Contracting for Tiedback Walls in Kentucky

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The Kentucky Transportation Cabinet has used a prebid design performance specification for two permanent tiedback walls. These walls were used for control or correction of active landslides. The walls comprised steel H-sections, timber lagging, and corrosion-protected tiebacks. Only approved tiedback wall contractors were permitted to participate in these projects. These approved contractors were given a packet of information on the projects. The packets contained all technical and administrative details deemed necessary to satisfactorily complete the work. Contractor input was solicited during development of the information packets. The contractors were to develop their own tiedback wall schemes. Tieback size, tendon type, bonded and unbonded length, and tieback location were their responsibilities. They were required to submit complete design calculations, construction plans, and any notes to the cabinet for review and acceptance 30 days before bids were opened. After design acceptance, the contractors were to prepare lump sum bids for their wall systems. On one wall contract the tiedback wall contractor was the prime contractor. On the other contract the wall contractor was a subcontractor. Both walls were completed satisfactorily. The cabinet is considering developing a post-bid design performance specification for tiedback walls. This would reduce the staff time involved in design review.

In late 1982, the Kentucky Transportation Cabinet began considering tiedback walls as an engineering technique for permanent landslide correction and control. Since that time, Kentucky has successfully completed two tiedback walls to contain landslides. Kentucky elected to use a prebid performance specification for these walls. The actual wall type selected for both projects comprised steel H-piles, pressure-treated timber lagging, and corrosion-protected tiebacks. The specification required that the piles be driven to and seated in solid rock. The lagging was open faced and backed with a drain path material (Figure 1).

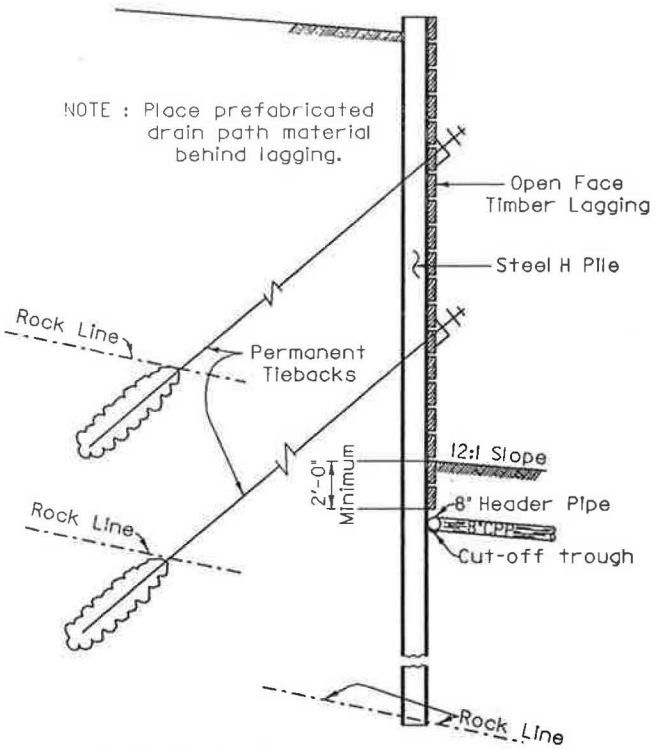

FIGURE 1 Typical section.

CARROLL COUNTY LANDSLIDE

In March 1983, the Transportation Cabinet's Division of Bridges was given the task of preparing a performance specification for control of an active landslide in the northern part of Central Kentucky. This slide is southeast of Carrollton on KY-227. This two-lane facility opened to traffic in 1974. Since its opening, the facility has been plagued by slides. These slides were being monitored by the Geotechnical Section of the Division of Materials. By the summer of 1982, a major slide had affected about 400 ft of embankment and encroached on about 200 ft of roadway. The slide in question was in a cut-fill section. Slope inclinometer readings showed the zone of movement to be 23 to 25 ft below the roadway shoulder. The rate of movement was 0.2 in. per month. No structures were affected, but the railroad track approximately 100 ft from and 30 ft below the roadway was in danger. The situation was further complicated by the presence of the bank of the Kentucky River about 100 ft from and 20 ft below the railroad (Figure 2).

