Horizontal Drilling by Using an Oriented Core at Wheeler Junction, Colorado

CHARLES S. ROBINSON

A horizontal diamond-bit core hole (7.30 cm in diameter) was drilled near Wheeler Junction in 1969 in conjunction with the studies for a possible tunnel on Interstate 70 about 148 km west of Denver. The tunnel, about 450 m long, was to be driven through a prominent ridge to reduce the length and the environmental impact of construction of I-70. The ridge is composed of highly sheared and partially altered Precambrian metasedimentary and granitic rocks within the Mosquito fault zone. The core hole was drilled along the east side of the proposed twin tunnels at about the invert of the westbound lane. The bearing and plunge of the hole were controlled by surveying and the use of wedges, and the core was oriented. Geotechnical and geologic data in their true relation to the alignment of the proposed tunnel were obtained from the oriented core. Horizontal drill holes from which oriented core is obtained can be used to obtain geotechnical and geological data for the design and construction of a tunnel at a much lower cost than would have been required for the driving of a pilot tunnel. The only limit to the use of the technique is the present equipment's ability to drill holes of no more than 1750 m.

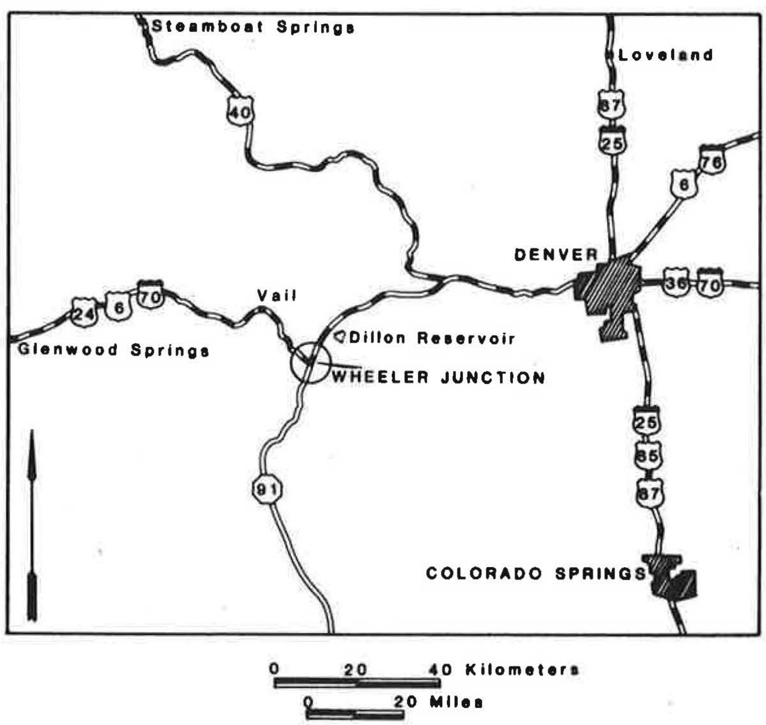
In the studies for the alignment of Interstate 70 west of Denver, Colorado, the feasibility of constructing a tunnel through a prominent rock ridge near Frisco, Colorado, was considered. To evaluate the geologic conditions, a diamond-bit core hole 7.30 cm in diameter was drilled. By controlling the core hole and by orienting the core, it was possible to obtain knowledge of the geotechnical and geologic conditions at depth along the tunnel at a considerably lower cost than would have been required to drive a pilot tunnel.

The rock ridge was along Ten Mile Creek about 9 km southwest of Frisco and about 1 km northeast of Wheeler Junction--the junction between I-70 and CO-91 (Figure 1). The area is typical of the high glaciated mountain areas of Colorado; it has deep, U-shaped valleys bounded by steep cliffs. The area was at the south end of the Gore Range in the central part of the southern Rocky Mountains. The rocks in this area are Precambrian metasedimentary rock (chiefly varieties of gneiss) that were intruded by Precambrian granitic rocks. At the proposed tunnel site the bedrock is cut by the Mosquito fault. The Mosquito fault is a major structure in Colorado. About 22 km southwest of Wheeler Junction, at Climax, Wallace (1) estimates that there has been about 2700 m of displacement along the fault. At the proposed tunnel site the rock is highly sheared, silicified, and cut by quartz veins that contain minor amounts of sulfide minerals.

The crest of the prominent ridge is more than 122 m above Ten Mile Creek. The purpose of a tunnel through the ridge was to shorten the highway between Frisco and Wheeler Junction and to reduce the environmental impact of the highway. The alternative to the tunnel was a high cut along Ten Mile Creek.

