American Association of State Highway and Transportation Officials (AASHTO)
United States Department of Transportation Federal Highway Administration (FHWA)

2002 Scanning Project

Innovative Technology for Accelerated Construction Of Bridge and Embankment Foundations.

Preliminary Summary Report

In June 2002, the Federal Highway Administration (FHWA) in a joint effort with the American Association of State Highway and Transportation Officials (AASHTO) organized a geotechnical engineering scanning tour of Europe. Its purpose was to identify and evaluate innovative European technology for accelerated construction and rehabilitation of Bridge and Embankment Foundations. Opportunities for cooperative research, development, and implementation of accelerated construction technology were also explored.

The technologies for accelerated construction and/or rehabilitation evaluated in this scanning trip included:

i. Bridge foundation systems, equipment and ground improvement methods.
ii. Embankment deep foundation systems, equipment and ground improvement methods.
iii. Embankment mat foundation systems, equipment.
iv. Embankment construction equipment and methods.
v. Innovative earth retention systems.
vi. Processes and implementation methods

Method

The geotechnical scanning team members included both geotechnical and structural (bridge design) engineers representing Federal, State, academic and private industry sectors. Team members were invited to participate based on their positions as leaders in the development and implementation of new technologies. The team met with technical and industry leaders of Sweden, Finland, Great Britain, Germany, Italy and Belgium to acquire detailed design and construction information for possible application in the United States. In order to effectively evaluate the equipment and techniques that may be used for accelerating construction, approximately 50% of the scanning activities were devoted to physical demonstrations of the technologies/methodology in Sweden, Holland, Germany, Italy and Belgium along with interviews including case study briefings with contractors and equipment manufactures.

Overview of Technologies and Practices Observed

The team identified thirty technologies and up to fifteen processes that offer a potential for accelerating construction and rehabilitation of bridge and embankment foundations. Many of the technologies also offer a potential for cost savings and, in a majority of the cases, an improvement in the quality over current practice. Tables 1 – 5 included in this report provide a brief summary of the technologies evaluated with respect to the areas identified previously in the introduction. Complete tables with a relative ranking of all the technologies in terms of anticipated improvements in construction time, cost, and quality will be included in the final report. The technologies that offer the greatest potential benefit clearly lead to recommended practices as outlined in the next section of this summary report.

Insight was also gained on other related construction practices in Europe that may benefit US practice. In several European countries, the emphasis was on maintaining traffic during construction, which often dictated the construction procedures and has led to innovations in parallel bridge construction. In several projects reviewed, the new bridge was constructed adjacent to the old bridge, foundation support was improved under the old bridge while maintaining traffic, then the new bridge was moved into final position by a transporter or sliding. Traffic disruption was held to a minimum, e.g., less than 72 hours in two cases. Another emphasis was on the reduction of noise, also a key factor in the U.S., which drove the use of some of the technologies listed in the tables. Public relations played an important role including offers to relocate families during the construction period.

Findings

The overall goal of the scanning trip is to implement technologies of best practice. With this perspective, the team identified European acceleration technologies and methods, and devised new ways in which these technologies could be applied in both the U.S. and Europe. This resulted in a vast and broad array of cross applications of technologies, methods and processes that was so large and complex that concise and effective communication of the scan's findings became a major concern. With much thought and discussion, the team strongly agreed that the findings should be presented in an easy to use tabular format that was organized around an end user's need. The goal was to devise a table(s) such that an engineer could enter with a specific need, and quickly see a list of applicable scan findings along with important supplemental information about the use of a specific technology for their specific need. An overview version of this approach is presented within Tables 1-5. The complete and detailed tables developed during the scan will be included within the final report. Selected technologies highlighted by the team as having a high potential for accelerating construction while maintain or improving both cost and quality are summarized in the following paragraphs.

Bridge Foundations (Table 1)
For bridge foundation construction, the standard of practice in the US for poor to marginal foundation conditions is driven piles or drilled shafts. Due to quality control/quality assurance problems with "auger cast" piling, "auger cast" or "continuous flight auger" piles are rarely used in U.S. bridge construction. Continuous flight auger (CFA) piles with automated computer

control and automated QC/QA would appear to offer a rapid alternative to the current practice that could be easily implemented. Bored cased secant (CSP) piles should also be evaluated as an alternate accelerated method that can provide both bridge support and excavation support in cut situations. For large projects with difficult drilling conditions and/or tight spaces, the use of a diaphragm wall constructed with a Hydro-Mill™ offers a rapid construction method with low noise and low vibrations that could also be used to support large loads.