This slide is in the northern part of the Outer Bluegrass topographic region of Kentucky. Glacial deposits and recent alluvium exist in many areas adjacent to the Kentucky River. The overburden soil is predominately a low-plastic clay. The depth to rock at the shoulder was about 35 ft. The water table was estimated to be 2 to 4 ft below existing ground at the roadway shoulder. The bedrock is predominately interbedded

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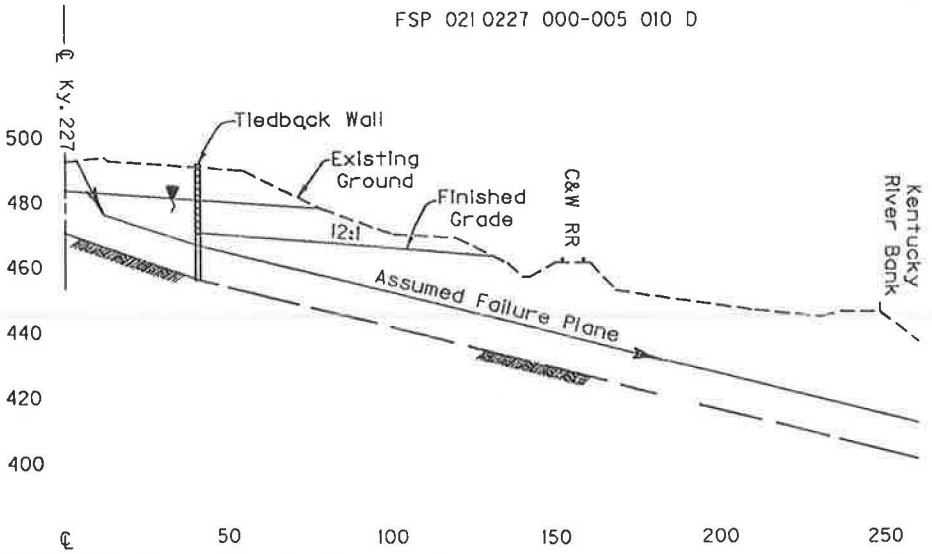

FIGURE 2 Carroll County slide correction.

Ordovician limestones and shales. The Kope formation is the main formation in the area. Highly weatherable shales make up 70 to 85 percent of this formation and are usually found in even to slightly irregular beds about 12 in. thick. Use of these shales during embankment construction for KY-227 was a major factor contributing to the problems along this roadway.

The three alternate corrective measures considered were a tiedback wall, horizontal drains, and railroad rails as driven piles. Neither moving the centerline of the road into the hill nor flattening the slope was considered a practical solution. Any alignment change would affect ½ mi of roadway and require considerable excavation as well as significant additional right-of-way.

Stability analyses that included the effects of horizontal drains gave an insufficient factor of safety of from 1.1 to 1.2. Previous successful experience with railroad rail piles had been with lengths of from 15 to 20 ft. The soil at the site was far too deep for this to be an effective solution. The tiedback wall offered various combinations of tieback capacities and spacings to resist the calculated landslide force. The design factor of safety was to be between 1.5 and 2.0 for a tiedback wall. The wall was estimated in the planning phase to be about 400 ft long and have 15 ft of exposed face at its tallest point.

A tiedback wall was a new product or technique to Kentucky. The design, details, and construction of such walls were not covered in the standard specifications; thus a specification would have to be developed. The development of this specification, in the form of a Special Note, was somewhat complicated by the short lead time provided for the project letting.

