTA.

2 FOCUS AND SCOPE OF THE PEER REVIEW

Objectives & Statement of Work

The scope of the APTA peer review panel was specified in an agreed upon statement of work as provided in Appendix A. One of the primary tasks of the APTA peer review panel was to examine the current conditions with regard to gas exposure and risk in the Wilshire Corridor and to develop an understanding of past studies related to the *Ross Dress for Less* explosion and subsequent studies. The panel was also requested to assess the specific risks associated with tunneling, and to recommend a course of action that addressed the following elements of tunnel construction and operation.

- Gas detection
- Mitigation of hazards
- Tunnel boring and station construction
- Safe operation
- Long-term monitoring and verification
- Technical feasibility

In addition to the formal statement of work, and as a means to best facilitate action on key questions facing Los Angeles MTA, the panel requested Los Angeles MTA provide an articulated set of questions in the context of the statement of work that needed answers. The questions provided were:

1. Is it safe to tunnel along the Wilshire Corridor?
2. Is it safe to construct cut and cover stations along Wilshire?
3. Is it safe to operate the system along Wilshire?

The panel began with these questions in mind as they first sought to understand what had changed since the time of the Ross Dress-for-Less explosion in 1985. This understanding would provide the proper context on which to assess current safety issues.

3 GENERAL CONCLUSIONS OF THE PANEL

The panel shared a unanimous perspective that it is, indeed, possible to both safely tunnel and safely operate a subway along the Wilshire Boulevard corridor using current tunneling, station construction and operation technologies. The panel also unanimously agreed that by following proper procedures and using appropriate technologies, the risk would be no greater than other subway systems in the United States.

The panel concurred as well that in 1985 the decision to hold further tunneling in abeyance was prudent, given the circumstances and extent of information and technology available at that time. Much has changed since then to significantly improve tunneling and operation safety. Since 1985 technology has improved, as has the experience of the City of Los Angeles from tunneling for large sewers on efforts such as the North East Interceptor Sewer (NEIS) and the East Central Interceptor Sewer (ECIS) projects. These projects used similar tunnel construction techniques to those recommended for the Wilshire Corridor.

The findings and recommendations provided throughout this report are presented as an independent perspective to assist the decision-making process with respect to subway tunneling and operations along Wilshire Boulevard.

4 DETAILED CONCLUSIONS OF THE PANEL

4.1 Observations about Conditions since 1985

Presentations made by tunneling and geology technologists during the panel review meeting, coupled with extensive reports of regional tunneling experience made available by Los Angeles MTA, provided insight into the evolution of conditions along Wilshire. Further insight was added from panel knowledge of tunneling projects similar to the proposed project. In this context, the panel provided the following observations regarding the period since 1985.

- Improvement in attitude with regard to safety
- Gas measurement instrumentation has improved
- Tunnel boring machine technologies have advanced and demonstrated a good safety record over the last twenty-year period
- Gained extensive construction and operational experience in tunneling
- No problems with deep basements along Wilshire
- Growth in knowledge about geology and methods to mitigate safety concerns in California and elsewhere

Improvement in Attitude with Regard to Safety

In the twenty years since 1985 there has been continuing improvement of safety in the construction industry. The industry has benefited from value added by creating a safety culture and by striving towards zero accident incidents. Today, safety receives priority attention throughout the process of design, construction, and operation of a transit system.

The "Ross Dress for Less" incident has served as a constant reminder of the need to be duly diligent. Also, since 1985 the Federal Transit Administration (FTA) safety requirements for any capital project have significantly increased and now require a rigorous safety certification review. Additionally, Los Angeles MTA's own safety record has improved over time; and, even as it relates to workplace (including construction) safety, Los Angeles MTA has been applying Dupont Safety Program practices.

Instrumentation has Improved

The instrumentation used to detect methane has been much improved in recent years. Portable instruments now come equipped with audible alarms and digital memories that record peak excursions of methane, so higher-than-normal methane levels are less likely to be overlooked.

Current Tunnel Boring Machine (TBM) Technologies Have a Good Safety Record

Up until the 1985 time frame, soft ground / soft rock tunnels were typically constructed with open face shield tunneling machines. These machines exposed tunnel workers to the soil during construction, which could increase the safety risk where methane or hydrogen sulfide gases are present in sufficient concentrations. Further, control of the tunnel drilling face relied upon the skill of the miners to apply temporary support using timber or mechanical face boards, adding an additional level of risk.

To improve tunnel boring safety, experimental work that began in the late 1970s has led to the development of tunnel boring machines using a closed-face tunnel shield. These boring machines support the tunnel face at the point of contact with the soil, thus reducing surface settlement caused by earth slides in the tunnel. During the 1980s, two distinct types of closed face tunnel boring machines were developed to handle specific soft ground/soft rock conditions. To deal with saturated homogenous non-silty ground the Slurry Shield Tunnel Boring Machine (STBM) was developed whereby bentonite slurry (similar to drilling mud) both supports the tunnel face hydraulically and acts as the transport medium for the excavated spoil. The STBM is a closed system whereby the extracted media is contained in a sealed transport tube routed fully outside the tunnel. Tunnel earth is also not exposed to workers in the tunnel, thereby reducing the risk associated with hazardous gases.

The Earth Pressure Balance Tunnel Boring Machine (EPB TBM), which is a variation of the Slurry Tunnel Boring Machine, is best equipped to deal with saturated homogenous soft clay,

silty sands, and soft rock. The Earth Pressure Balance Tunnel Boring Machine was developed whereby the control (throttling) of the release of the excavated material from the cutter head, combined with shoving the machine forward, applies a net positive pressure to support the face, again unlike open faced machines. The EPB machine, however, is not a totally closed system. Excavated soil material is transported to the surface using open conveyor systems.

The slurry shield tunneling machine (STBM) is best suited to reduce the inflow of gas and water into a tunnel and can be used along the Wilshire corridor, given the types of soils encountered. Also, these machines can operate at more shallow soil depths without causing ground surface settlements. This is an advantage along the Wilshire Corridor where the preferred alignment is shallow in order to minimize exposure to gas. Appendix B provides additional discussion on the mechanics and technology of STBM and the tunnel lining methods normally used in conjunction with these machines.