Embankment Foundations (Tables 2 &3)
For embankment foundation construction over soft, compressible soils, the Europeans were using piled embankments to accelerate construction over classically using surcharge with or without wick drains. Although this is very familiar technology in the U.S., it is often associated with high cost and difficult access problems. However, with some of the advances in pile technology (i.e., faster installation, lighter equipment, and lower cost) as identified on this tour, piled embankments were considered by the team as a much more attractive alternative that should be explored as a viable alternative for most soft ground projects.

An embankment mat support system may be required to spread the load over the foundation soil or piles depending on the soil conditions, type of pile and deep foundation spacing. Load transfer mats constructed with geosynthetic reinforcements, and often combined with lightweight aggregates or geofoam, offer a viable solution with the design methods supported by both U.S. and European practice. Stabilization of the upper 3 to 5 m of soil materials though either mass mixing or rapid impact compaction may also hold some promise in constructing foundation support mats with and without deep foundation systems.

Embankment Construction (Table 4)
Several technologies evaluated on the tour offer the potential to accelerate placement and compaction of fill for construction of the embankment itself, while maintaining or improving cost and quality. Lightweight fills have been used in the U.S. to a limited extent to reduce placement and surcharge time in soft soil conditions. The frequency of use in Europe appears to be increasing (almost routine). Increasing the use in the U.S. should increase availability and decrease cost, making lightweight fills such as geofoam an attractive alternative to surcharge fills and accelerating construction. The rate of embankment construction could also be significantly increased through the use of high-energy impact, rolling compactors and rapid impact hydraulic hammer compactors, both of which appear to provide a much greater depth of compaction allowing for placement of thicker fills. Also, very promising is the use of instrumentation on the compaction equipment to measure dynamic modulus, which can be used for improving compaction uniformity, effective compaction effort and potentially compaction quality control.

Earth Retention Systems (Table 5)
Rapid construction alternatives to conventional bridge retaining wall construction (i.e., using sheeting and shoring with cast in place walls) were identified that could be easily implemented. The technologies include bored cased secant piles and continuous diaphragm walls, both of which can be used for the retaining wall as well as the support of the bridge. Both of these methods can be used on sites where difficult drilling is anticipated and both methods produce low noise and low vibrations.

Processes and Approaches
The team agreed that the Scan findings with the greatest potential for accelerate construction where processes and approaches as listed at the bottom of each of the tables. The common theme between all of these processes is: *simplicity through sophistication.*

Practically all of the equipment and construction methods presented in Tables 1-5, employed real time automated installation control and documentation. These systems monitor, measure, control, and document critical aspects of their technology and, thereby, allow for rapid construction without compromising quality. In fact, in most cases they improve quality. In addition to faster installation, these technologies and methods accelerated construction by reducing, or eliminating, QC methods, which are intrusive to the construction process.

We also observed the simplicity through sophistication approach being applied to construction materials. Specifically, one of the most exciting finds of the trip was the common usage of Self Consolidating Concrete (SCC) in Sweden. SCC is not a new technology, but SCC research, development, and implementation to the highly advanced level of common usage is a new achievement.

By using advanced SCC technology, Sweden is able to pour concrete in intricate forms and/or dense reinforcement situations significantly faster, with fewer workers, smaller pumps, and achieve high quality. SCC should lead to a longer life via superior coverage of reinforcement, and very low permeability. It provides significant benefit when post tension or other ductwork is present. Since vibration is not needed, ductwork can not be pushed out of alignment or crushed.

Several other European Community (EC) standard processes were also identified that could lead to both improvements in construction rate and quality at a moderate cost including: 1) requiring the contractor and designer to have a quality control and quality assurance program modeled after the ISO 9000 series process and 2) increasing requirements for computer automated equipment control and requiring generated data to be provided as part of the quality control program. A process to evaluate which method would provide optimum acceleration considering the total scope and integration with all phases of the project (i.e., how accelerated construction methods fit in with the critical path for project completion) was presented by the German Federal Highway Administration (BASt). This process will be detailed in the final report and will be used by the team as a model to help agencies identify opportunities and the optimum method for accelerated construction.

Tentative Implementation Recommendations

The overall goal of the scanning trip is to implement technologies of best practice. With this objective clearly in mind, an implementation ranking was developed using the following two step process:

(1) the team as a whole reviewed and discussed each technology with respect to it's potential for accelerating construction;
(2) Each team member selected the two technologies for which they had the strongest desire to Champion their implementation.

The selected technologies for immediate implementation action include:

- Column Supported Embankment
- CFA and CSP Bridge Foundations
- Automated Computer Installation Control And Installation Documentation
- Self Consolidating Concrete

Many of the other technologies listed in the tables show great promise, but successful implementation requires a Champion. In addition, due to the diversity of team members (Contractor, Consultant, DOT, Federal, Geotechnical, and Structural Engineers), the ranking should be an excellent indicator of the accelerated technologies preferences of the Highway construction community as a whole.