This Special Note was patterned after the sample specification in Chapter 7 of Federal Highway Administration Report FHWA-RD-82-47, *Tiebacks (1)*. The following are some of the items addressed in the note:

1. Scope of work;
2. Design criteria;
3. Tieback description, geometry, and capacity;
4. Geotechnical data;
5. Maintenance of traffic;
6. Instrumentation and monitoring;
7. Installation requirements for piles, lagging, and tiebacks;
8. Material specification and testing requirements;
9. Tieback testing including creep, performance proof, and liftoff testing;
10. Record requirements;
11. Minority business enterprise requirements;
12. Method of measurement and basis of payment;
13. Plan and elevation views, typical sections, cross sections;
14. Other references to other departments, documents, specifications, and so forth, that wall contractors would need; and
15. Staff and experience requirements of wall contractors in the design and construction of tiedback walls.

By the middle of May 1983, the first draft of the Special Note was completed. Unfortunately, time did not permit in-depth review and input by many outside agencies.

By the first part of August 1983, an information packet containing the Special Note was made available to a group of tiedback wall contractors. At this time, these specialty contractors were encouraged to review the note in detail and to provide their suggested changes or exceptions. Seven tiedback wall contractors provided critiques of the draft. Unfortunately, three of the seven contractors eliminated themselves because of the time constraints.

The Special Note required the interested contractors to submit, within 28 calendar days, a set of design and construct documents. These were to include complete design calculations and a complete set of detailed construction plans for review and approval. Their plans were to include any notes or specifications pertinent to their wall that either conflicted with or were not covered in the cabinet's current standards and specifications, guidance manuals, or special provisions. Each contractor's submission was reviewed separately. Any changes suggested by any contractor, which were approved by the cabinet,

were made available to all contractors. Proprietary items were permitted but would not be specified. The contractors were to show on their construction plans any and all details necessary to provide a satisfactory tiedback wall.

Each contractor's design calculations were to include designs for every component of their wall. Their format was to be such that engineers totally unfamiliar with tiedback wall design could follow their calculations.

The review was quite time consuming. Each contractor appeared to have a different method for attacking tiedback wall design. The shapes of the final construction pressure diagrams were not uniform. Treatment of passive pressure varied. Economics affected pile spacing, waler size, number of rows of tiebacks, and many other details. Cabinet personnel went through an educational process with each design. This was most inefficient but worthwhile when the long-term educational value is considered.

It was difficult to make comparisons of the submitted wall designs. Instead of a comparison of numbers of piles, walers, tiebacks, and the like or individual tieback loads, a comparison of resistance per foot of wall was attempted. Resistance per foot of wall varied significantly from contractor to contractor. The major reason for this variation appeared to be the cabinet's inexperience with tiedback wall design. A clear definition of the landslide problem and a specific design pressure diagram must be provided to the wall contractors.

Many telephone calls were made to the specialty contractors to clarify submissions and solicit suggestions. The cabinet had 15 calendar days to review the submissions from four contractors. According to the original note, the contractors would then have 8 calendar days to provide the cabinet with revised designs and plans.

During the review of the first submissions, a field inspection of the site revealed that the area affected by the slide had grown laterally. This was about 4 months after a tiedback wall was selected for controlling this slide. Relatively speaking, the type of work did not change. However, plans needed to be developed for a longer wall. Initially, the estimated increase in length was anticipated to be 200 to 300 ft. When the final addendum was mailed, the increase in length was 600 ft. A wall 1,000 ft long with 16 ft of exposed face at its highest point was now required.

The cabinet had to initiate and hastily complete a comprehensive drilling, sampling, and testing program for the additional wall length. This was accomplished by the cabinet's Geotechnical Section.

Numerous parts of the design criteria originally presented in the Special Note were changed. These changes affected lagging design, pile design, drainage requirements, pile and waler corrosion protection, tieback testing, and the use of a dynamic pile-driving analysis to name several. Possibly the most significant change was in the design pressure diagram or design force per linear foot of wall. This change required the specialty contractors to completely redo and submit new designs and revised plans. The date for providing the cabinet with final design and contract plans was changed. Unfortunately, the letting data was not changed. Consequently, any discrepancies or deficiencies in the final submission could disqualify a specialty contractor.