Much more construction and operational experience in tunneling

The tunneling industry has had to face the challenges of constructing tunnels in more adverse conditions and to higher standards as the appetite for better urban infrastructure has increased. Since 1985, Los Angeles MTA has funded several studies that examined how to safely deal with both methane and hydrogen sulfide gases in the LA basin. The results of these studies are applicable to tunneling in the Wilshire corridor. The panel also noted that over twenty years of other tunneling experience in southern California has added extensive knowledge about the regional geology and methods to mitigate safety concerns.

No problems with deep basements along Wilshire

There has been an absence of methane problems in post-1985 deep basement construction of buildings fronting Wilshire Boulevard.

4.2 Tunnel / Station Construction & Operation Findings

The panel was charged with determining if it was safe to construct and operate transit tunnels along the Wilshire Corridor. In addressing the question of tunneling safety, the panel agreed on the findings that follow. The panel also provided recommendations, should tunneling be undertaken along the Wilshire Corridor.

Both Methane and Hydrogen Sulfide Gases are Present in Soils along Wilshire Corridor

Closed-Face Slurry Machines Improve Safety over Open-Faced Systems and Earth Pressure Balance Machines

Closed face slurry tunnel boring machines improve safety by minimizing leakage of gases into a tunnel, thus minimizing a worker's contact with the material excavated from the boring face. Details explaining the technology of the closed-face TBM and the associated use of tunnel wall liners are provided in Appendix B.

Successful Experience with Large Diameter Sewer Tunnels in Gas Affected Ground

Recent local experience in Los Angeles has seen the successful safe construction of large diameter sewer tunnels in gassy ground. Gas monitoring and ventilation systems have been applied to manage the presence of gas in a safe manner.

Up-to-Date Information on Gases is Now Available

Los Angeles MTA has provided up-to-date information on gases from bore-hole data along Wilshire. There is a wide array of boreholes in the Wilshire area that are monitored to detect the presence of methane and hydrogen sulfide; and the information available to the designers is continuing to be updated , an increase in knowledge over that available in 1985.

On October 19 and 20 of 2005 methane and hydrogen sulfide were measured in the monitoring wells along Wilshire Boulevard. In this limited investigation, hydrogen sulfide was found in only two wells, giving relatively low concentrations for an unventilated space of 157 ppm and 10 ppm. The methane measurements also gave low values for the most part. Most of the wells had a low concentration and/or low pressure.

LA Tunneling Design Practice After 1985

The design and construction of the Metro Red Line Subway followed the recommendations of the 1985 Los Angeles City Methane Gas Task Force. This resulted in a unique combination of features and activities, including complete encasement of all underground structures in 100-mil thick high-density polyethylene membrane (HDPE) tunnel liners and a sophisticated gas sniffing and ventilation system with signals monitored and controlled by the Rail Operations Center.

Deep Basement Construction

In recent years, deep basement construction, some exceeding 50 feet in depth and some built in tar-sands, have been constructed safely along Wilshire without incident. Tar-sands often contain high concentrations of methane and hydrogen sulfide gases. New construction in the Corridor follows recommended construction practices including the use of shielding material (such as RCPE - reinforced chlorinated Polyethylene) between earthen soils and building structure.[1]

Station Location Siting Can Mitigate Risk

Stations along the Wilshire alignment can be sited to minimize intrusion into the San Pedro soil layer, thus reducing associated problems of exposure to gases. The San Pedro formation contains more methane than the alluvial deposits and the Lakewood formation above it.

[1] Task Force Report on the March 24, 1985 Methane Gas Explosion and Fire in Fairfax Area, City of Los Angeles, Tom Bradley, Mayor, June 10, 1985.

Station Construction

Cut and cover construction has improved over the last 20 years. Experience from numerous urban projects has improved the industry's understanding of deep excavation construction. These improvements include better design and predictive tools, more robust retaining wall and bracing systems, and higher quality construction.

Tunnel and Station Ventilation Capabilities

The tunnel and station ventilation systems can be designed to clear expected levels of gases.

New Double-Gasket Tunnel Liner Design

During the course of presentations given by tunneling technologists and Los Angeles MTA during the peer review meeting, it was learned that a new tunnel liner gasket was being developed with the aim of creating an improved seal to better resist leakage caused by seismic events (Figure 1). This is a new design and extensive field experience has not yet been developed.

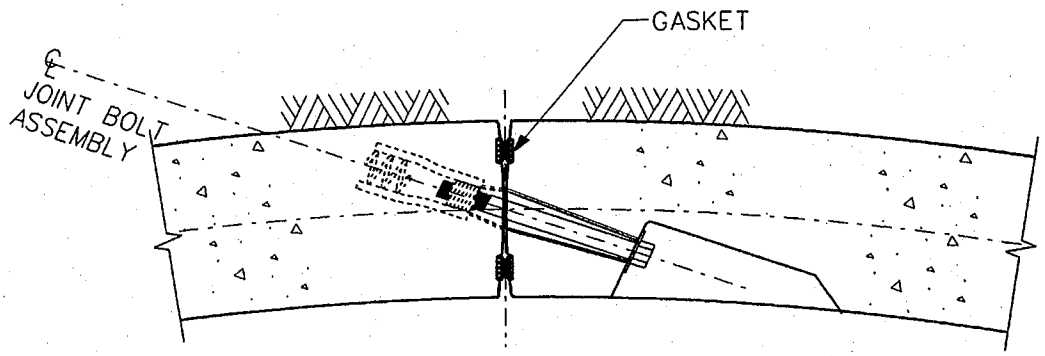

Figure 1 Double Gasket Liner

Panel Points to Two Case Studies for Review

The panel pointed to two case studies on abandoned tunneling efforts resulting from excessive water inflow problems and hydrogen sulfide gas. The Detroit River Outfall project saw problems with large water inflow laden with hydrogen sulfide gas. A report on this project by Traylor, et al, published by the 2003 Rapid Excavation and Tunneling Conference, details the experience of tunneling through high levels of water and hydrogen sulfide gas. The Spanish Fork Canyon water project in Utah is another useful example regarding lessons learned when encountering saturated hydrogen sulfide gas.

4.3 Tunnel / Station Construction & Operation Recommendations

Tunnel Liner Gasket Design

Although a new double-gasket tunnel liner design shown in Figure 1 has been developed with the aim of creating an improved seal during seismic incidents, the panel recommends staying with a single gasket liner followed by the installation of a high density polyethylene (HDPE) continuously welded membrane and secondary concrete lining (2 pass system) - a proven technology. This system has been used worldwide to create impermeable tunnel linings dating back from the late 1980s. Slurry Tunnel Boring Machines use a pre-cast concrete segmented bolted liner relying upon a single compressed gasket and grouting to make the liner impermeable. Also, the double-gasket liner used as a single pass system does not provide the redundancy necessary to keep out ground gases.