Therefore, the above list isn't necessarily a ranking of technologies with the greatest technical potential for accelerating construction. It is a list of European accelerated construction technologies with the greatest potential for implementation. This should provide us with the direction needed to ensure that our resources are not diluted, and focused. Plans for implementation of all potentially beneficial technologies will be detailed in the final report.

Implementation

An implementation plan was reviewed at the closing of the tour, which will consist of: 1) presentations on new technologies at engineering meetings, a number of which were identified (see attached); 2) invited equipment demonstrations by manufacturers; 3) cooperative efforts with European organizations; and, 4) local efforts by team members to use the technologies within their organizations on demonstration projects. A Scan Technology Implementation Plan team was also organized to develop request for seed funding to assist in the implementation efforts for specific high priority technologies. The complete implementation program will be detailed in the final report

Table 1. Bridge foundation systems, equipment and ground improvement methods for accelerated construction and rehabilitation on poor subgrades.

Technology or Process	**Anticipated Accelerated Construction Performance**	**Comments**
Base Line Technology for Comparison – Driven Piles and Drilled Shafts		
Vibro-jet of Sheet Pile Driving	Speeds driving of sheet piles through layered soils	End abutments with grouting through vibro-jet pipes
Self Drilling Micro Piling	Self drilling and grouting for one step installation	Confined conditions with difficult ground for drilling or driving
Screw Piling	Requires one third the time of auger cast piles and much lighter and smaller equipment	Best use in relatively weak soil conditions for foundations with low vertical and lateral loads per pile. Auto control
Continuous Flight Auger Piles (CFA)	Rapid vertical or slight batter pile installation	Use only with automated control & documentation; best in weak to medium soil (easy drilling)
Bored Piling - Cased Secant Pile (CSP)	Rapid vertical and lateral support	Similar to CFA piles, but casing assists in some soil conditions
Continuous Diaphram Wall and Hydro-Mill™ Diaphragm Walls	One step excavation and grouting with minimum mess	Use for large projects with difficult drilling conditions, large loads, low noise restrictions, and/or tight spaces
Applicable Processes from Scanning Tour: • Contractor/Designer QC/QA Required ISO 9000 • Self-Compacting Concrete • Automated Control QC Documentation Of Installation		

Table 2. Embankment deep foundation systems, equipment and ground improvement methods for accelerated construction on poor subgrades.

Technology or Process	Anticipated Accelerated Construction Performance	Comments
Base Line Technology for Comparison – Surcharged embankment on poor subgrade		
Embankment on Piles	Saves surcharge time; no surcharge required	Newer piles (e.g., GEC, CSV, CFA, AU-Geo, Screw Piles) may reduce cost
Deep Mixing (Lime-Cement) Columns	Reduce surcharge requirements	Advances in QC, mixing, equipment, and uniformity
Mass Stabilization	Saves time when compared to preloading	Effective for 3 to 5 m depth in peat, mud or soft clay
Geotextile Encased Columns (GEC)	High bearing capacity, saves time required for surcharge and low noise	80% to 90% settlement in 3 months
Screw Piling	Similar to driven piles, but with low noise and vibration	Lower capacity friction piles. Variety of systems available
Combined Soil Stabilization (CSV) System	One step installation of cement columns	Low weights, easily mobilized equipment
Continuous Flight Auger Piles (CFA)	Rapid pile installation for vertical or slight batter piles	Installation rate of 400 to 500 m per day at low cost; not suitable for soils with obstruction
Turbo-Jets	Rapid vertical column for soil support	Control appears better than jet grouting
AU-Geo	Fast mass stabilization	Not presented, more information required
Applicable Processes from Scanning Tour: • Contractor/Designer QC/QA Required ISO 9000 • Automated Control QC Documentation Of Installation		

Table 3. Embankment mat foundation systems, equipment for accelerated construction.

Technology or Process	Anticipated Accelerated Construction Performance	Comments
Base Line Technology for Comparison – Normal (possibly staged) fill construction; assumes close spacing and arching for piled foundations		
Load Transfer Mat -Concrete Slab	No surcharge required; could use prefab mats	Soft foundations – highest cost
Load Transfer Mat – Concrete Caps	No surcharge required	Requires hard piles/columns that are closed spaced
Load Transfer Mat – Geosynthetics	No or reduced surcharge required	For hard piles/columns need to check punching shear; works well with soft piles
Load Transfer Mat – Caps and Geosynthetics	No or reduced surcharge required	Arching and spacing versus geosynthetic strength
Light Aggregates	Reduces or eliminates surcharge	Geofoam, flowable fill, etc.
Mass Stabilization	Saves time when compared to preloading	Works well for soft and/or organic soils
Automatic Controlled Variable Roller Compaction	Speeds compaction eliminating wasted time.	Compaction efficiency and uniformity improved; minimizes passes required
Applicable Processes from Scanning Tour: • Designer On Board During Construction • Contractor Involved Design • Contractor/Designer QC/QA Required ISO 9000 • Real Time Lab Testing and Data Storage • Real Time Design (For example: Analysis of Controlled Deformation ADECO-RS) • 10 year Warranties/Insurance		

Table 4. Embankment construction equipment and methods for accelerated construction.