In addition to the monitoring by the cabinet's Geotechnical Staff, the Kentucky Transportation Research Program (KTRP) received approval and funding from FHWA to monitor the wall with several types of instruments. The contractors had been forewarned that there would be some instrumentation required by the cabinet for monitoring wall movements during and after construction. This would be in addition to the normal monitoring common to tiedback walls such as tieback stressing and testing. Types of instruments to be added were extensometers, load cells, slope inclinometers, groundwater observation wells, tiltmeters, and earth pressure cells. Instrument locations would be determined in the field by KTRP, the cabinet, and the contractor. Optical surveys would be made to develop a settlement profile of the pavement behind the wall. The contractor was directed, by the Special Note, to cooperate with instrument installation by the cabinet and KTRP. None of the contractors expressed any disagreement or difficulties with incorporating this instrumentation program into their actual wall construction. Actually, tiedback wall contractors expressed considerable interest in this monitoring program. However, there is no way of determining how much, if at all, this additional instrumentation and monitoring affected their bid or their construction scheduling.

The final Special Note and contract plans were ready for bidding by September 1983. This was 6 months after the task began.

When construction began, cabinet inspectors went through an educational process. Their knowledge of permanent tieback construction methods had come from reading various industry publications.

Deficiencies in the Special Note did present some problems to the cabinet's inspectors during construction. Fortunately, there were no major or cost-affecting situations as a consequence of gaps between the Special Note and the cabinet standards and specifications. Problems such as controlling excessive pile deflection were resolved at the site, and other problems were resolved by the local district office or the Division of Bridges. All questions were settled informally in an arbitration type of effort.

The Special Note limited the allowed deflection of the wall during tieback stressing. However, the text was somewhat vague in providing guidelines for handling deflection exceeding the tolerance. The wall was constructed in the spring of 1984. That spring was wetter than normal, which contributed to excessive deflection of the soldier piles. The field decision was to place mass concrete as a reaction beam behind selected H-piles.

There also appeared to be an excessive amount of tieback failure during stress testing. The specialty contractor's previous experience in Kope shales had been high up in the formation. The consensus was that the shales at the site were lower in the formation and weaker than anticipated. Also, the drilling process could have caused slick or smeared holes that inhibited grout penetration into the formation.

Probably the most significant shortcoming that affected construction was the lack of specific instructions for stage removal of earth in front of the wall. Because the wall, not counting the required excavation, was less than 40 percent of the total contract, the specialty contractor was a subcontractor on this project. The prime or general contractor elected to do all earth moving including that required for wall construction. The cabi-

net gave no specific earth-moving directions in the tiedback wall Special Note. None of the other contract documents addressed this problem. Earth moving for a tiedback wall is significantly different from normal earthwork procedures. Staged removal is required to ensure adequate passive restraint in front of the wall until the tiebacks are stressed. This potentially difficult situation was left, by default, for the contractors to resolve. Fortunately, no serious conflicts occurred.

The wall was completed to the cabinet's satisfaction. There were some allowances in wall alignment criteria normally expected by the cabinet. However, these alignment criteria were set up for cast-in-place concrete walls and were not deemed necessary for a tiedback wall. This wall is pleasing to the eye and, in time, with vegetation on the down slope, will blend in quite well with its surroundings.

The wall was bid "lump sum" exclusive of the required earth moving. It was constructed for just over $31.10 per square foot of face. The square foot face measurement includes the lagging buried 2 ft throughout.

The results and final report of the instrumentation program for the Carroll County tiedback wall are unavailable at this time. However, preliminary findings are encouraging. During May 1984, very little wall movement was measured. At that time, the wall was essentially complete. By November 1985, movement had virtually ceased.