Tunnel Alignment & Station Location

Alignment should be as high as possible in the earthen strata, minimizing construction in the San Pedro formation as much as possible, particularly in the unsaturated portion. The unsaturated portion has hydrogen sulfide in gaseous form, which increases the risk for tunnel exposure.

Locate stations to minimize exposure to tar-sands and highest gas concentrations.

Locate Abandoned Wells

Be diligent in locating abandoned wells and develop procedures for responding, should they be found.

Be Aware of Lessons Learned

Periodically review other tunneling projects to make use of lessons learned. Pay particular attention to the two experiences noted.

Use a trial pit constructed in tar sand areas to measure earth and gas pressures

Program Management

Budget adequately for instrumentation, monitoring, and training; perform periodic, independent safety reviews at least every five years.

5 GENERAL RECOMMENDATIONS

- ***Hydrogen sulfide is greater risk than methane***

  Considering both safety and community impact, the overall risk associated with hydrogen sulfide is probably greater than the methane risk. So decisions regarding tunnel alignment and station location should primarily consider hydrogen sulfide. Hydrogen sulfide is a greater risk because the mining industry has less experience in dealing with it and because it causes problems at much lower concentration levels.

- ***Implement redundancy principles in safety design***

  Redundancy principles must be implemented in designing for methane and hydrogen sulfide mitigation. Redundancy provides one or more "back up" safety systems necessary, should a primary safety system fail.

- ***Ensure that an owner controlled quality assurance program is implemented***
- ***Stick to proven technologies***

Together with these general recommendations, the panel emphasizes the importance of overseeing designers and contractors as well as monitoring tunnels after construction. An independent review reporting directly to MTA is recommended.

6 SECONDARY ISSUES

- The construction of cross-passageways will increase exposure to gassy ground and will require special treatment.
- Ancillary rooms off tunnels or in stations should be designed for air monitoring and be well ventilated.
- Technologies for methane degasification and hydrogen sulfide in-ground remediation for both saturated and unsaturated zones should be investigated. Implementation of these technologies will require long lead-time because of environmental reviews.
- The panel also recommends that procedures be developed for possible membrane repair should seismic incidents or fires occur.

7 ACKNOWLEDGEMENTS

The peer review panel extends its sincere appreciation to all Los Angeles MTA personnel, technical staff, and their consultant presenters for their professional and full cooperation throughout the review. During all meetings, discussions and site tours, the collective staff provided the panel with comprehensive information that greatly assisted the review process. The panel members stand available should any additional information or clarifications be required.

APPENDIX A - Statement of Work

APTA PEER REVIEW
TUNNELING IN GAS IMPACTED SOIL

Los Angeles County Metro
October 17, 2005 (Revised)

Statement of Work
Panel Meeting October 24 – 27, 2005

In 1986, a Congressional ban was imposed on federal funding for Los Angeles MTA tunnel construction along Wilshire Boulevard, following a 1985 methane gas explosion and fire at the Ross Dress-for-Less store east of Fairfax Boulevard and Wilshire. The ban was imposed at the behest of Rep. Henry Waxman who raised concerns about the safety of tunneling through the old oil fields in the area. Prior to any further subway tunneling, removal of the moratorium would be necessary. An independent review panel has been suggested as a means of further evaluating the safety of such future tunneling options.

The overall task objective of the panel is to conduct an independent evaluation and report on gas related safety issues associated with the proposed extension of the Red Line Subway along Wilshire Boulevard, taking into account currently available technologies. The evaluation should include both tunnel and station construction methods and the long- term performance of these structures.

The panel report, in addition to summarizing the findings from the panel's evaluations, should provide a conclusion as to whether tunnel and station construction and operation along Wilshire Boulevard can be implemented in a safe manner in view of available construction and gas mitigation technologies.

APPENDIX B - Panel Meeting Agenda

AGENDA
Tunneling in Gas Impacted Soil

Sunday, October 23, 2005	
6:30 p.m.	Peer Review Team Members Get acquainted w/Staff
Monday, October 24, 2005	
8:00 a.m. – 8:30 a.m.	Continental Breakfast
8:30 a.m. – 10:00 a.m.	Metro overview of Red Line Wilshire Subway Project
10:00 a.m. – 10: 15 a.m.	Break
10:15 a.m. – 12:00 p.m.	History leading up to Congressional ban on using federal funds for tunneling in gas impacted soils
12:00 p.m. – 1:00 p.m.	Lunch
1:00 p.m. – 5:00 p.m.	Tour of Wilshire Corridor and current Red Line Subway Line and Stations
6:30 p.m.	Dinner – Panel and Metro/City Staff
Tuesday, October 25, 2005	
8:00 a.m. – 8:30 a.m.	Continental Breakfast
8:30 a.m. – 10:00 a.m.	Review of geology and extent of gas along Wilshire Boulevard
10:00 a.m. – 10:15 a.m.	Break
10:15 a.m. – 12:00 p.m.	Review of City of Los Angeles tunneling experience with gas impacted soils
12:00 p.m. – 1:00 p.m.	Lunch
1:00 p.m. – 3:00 p.m.	Panel evaluation and discussion on possible tunneling methods in gas impacted soils
3:00 p.m. – 3:15 p.m.	Break
3:15 p.m. – 5:00 p.m.	Panel evaluation and discussion of disposal options for soil excavation that may contain gas
6:30 p.m.	Dinner – Panel and Metro/City Staff
Wednesday, October 26, 2005	
8:00 a.m. – 8:30 a.m.	Continental Breakfast
8:30 a.m. – 10:00 a.m.	Panel evaluation and discussion on open excavation for Stations in gas impacted soil
10:00 a.m. – 10:15 a.m.	Break
10:15 a.m. – 12:00 p.m.	Panel evaluation and discussion on long term safety implications of subway operation in gas impacted soils
12:00 p.m. – 1:00 p.m.	Lunch
1:00 p.m. – 3:00 p.m.	Compilation of findings and recommendations
3:00 p.m. – 3:15 p.m.	Break
3:15 p.m. – 5:00 p.m.	Preparations for exit conference
6:30 p.m.	Dinner – Panel and Metro/City Staff
Thursday, October 27, 2005	
8:00 a.m. – 9:00 a.m.	Breakfast
9:00 a.m. – 12:00 p.m.	Peer Review Exit Conference
12:00 p.m. – 1:00 p.m.	Lunch
1:00 p.m. – 5:00 p.m.	Peer Review Panel departures