Technology or Process	Anticipated Accelerated Construction Performance	Comments
Base Line Technology for Comparison – Controlled fill placement and compaction		
Light Aggregates		
Rapid Impact Compaction	Building with thick fills and rubble fills	Currently used for building on rubble fills; quality of compaction needs evaluation
Automatic Controlled Variable Roller Compaction	Speeds compaction eliminating wasted time.	Compaction efficiency and uniformity improved; minimizes passes required
Accelerated Site Investigation	Large area rapid QC by using ground probing radar or resistivity	Works for all cases
Horizontally Vacuum Consolidation	Rapid consolidation of soft soils and below water soils without surcharge	Allows use of hydraulic fill and dredge spoil
Dynamic Stiffness Gauge	Rapid QC, approximately 2 minutes per test	Works for granular soils
Higher Energy Compaction Impact Roller	Allows use of thicker fills	Quality of compaction needs evaluation
Applicable Processes from Scanning Tour: • Contractor/Designer QC/QA Required ISO 9000 • Real Time Lab Testing and Data Storage • 10 year Warranties/Insurance • Automated Control QC Documentation Of Installation		

Table 5. Innovative Earth Retention Systems for accelerated construction and rehabilitation.

Technology or Process	Anticipated Accelerated Construction Performance	Comments
Base Line Technology for Comparison- temporary sheeting and shoring with CIP wall		
Deep Mixing (Lime-Cement) Columns	Stabilizes soil to allow excavation without sheeting and shoring	Not applicable in tight R/W conditions; requires CIP wall
Vibro-jet of Sheet Pile Driving	Speeds driving of sheet piles through layered soils	Quality can be improved with post grouting
Self Drilling Nails	Self drilling and grouting for one step installation	Use for difficult drilling (cobbles & boulders)
Bored Piling - Cased Secant Pile (CSP)	Rapid vertical and lateral support	Depressed section in weak ground
Berlin Wall (Micropile Wall)	Lateral wall support with vertical capacity	Used for difficult drilling (cobbles & boulders) above groundwater
Continuous Diaphragm Walls (CDW)	One step excavation and concrete placement with minimum mess (no slurry)	Tight site conditions, low headroom, low noise & vibration, limited to 10 m, setup cost is high
Hydro Mill Diaphragm Walls	One step excavation and slurry placement with minimum mess	High mobilization costs, but useful in difficult drilling conditions (cobbles & boulders), good control on alignment with automated control system
Turbo-Jets	Rapid vertical column construction with limited spoil	Appears to provide better control than jet-grouting
Applicable Processes from Scanning Tour: • Designer on Board During Construction • Contractor Involved Design • Contractor/Designer QC/QA Required ISO 9000 • Automated Control QC documentation of installation		

AASHTO & FHWA SCAN PROJECT:

Innovative Technology for Accelerated Construction of Bridge and Embankment Foundations

Implementation Activities - Planned Presentation
June 12, 2002

- ADSC Annual Conference, July 2002. Champion, Allan McNabb
- AASHTO Annual Construction Committee Meeting, August 2002. Champions, Randy Cannon and Shastry Purcha
- Western Bridge Engineers Seminar, October 2003. Champion Myint Lwin
- Southeastern Geotechnical Engineers Conference, October 2002, Champion Shastry Purcha
- Northwest Geotechnical Engineers Conference, October 2002, Champion Myint Lwin
- Midwest Geotechnical Engineers Conference, October 2002, Champions Sam Mansukani, Kevin McLain.
- Deep Foundations Institute (DFI) Conference "Time Aspects of Deep Foundation Construction" December 2002. Champions Dick Shore, Ali Porbahaie.
- Transportation Research Board Sunday Workshop "Innovative Technology for Accelerated Construction of Bridge and Embankment Foundations" January 2003. Champions Chris Dumas and Barry Christopher.
- Florida DOT Annual Construction Conference, April 2003. Champion Shastry Purcha.
- AASHTO Annual Bridge Committee Meeting, May 2003. Champions Randy Cannon and Myint Lwin..
- International Bridge Conference, June 2003. Champions Randy Cannon and Myint Lwin.
- TRB Technical Committees, e.g. A2F04 Bridge Construction, January 2003, Champion Each Team Member in Attendance.
- Joint Research, Partnering in Construction, Champions TBA.
- One-on-One with State Agencies, Champions Each Team Member.