CAMPBELL COUNTY LANDSLIDE

In January 1984 the Division of Bridges was notified of another potential tiedback wall use. An active landslide had closed the northbound lanes of US-27 in northern Kentucky. This was classified as an emergency project.

This slide was north of Alexandria on US-27. US-27 was initially constructed as a two-lane facility and later widened to a four-lane facility by placing additional fill. The initial two lanes at the site were constructed in a cut-fill section. The slide affected about 300 ft of embankment with cracks and scarps reaching the roadway centerline. In places, the two northbound lanes of pavement had dropped as much as 8 ft. The failure of the added two lanes, built as a side-hill embankment, occurred during August 1983.

The geotechnical investigation of the slide was initiated at this time. The depth to rock at the shoulder was about 50 ft at the deepest point. The failure plane was estimated to be 10 ft above the rockline. The water table was deep. It was measured to be from 6 to 10 ft above the rockline. No structures were affected. The total drop from shoulder to toe was 50 ft at the critical section (Figure 3).

This slide is in the northern part of the Outer Bluegrass topographic region of Kentucky. The bedrock comprises interbedded limestones and shales. In addition to Kope formation shales, the shales are from the Fairview and Bull Fork formations. These shales are also highly weatherable and, when used in embankments, are a primary cause of slope instability. Compaction of these shales is inhibited by the presence of flaggy limestone slabs. These slabs prevent breaking down of the shales and cause voids in the fills by interfering with compaction equipment. Additional voids are created as runoff seeps through the fills and causes the shale to slake.

Three corrective measures were studied. One involved a flattened slope with a large berm at the toe. This was rejected because it required a prohibitive amount of additional right-of-way to achieve an adequate safety factor. The second alternative was a tiedback wall. This was initially rejected as being too costly. The most economical alternative was a combination shear key and berm correction.

During January 1984 the landslide problem was discussed among various divisions within the cabinet. The prudence of excavating for a shear key in an unstable area was questioned. An additional alternative, using stone columns, was suggested. However, the amount of soil to be replaced by stone columns was considered excessive. Extra right-of-way would also be required for this alternative.

The tiedback wall option was reconsidered and, in the end, selected for the correction. It was thought that actual con-

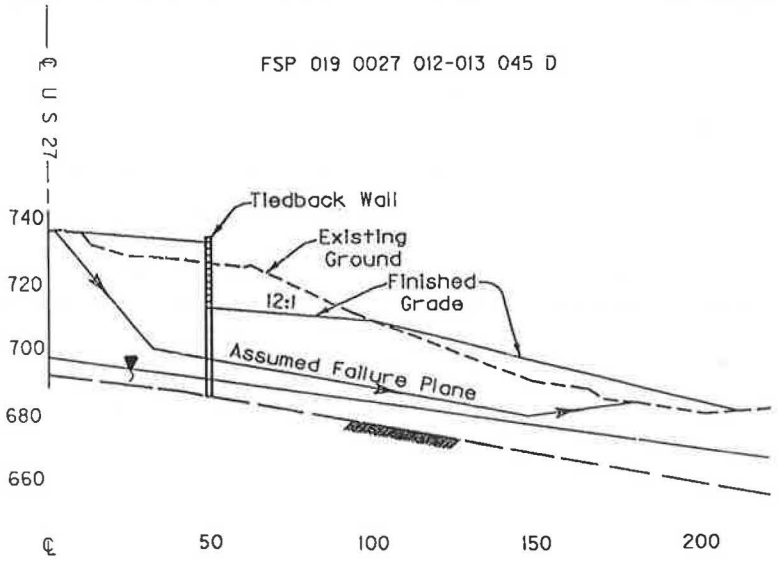

FIGURE 3 Campbell County slide correction.

struction of a tiedback wall could be initiated more quickly than the berm and shear key alternative. Construction of the berm and shear key alternative could not begin until the dry season in late spring. It was also thought that tiedback wall construction would be within the present right-of-way.