APPENDIX C - Slurry Shield Tunnel Boring Machine

Tunneling with a Slurry Shield Tunnel Boring Machine (STBM)

Slurry shield tunneling technology has been in use for over 20 years. In that period it has proven to be a reliable tunneling method. Slurry shield TBMs (STBM) are primarily used in saturated granular soils, but they also provide a means for constructing tunnels without exposing workers to the excavated soils and groundwater. This is accomplished by having the rotary cutter head of the STBM sealed from the remaining sections of the STBM. As the cutter head of the STBM rotates and advances forward, the soils encountered are put into suspension with bentonite clay slurry. This slurry mixture is then pumped from the sealed cutter area, through a closed piping system, to the surface where it is discharged into a sedimentation system. There the soil is removed by screens and centrifuges and the "cleaned" slurry recycled for continued STBM use. Figure C-1 shows a schematic diagram of the slurry and earth pressure balance machine cutting heads. Figure C-2 shows the routing of material from the slurry machine to the ground surface.

Another feature of slurry shield TBMs is that they provide a positive means of limiting surface settlements. Regulating the slurry pressure at the face of the STBM controls surface settlement. By matching, or in some instances slightly exceeding, the in-situ soil and groundwater pressure the soil surrounding the STBM can be prevented from moving towards the STBM and causing surface settlement. Additional surface settlement control is achieved by grouting the small void that occurs between the shield and the initial liner.

Along the Wilshire Boulevard, the final tunnel construction would be a three-layer system, consisting of an initial tunnel lining, an inert membrane liner, and a final cast-in-place tunnel lining. The initial lining would consist of pre-cast concrete liner segments, shown in Figure C-3 installed behind the cutter head, but within the TBM shield area. These liner segments would be precision cast to ensure proper mating and fitted with synthetic gaskets for water tightness. The installation in a tunnel showing the clamped joints is depicted in Figure C-4. The membrane liner would be fitted inside the initial liner and would be a continuously welded layer of High Density Polyethylene (HDPE) material. The final lining would be a layer of reinforced, cast-in-place concrete. These layers are shown in Figure C-5.