Because a Special Note for a timber-lagged, steel H-pile tiedback wall existed, the cabinet decided to use a similar wall for this landslide correction. The wall would be about 328 ft long and have 22 ft of exposed face at its tallest point.

Site-specific modifications were made to the note and it was mailed to interested wall contractors 6 calendar days after the decision was made to use a tiedback wall. These contractors were also notified of an on-site inspection of the landslide scheduled for January 18, 1984. Tentative scheduling was to have a bid opening 7 weeks from this date. This project was definitely a fast-track effort. Unfortunately, it was realized during the on-site meeting that the slide had moved significantly and new cross sections were needed. Consequently, the schedule was delayed 1 week.

The specialty contractor would be the general contractor on this project because the tiedback wall was approximately 80 percent of the project. Contractors were given 2 weeks to provide the cabinet with designs and plans for review and approval. After a week for the cabinet's review, contractors would have another 2 weeks to revise their designs and plans. Contractors who provided satisfactory final designs and plans would be notified to submit bids. Notification to the successful contractor was to be given 1 week from the cabinet's receipt of final plans.

Other than site-specific details, there were no significant changes in the note. There would not be an intensive instrumentation and monitoring program by KTRP. Slope inclinometers would be installed by cabinet personnel with the contractor's cooperation. At the ends of the lagged portion of the walls, two additional piles were to be installed. This was not done on the first project. These piles were to be identical to the piles in the last sections of the wall at each end. These end piles were in line with the wall and spaced the same as the last wall piles. This was to assist in containment of the slide and to allow for extension of the wall by cabinet personnel without the need for pile-driving equipment.

The wall contractor, as the prime contractor, was responsible for meeting the federal Minority Business Enterprise (MBE) requirements. This proved difficult because the wall itself constituted the major portion of the work to be performed on this project.

Construction of this wall had a significant difference from that of the Carroll County wall. The embankment had failed and the slide mass was still moving significantly. Many of the driven piles would have in excess of 10 ft of pile sticking out of the ground. Before tiebacks were installed, the area behind these piles would need to be partially excavated to remove loose material. Next the contractor would need to install lagging then backfill up to a certain elevation before installing any tiebacks. During the time between pile driving and tieback stressing, many piles were pushed out of alignment by slide movement. Consequently, the finished product has a lot of kinks in its alignment. This was not considered detrimental to wall performance and proved that the tieback solution could be applied to active slides.

A major oversight was the cabinet's method of paying for earthwork. The earthwork bid item for this project was "Roadway Excavation," which is paid plan quantity unless the cabinet changes the scope of work. Needless to say, the quantity bid did not agree with the quantity to be handled at the time of construction. The bid quantity was based on cross sections taken 3 months ahead of time and this was an active landslide. The problem was not so much the quantity involved as the handling of the material and the unsuitability of some of the material for backfill. In the end, material had to be hauled to waste sites and borrow material brought in for embankment construction.

The lack of sufficient geotechnical data created a problem with ordered pile lengths. Drilling was not done near the ends of the wall. A projected rockline was used on the contract plans. The rockline encountered was 10 to 20 ft below the projected rockline at the ends. Though the contractor was paid for the additional pile length required, pile splicing, which had not been anticipated, was required. Because approximately 100 ft, or one-third, of the wall was affected, this had a significant effect on construction scheduling. It was imperative to have quick and efficient wall construction to ensure that the slide did not progress to the point where the remaining two lanes of US-27 would be closed.

This wall was bid lump sum exclusive of excavation and other roadway items. In addition to the lump sum bid, the wall contractors were to submit unit price bids for wall components. This would provide a convenient method for possible wall extension during construction. It would also give the cabinet an idea of the cost of tieback installation as a function of size and capacity of the tieback.

This wall, excluding earth moving, was constructed for just over $49.60 per square foot of face. The square foot of face measurement includes the lagging buried 2 ft throughout.