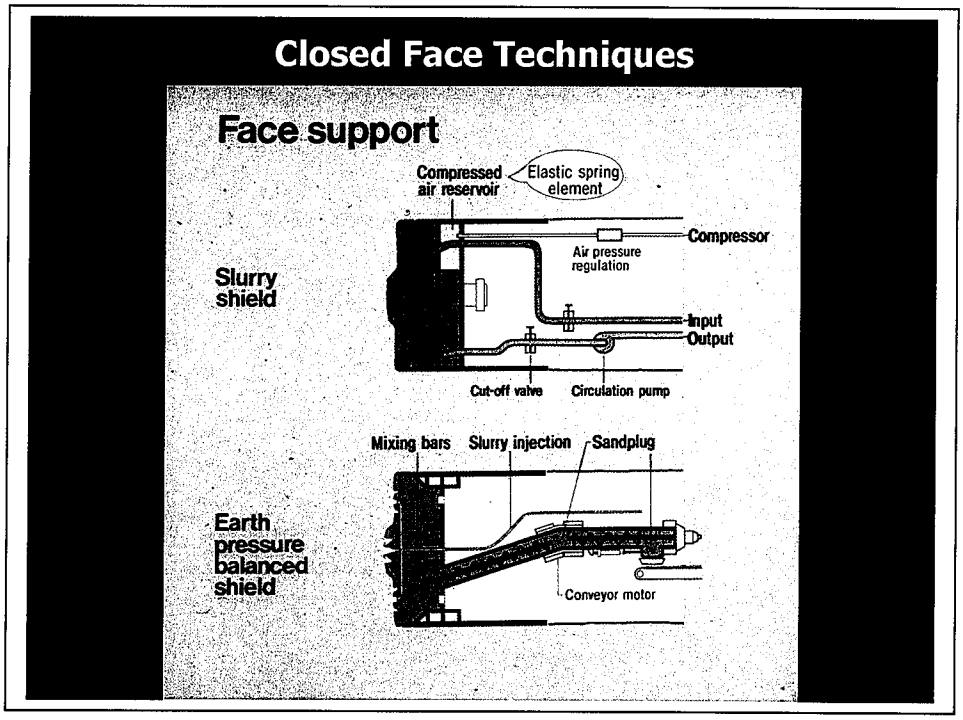

Figure C-1 Slurry and EPB TBM

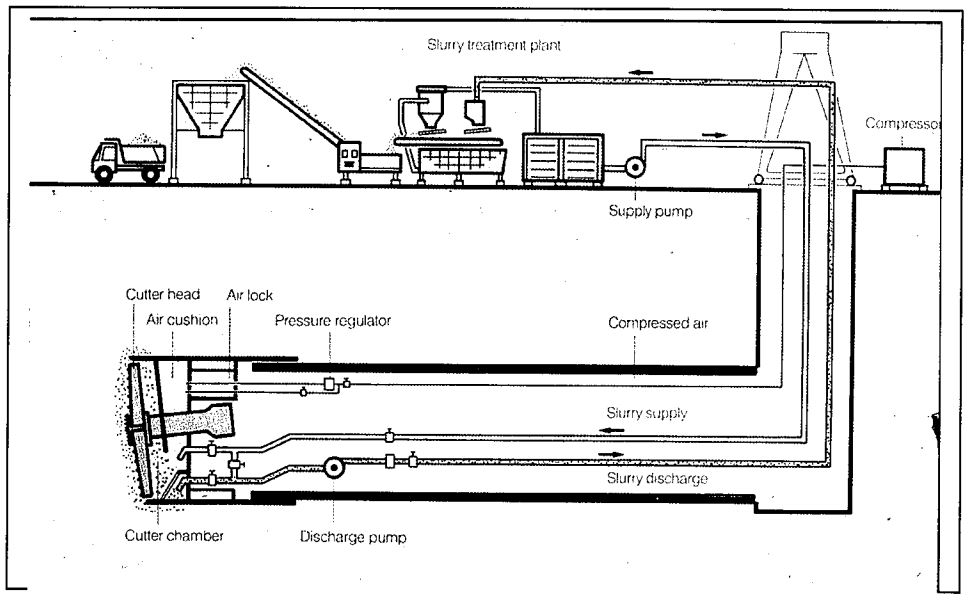

Figure C-2 Slurry Material Conveyance

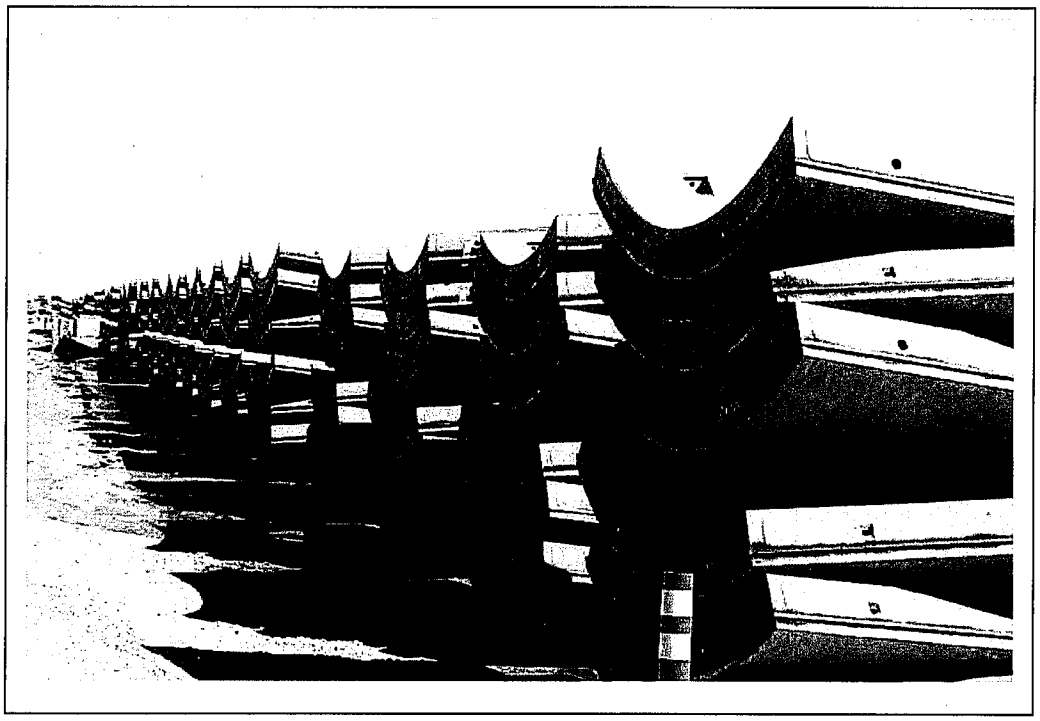

Figure C-3 Concrete Liners

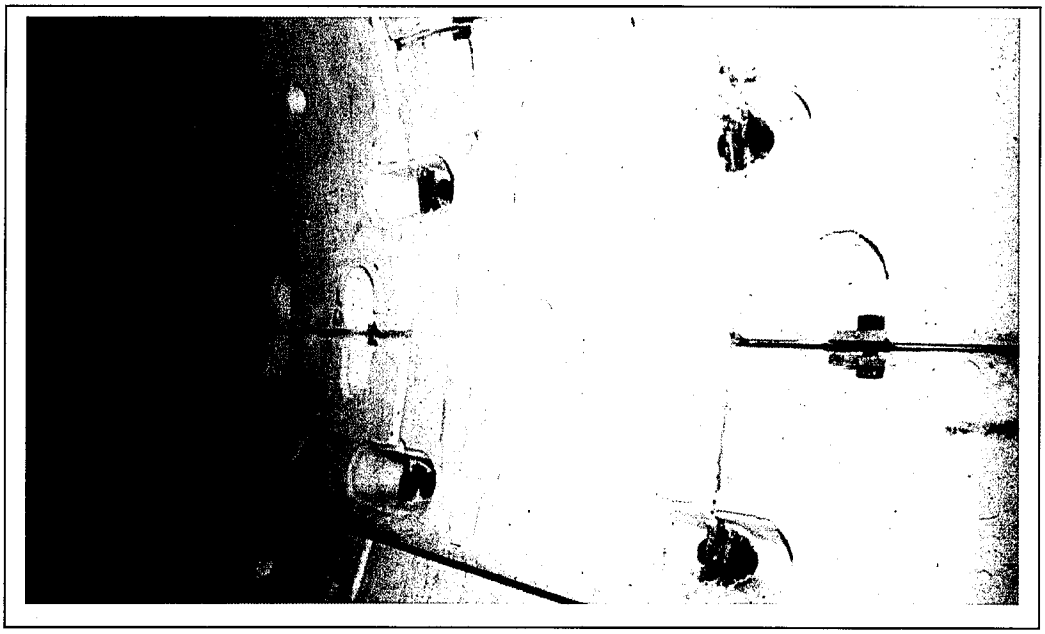

Figure C-4 Installed Concrete Liners

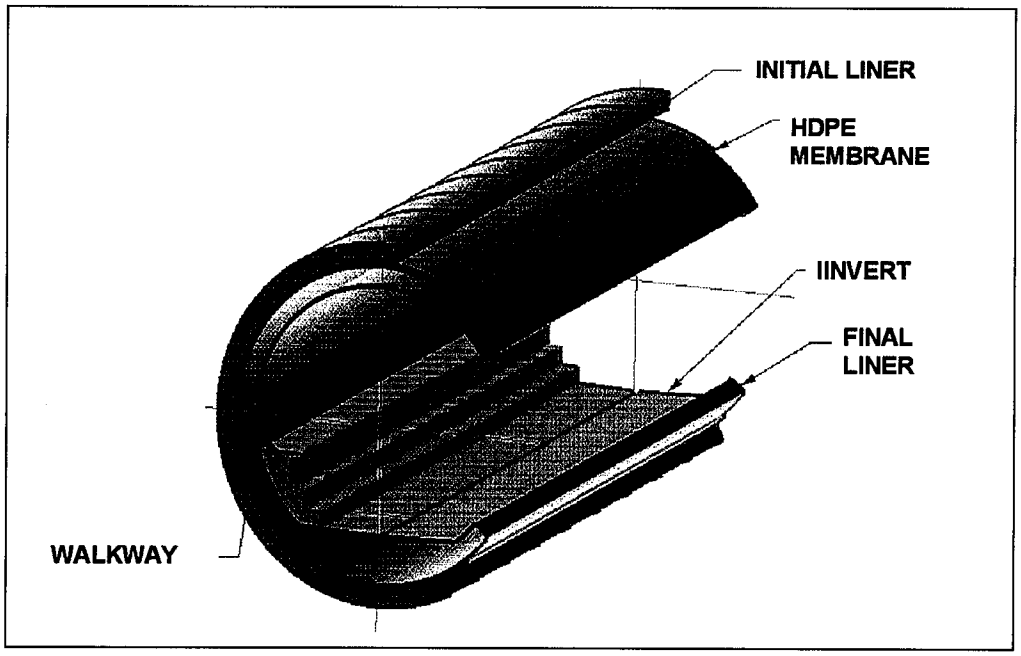

Figure C-5 Tunnel Liners and Membrane Orientation

APPENDIX D - Document List

1. Los Angeles MTA briefing binder provided to panel containing miscellaneous historical and background references
2. Metro Quarterly information pamphlet (summer, 2005)
3. Major Construction Program Summary (status as of June 2005)
4. Wilshire Corridor Tunneling History (Dennis Mori-October 24, 2005)
5. Congressional Record- House, Thursday, August 7, 1986:
   99th Congress, 2nd Session/ 132 Congressional Record H5638
6. Subway Design Technical Report-Appendix C (Korve Engineering/ Mott MacDonald)
7. Technical Presentations power-point handout (10/25/05)
8. Construction of the Detroit River Outfall No. 2, Chapter 41
9. Summary Sheet- Wilshire Blvd. "New Construction in Methane Prohibition Zone" (1985-2002)
10. Summary Report- "Results of Hydrogen Sulfide, Methane and Pressure Survey for Monitoring well/ Vapor Probes" (Todd Stanford, Principal Scientist, TRC, October 21, 2005)
11. "Tunneling In Los Angeles- Where Are We Now"- power-point presentation
    "Tunneling Technologies" – power-point presentation (Dan Eisenstein, October 25, 2005)
12. "Use of Slurry TBM's In Ground With Methane Gas" –Herrenknecht (Rehm, Berger, 08/05)
13. "City of Los Angeles Experiences and Successes with Tunneling through Gas Impacted Soils" – PowerPoint Presentation, Tim Haug, P.E., Ph.D., Michael Mulhern, E.G., H.G., Rajni Patel, P.E.
14. "Los Angeles MTA's Eastside Light Rail Transit Project" – PowerPoint Presentation

APPENDIX E - Panel Member Qualification Briefs

John T. Christian, Ph.D.
Jeff Hewitt
Fred H. Kissel, Ph.D.
Henry M. Nutbrown
Raymond E. Sandiford, P.E.

APTA Peer Review Technical Resource Summary

Los Angeles County MTA
Wilshire Tunneling Project

John T. Christian
Consulting Engineer
Prototype Engineering, Inc.

Areas of Technical Expertise

John T. Christian has extensive experience in Geotechnical Engineering, Soil Dynamics, Earthquake Engineering, Geotechnical Reliability, Computer Applications, Finite Element Analysis, and Engineering Management. He is an expert on earthquake engineering, dynamic analysis, evaluation of soil liquefaction, amplification of seismic waves, stability of slopes, dynamic soil-structure interaction, and probabilistic seismic hazard assessments. His geotechnical engineering work has included earth dam analysis and design, evaluation of flow through porous media and earth dams, geotechnical aspects of nuclear power plants, solid waste landfills, foundation engineering, offshore caissons and production facilities, mooring facilities, and pipelines. He is a pioneer in the use of computer methods, the co-author and co-editor of a seminal book on Numerical Methods in Geotechnical Engineering, and co-author of a book on Productivity Tools for Geotechnical Engineers. His co-authored book on Reliability and Statistics in Geotechnical Engineering was published in 2003.

As Vice President of a major engineering firm, he was involved in the design, evaluation, and construction of a large number of nuclear power plants and other facilities for energy generation and distribution. He also had a variety of corporate management functions, including oversight of computer activities, corporate computer disaster recovery, and standards and qualification of software. He has managed an expert system development group. He has applied probabilistic concepts to geotechnical engineering, winning the ASCE Middlebrooks Prize in 1996 for a paper on the uses of reliability approaches to the design of embankments. In 2002-2003 he served as the Chairman of the National Academy of Engineering committee that reviewed the status of the $14.6 billion Boston Central Artery/Tunnel Project (the "Big Dig") and proposed management changes to expedite its completion.

In addition to serving on the editorial boards of several professional journals, he has been the Editor-in-Chief of the ASCE Journal of Geotechnical and Geoenvironmental Engineering and is a charter member of the ASCE Geo-Institute's Committee on Computer Applications. He is the former Chairman of the Geotechnical Engineering Division of the American Society of Civil Engineers and of the U. S. National Society of the International Society of Soil Mechanics and Foundation Engineering. He is the former Chairman of the Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, in which capacity he was instrumental in revising the undergraduate design criteria. He has been elected to membership in the National Academy of Engineering and to Honorary Membership in the American Society of Civil Engineers. He delivered the Terzaghi Lecture of the American Society of Civil Engineers in 2003.

Summary of Tunneling Projects

Massachusetts Central Artery / Tunnel Project – "Big Dig"

Experience Summary

Experience:

April 1994 to present **Consulting Engineer**, Massachusetts

June 1973 to April 1994 **Stone & Webster Engineering Corporation**, Boston, Massachusetts
Vice President 1989– 1994
Executive V. Pres. – SW Advanced Systems Development Services 1989 – 1992
Senior Consulting Engineer 1980 – 1994
Consulting Engineer 1976 – 1980
Consultant, Geotechnical Division 1973 – 1976

July 1966 to June 1973 **Massachusetts Institute of Technology**, Cambridge, Massachusetts
Assistant and Associate Professor of Civil Engineering

Sept. 1963 to July 1966 **National Science Foundation**, Washington, D. C.
NSF Graduate Fellowship at Massachusetts Institute of Technology

Sept 1959 to August 1963 **United States Air Force**, San Angelo, Texas, and Frankfurt am Main, Germany
Second and First Lieutenant

Additional Experience:

July 1966 to July 1973 **Consultant in Geotechnical Engineering**, Cambridge, Massachusetts