CONCLUSION

Kentucky had had essentially no experience in tiedback wall construction when the Carroll County slide correction was initiated. To prepare a detailed set of plans and specifications, the cabinet had to rely on contractor personnel for guidance. However, the cabinet wanted to maintain control of the design. The performance specification option was selected because it permitted shared responsibility for design, construction, and performance of the completed tiedback wall. By reviewing the various designs submitted by contractors, cabinet personnel would gain considerable knowledge for the future.

The intent of the technical prequalifications and design and plan development requirements was to prevent contractors inexperienced with tiedback walls from participating in the wall contract. It was thought that this would ensure adequate design, efficient construction, and a cost saving. It was particularly important that the cabinet's first attempt at tiedback wall construction be well thought out from design through construction to maintenance. Conflicts or litigation would unfairly preclude consideration of tiedback walls for future use.

Target dates are good. Otherwise, tasks may never be completed. However, completion dates that are controlled by contract letting dates can prove costly. Potential contractors are left

out of the process. Prices are inflated to cover uncertainties that time does not permit contractors and the contracting agency to address. Time did not permit predesign or prebid conferences on the Carroll County project. Still, with all these snags and difficulties, all the specialty contractors were most cooperative. They continually went above and beyond the normal effort expected to assist the cabinet in obtaining a workable Special Note.

A prebid performance specification is a good way to get started in the tiedback wall business. The contracting agency gets exposed to many different wall concepts and design philosophies. The agency establishes the scope of work and maintains control over the type, size, location, and design of the wall. The contractor is free to select an economical tieback system within the guidelines provided. Responsibility for the finished wall is shared between the agency and the contractor. An environment of cooperation is practically mandated. Cost savings through a design and construct effort are recognized. Participation and innovation by qualified contractors are certain to be obtained by the contracting agency.

It is recommended that agencies unfamiliar with tiedback wall design and construction pattern their first efforts after the sample specification in the FHWA *Tiebacks* Report *(1)*. Modifications will certainly be necessary. In particular, the method of handling stage removal of earth in front of the wall should be covered in detail. When the wall contractor is not doing the earthwork, specific guidelines and instructions should be included in the note. In some cases, a signed agreement between the two contractors may be necessary.

Plan quantity should not be the pay item for active slides. Pay items for field measuring, soil manipulation, waste, and borrow should be considered. Flexibility in payment methods would enhance contract performance.

Contractors should be provided with identical design lateral pressure diagrams. Modifications should be permitted after tieback designers have reviewed the Special Note. However, the final design provided by all contractors should be based on the same diagram.

Kentucky is considering switching to a postbid performance specification for future tiedback walls. Now that the cabinet has gone through an in-depth educational process for two tiedback walls it is believed that there is sufficient expertise within the agency to take this step. This should increase the cost savings and would certainly decrease the cabinet's review time.

The cabinet would still set the scope of work, describe the type of wall required, and outline the design criteria. The major effort before bidding would be placed on contractor qualification requirements. In addition to company qualification requirements related to design and to professional engineers employed, emphasis would be placed on the company's people who would be doing the actual wall construction. Experience requirements would be established for the superintendent, the foremen, the drillers, and the stressing foreman. In particular, foremen, except the stressing foreman, would be required to be at the jobsite at any time construction is in process.

It is preferred that the tiedback wall contractor be the general contractor. When the wall contractor is a subcontractor, the general contractor should be required to specify the wall contractor selected. A signed agreement between the two should be a required submission of the bidding package.

A well-written postbid performance specification will permit prebid tiedback wall contractor approval with postbid design approval agreeable to all parties involved. The contracting agency obtains a design and build project and still gets a competitive bidding effort.

REFERENCE

1. D. E. Weatherby. *Tiebacks*. Report FHWA-RD-82-47. FHWA, U.S. Department of Transportation, 1982, pp. 120–128.

Publication of this paper sponsored by Committee on Transportation Earthworks.