Professional Affiliations:
National Academy of Engineering – Member
American Society of Civil Engineers – Honorary Member
Former Chairman of Geotechnical Engineering Division
Editor, Journal of Geotechnical & Geoenvironmental Engineering
Member of Committee on Soil Dynamics
Charter member and former chairman of the ASCE Geo-Institute's Committee on Computer Applications
Former member of various other committees of the GT Division
Boston Society of Civil Engineers Section of ASCE – Honorary member
Former Chairman of Computer Group
Accreditation Board for Engineering and Technology - Fellow
Former Chairman – Engineering Accreditation Commission
Massachusetts State Board of Building Regulations and Standards
Member of Seismic Advisory Committee
Int. Society of Soil Mechanics and Geotechnical Engineering – Member and

Former Chairman of US National Society of SMGE
U. S. Society for Dams – Member
Seismological Society of America – Member
Earthquake Engineering Research Institute – Member
American Association for the Advancement of Science – Member
University of Texas at Austin - Former Member of Visiting Committee for Department of Civil Engineering
National Center for Earthquake Engineering Research – Former Member of Scientific Advisory Panel
International Journal for Numerical and Analytical Methods in Geomechanics – Member of Advisory Board
Engineering Geology – Member of Editorial Board

Awards: Terzaghi Lecturer - 2003
Elected Member, National Academy of Engineering – 1999
Elected Hon. Member of American Society of Civil Engineers – 2001
T. A. Middlebrooks Award, American Society of Civil Engineers – 1996
Fellow of ABET – 1995
Boston Society of Civil Engineers Sections, ASCE – Hon. Mem. – 1988
Int. Association for Computer Methods and Advances in Geomechanics – Excellent Contributions Award – 2001
Outstanding Correspondent Award, ASCE – 1978
Desmond Fitzgerald Medal, BSCES of ASCE – 1973
Sigma Xi National Scientific Research Honor Society – 1966
U. S. Air Force Commendation Medal – 1963
Tau Beta Pi National Engineering Honor Society – 1956
Chi Epsilon National Civil Engineering Honor Society – 1955

Publications: Over ninety refereed or invited papers and co-author or co-editor of three books.

Professional Registrations:
Massachusetts, Professional Engineer #23150
Maine, Professional Engineer #3608

Education:

1966 **Massachusetts Institute of Technology**, Cambridge, Massachusetts
Ph. D. in Civil Engineering

1959 **Massachusetts Institute of Technology**, Cambridge, Massachusetts
M. S. in Civil Engineering

1958 **Massachusetts Institute of Technology**, Cambridge, Massachusetts
B. S. in Civil Engineering

1989 **Northeastern University**, Boston, Massachusetts
Management Training Program

APTA Peer Review Technical Resource Summary

Los Angeles County MTA
Wilshire Tunneling Project

Jeff Hewitt
Senior Vice President Engineering
RAV Project Management Ltd.

Areas of Technical Expertise

Project Management
Programme Management
Contract Management
Tunnels – Hard Rock and Soft Ground
Railways
Heavy Civils
Design & Build

Summary of Tunneling Projects

Taiwan High Speed Rail Project – Owners Representative for C260
Leader of tender evaluation and negotiation for C210, C215, C240 and C260 tunnel contracts.

Manila North Rail Project – Project Director through Financing Phase

Taits Cairn Tunnel, Hong Kong – Construction Manager

Washington DC Metro Tunnels – Consultant

Cairo Waste Water Scheme Tunnels – Construction Manager

Don Valley Sewer Tunnels – Tunnel Agent

Monasavu Fiji Hydroelectric Scheme – Tunnel Agent

Eraring Power Station Outfall Tunnel – Project Manager

Lilyvale Dam Diversion Tunnel – Project Manager

Tickhole Rail Tunnel – Newcastle – Project Manager

Hong Kong MTR Contract 107 – Tunnel Agent

Tyne Syphon Tunnel – Section Engineer

Hong Kong MTR – Trial Tunnels Engineer

Foyers Aqueduct Tunnel for Hydro Scheme – Assistant Engineer

Experience Summary

Associateship of Camborne School of Mines

Member of Institution of Mining and Metallurgy. Chartered Engineer

Mine Manager's Certificate, Government of Fiji

University of Bristol, Management Course

Fellow of Institution of Mining and Metallurgy. Chairman of Hong Kong Section IMM

Overseas member of Council IMM – London

Site Preparation Contract for Hong Kong Replacement Airport –Project Director

Copper Mining – Underground, Zambia

APTA Peer Review Technical Resource Summary

Los Angeles County MTA
Wilshire Tunneling Project

Fred N. Kissell, Ph.D.
Fred Kissell Mine Safety Consulting

Education: PhD Chemistry, University of Pittsburgh 1965, Postdoctoral Research 1965-67
BS Chemical Engineering, Carnegie Mellon University 1961

Expertise: Dust and methane control for mining and tunneling

Publications/Patents: 135 publications, 8 patents

Selected Recent Publications:
Kissell FN, editor. Handbook for Methane Control in Mining, NIOSH Publication (in press)
Kissell FN, editor. Handbook for Dust Control in Mining, NIOSH Publication No. 2003-147.
Kissell FN and HK Sacks. Inaccuracy of Area Sampling for Measuring the Dust Exposure of Mining Machine Operators in Coal Mines, Mining Engineering, February 2002, pp 33-39.
Kissell FN and Thimons ED. Test Report on the Machine-Mounted Continuous Respirable Dust Monitor, Proc. 7th Intl. Mine Ventilation Congress, Cracow, Poland, June 2001.
Kissell FN. Insights on Technology Transfer from the Bureau of Mines, Journal of Technology Transfer, Vol. 25, 5-8, 2000.

Major Honors/Recognition:
1979 IR100 award given by R&D Magazine to inventors of the 100 most significant new technical products of the year
1986 BuMines Meritorious Service Award
1990 National Academy of Sciences report cites respirable dust control as the major technological contribution by the Bureau of Mines during the decade of the 1980's
1993 Society of Mining Engineers Howard Eavenson Award given annually to the U.S. resident who has ---"contributed the most to the advancement of the coal industry" --
1999 Society of Mining Engineers Howard Hartman Award for –"distinguished contributions in practice, teaching, or research in the field of underground ventilation engineering."

Special Activities, most recent
Member, Tunnel Review Board for Los Angeles Metro System
Consultant to DOE Yucca Mtn. Project, Las Vegas NV
Consultant to Army Corps of Engineers, Ft Knox KY
Chair, Subterranean Spaces Committee, National Fire Protection Association

APTA Peer Review Technical Resource Summary

Los Angeles County MTA
Wilshire Tunneling Project

Henry M. Nutbrown
Assistant General Manager of Engineering & Construction
Port Authority of Allegheny County

Areas of Technical Expertise

Bachelor of Science, Penn State University 1966
Professional Engineer License, Pennsylvania
Thirty-nine years in the Engineering Profession
Fourteen years District Engineer, PENNDOT
Engineering Management, Operations, Maintenance

Summary of Tunneling Projects

1999-2005

- North Shore Connector – 2,400 LF under river twin tube tunnel; led planning and engineering through the environmental studies, preliminary engineering and final design to current bid stage of project; $393 million project, five years planning and design, five years construction.

1994-1996

- Ft. Pitt Tunnel – Led design and project administration for rehabilitation of 5,600 LF interstate highway tunnel; 150,000 average daily traffic at Pittsburgh's west door.

1974-1976

- Liberty Tunnel – Led construction effort to complete reconstruction/rehabilitation of 9,520 LF twin tube highway tunnel under Mt. Washington.

Experience Summary

As Assistant General Manager of the Engineering and Construction Division for Port Authority of Allegheny County, Mr. Nutbrown is responsible for the largest program of major capital projects in Port Authority history. These capital projects include the now completed $320 million West Busway, $500 million South Hills Light Rail Modernization, $64 million Martin Luther King, Jr. Busway Expansion and the $390 million North Shore Connector. Delivering these projects requires managing a staff of 35 engineers and technical personnel, in addition to numerous consultant engineering firms and private outside contractors. Prior to joining Port Authority, Mr. Nutbrown held numerous positions with the Pennsylvania Department of Transportation, including 14 years as District Engineer of District 11. He was appointed District Engineer in January 1985. As District Engineer, he managed an organization of more than 800 employees and a total operating budget of approximately $200 million. He was responsible for maintenance, restoration and construction of a state system of 2,500 miles of roads and 1,889 bridges in Allegheny, Beaver and Lawrence counties. Mr. Nutbrown holds a Bachelor of Science degree in Civil Engineering from the Pennsylvania State University, has been a Registered Professional Engineer in the Commonwealth of Pennsylvania since 1970 and has attended numerous technical courses to remain current in his field.

APTA Peer Review Technical Resource Summary

Los Angeles County MTA
Wilshire Tunneling Project

Raymond E. Sandiford, P.E.
Chief Geotechnical Engineer
The Port Authority of New York & New Jersey

Areas of Technical Expertise

As Chief Geotechnical Engineer of the PANYNJ, I manage a group of 15 engineers and designers involved in the design of building foundations, tunnels and substructures. My group performs technical studies, engineering analyses, and contract document preparation. I have over 30 years experience in soil and rock mechanics engineering, with specialties in soft ground improvement, soft ground tunneling (Micro-tunneling), and brownfield development. Of particular application to the LA-MTA assignment, I have experience with methane gas mitigation. Our brownfield development has taken place over refuse landfills that continually generate methane gas. Our facilities are designed and detailed to prevent gas from entering the buildings and are instrumented to detect if any gas should enter the building.

Summary of Tunneling Projects

- PATH Exchange Place, Bedrock tunneling with roadheaders, Project Engineer
- JFKIA AirTrain, Cut and Cover Tunnel, Client Engineer.
- JFKIA Micro tunneling, slurry shield tunneling, Project Engineer.
- Newark Liberty Airport Microtunneling, slurry shield tunneling, Project Engineer.
- LaGuardia Airport – Mass transit connection, conceptual engineering EPBM, sponsoring Client Engineer.
- Access to the Regions CORE, ongoing EIS and preliminary engineer effort for new tunnel under the Hudson River, sponsoring Client Engineer.

Experience Summary

B.S. State University of New York at Stony Brook

M.S. Columbia University

P.E. Registration in New York and New Jersey

A list of publications is attached.

PUBLICATIONS

Sandiford, Raymond E. et al, 1991, USE OF PIEZOMETRIC CONE PENETRATION TESTING WITH ELECTRICAL CONDUCTIVITY MEASUREMENTS (CPTU-EC) FOR THE DETECTION OF HYDROCARBON CONTAMINATION IN SATURATED GRANULAR, Current Practices in Ground Water and Vadose Zone Investigations, ASTM STP 1118.

Sandiford, Raymond E. et al, 1993, INSTRUMENTED LOAD TEST IN A BENT PILE, Proceedings: Third International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri.

Sandiford, Raymond E. et al, 1996, APPLICATION OF GEOSYNTHETICS IN THE CONSTRUCTION OF AN OVERRUN AREA AT LAGUARDIA AIRPORT, Proceeding of the Geosynthetics Research Institute, GRI-9, Philadelphia.

Sandiford, Raymond E., et al 1996, Evaluation of Enhanced Consolidation for Dredged Material Disposal, Newark Bay Confined Disposal Facility, International Workshop on Technology Transfer for Vacuum-Induced Consolidation: Engineering and Practice, ISSMFE (TC-17), Port of Los Angeles.

Sandiford, Raymond E. et al, 1999, DESIGN AND CONSTRUCTION OF THE RUNWAY 13-31 OVERRUN AREA AT LAGUARDIA AIRPORT, ASCE, Geo-Institute Geo-Boston.

Sandiford, Raymond E. et al, 2000, PILE LOAD TESTING AT JFK INTERNATIONAL AIRPORT, DFI 2000 International Conference Proceedings, New York, NY.

Sandiford, Raymond E. et al, 2004, RESTORATION OF PATH SERVICE TO LOWER MANHATTAN, Proceedings: Fifth International Conference on Case Histories in Geotechnical Engineering, New York, N.Y.

Sandiford, Raymond E. et al, 2004, THE HOWLAND HOOK MARINE TERMINAL PORT REDEVELOPMENT ON STATEN ISLAND, NYC, ASCE, Geo-Trans, Los Angeles.

Sandiford, Raymond E. et al, 2004, The JFK International Airport AirTrain JFK Terminal at Jamaica, Queens, NYC, ASCE, Geo-Trans, Los Angeles.

Sandiford, Raymond E. et al, 2004, EVOLUTION OF DEEP FOUNDATIONS FYSTEMS USED AT THE PORT IVORY FACILITY SITE: 1906-2004, Deep Foundations Institute, Vancouver, B.C.