The investigations for the proposed tunnel included detailed geologic mapping of the surface in the vicinity of the tunnel and the drilling of a core hole at about the invert on the east side of the westbound lane. The geologic mapping was initiated by Charles S. Robinson and Associates under a contract with the Colorado Division of Highways in July 1969. The core drilling was done by Boyles Brothers Drilling Company. The core hole was surveyed and directionally controlled, and the core was oriented and logged by Charles S. Robinson and Associates. Drilling started August 1, 1969, at the

Figure 1. Index map that shows location of Wheeler Junction, Colorado.



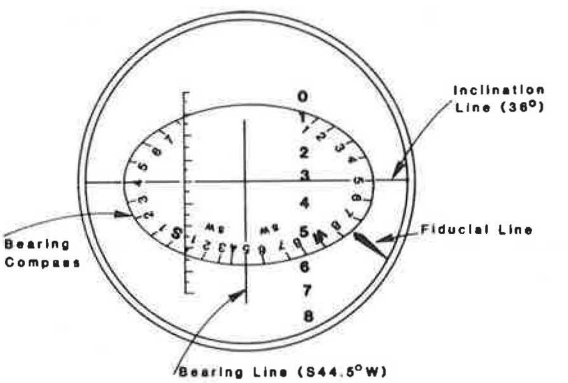
west end of the proposed tunnel and was completed to a depth of 359 m by November 15. A hole from near the east portal was started December 15, 1969, and drilled to 157 m by March 15, 1970.

HORIZONTAL DRILLING

Horizontal drilling has been conducted for drainage of slopes, for removal of methane from coal mines, and for exploration in the mining and the construction industries. The prinicipal reason for the use of horizontal drill holes in underground construction is to determine geologic conditions before construction. The alternative, in tunnel construction, is a pilot tunnel, which gives more-complete information but, depending on conditions, will cost about 10 times as much as will a horizontal drill hole. Horizontal drilling for tunnel construction apparently was first used about 1964 (2). Drilling methods have included diamond-core drilling, rotary drilling, and in-hole percussion-type drilling. The longest hole (1615 m) was drilled as part of the investigations for the Seikan tunnel project in Japan and was drilled by using a rotary bit. Most holes more than 610 m long are drilled by using diamond-coring techniques (2). The longest horizontal diamond-core hole (1220 m) is reported (2) to have been drilled in South Africa.

To drill the hole at Wheeler Junction, a Longyear 44 was mounted on a 3-m^3 block of concrete. The contract between the Colorado Department of Highways and Charles S. Robinson and Associates required a continuous core hole of about 457 m that had the core oriented and no more than 1 percent deviation. The drill was aligned by transit along the line of the hole. The drilling was NX size by using wire line and a double-tube core barrel. Drilling from the west end had advanced to a depth of 360 m when the hole had to be abandoned because two wedges used to control the direction of the hole became stuck. A second core hole was started near the east portal of the proposed tunnel and drilled to a depth of 157 m.

Figure 2. Survey disk for Eastman R Single Shot.



SURVEYING AND CORE ORIENTATION

The surveying of the drill hole and the orientation of the core were done with the use of an Eastman Oil Well Survey Company R Single Shot instrument. The R Single Shot records on a photographic disk the magnetic direction and the inclination of a point in an uncased drill hole. The recording is made by inserting the instrument to a predetermined depth. The position of a very sensitive plumb bob is photographed in reference to a calibrated compass card and a concentric-ring glass. Figure 2 is an example of the survey disk for an Eastman R Single Shot. The hole was surveyed at intervals of 8-30 m or whenever an orientation of core was required.

Core orientation was done by using a special core-scribing tool that was aligned with the Eastman R Single Shot. Figure 3 is a schematic drawing of the scribing tool.

To orient the core, the retaining ring in the core barrel and the liner of the core barrel were removed and approximately 25 cm of core was drilled. The rods, core barrel, and bit were removed from the hole. An aligned assembly (which consisted of the scribing tool, the surveying instrument in the instrument case, and four aluminum rods) was attached to the drill rods and inserted or pumped into the hole. The fiducial line in the surveying instrument is aligned with the fiducial knife edge in the scribing tool. The scribing tool was forced over the stub of rock left in the hole in order to scribe lines down the side of the core. The assembly was left stationary in the hole long enough for the survey instrument to record the bearing and inclination of the hole and the fiducial line. The drill rods were rotated about a quarter turn to break off the rock stub, and the rods, surveying tool, and scribing tool were extracted from the drill hole together with the rock stub. The scribed rock stub was removed from the scribing tool and placed in the core box so that it lay with the fiducial line up. Core in the core box and additional core drilled were oriented by matching pieces with the scribed stub. The fiducial line was marked on the matching core by using a chalk line or by using a straightedge and a felt-tipped pen.

Figure 3. Core-scribing tool.

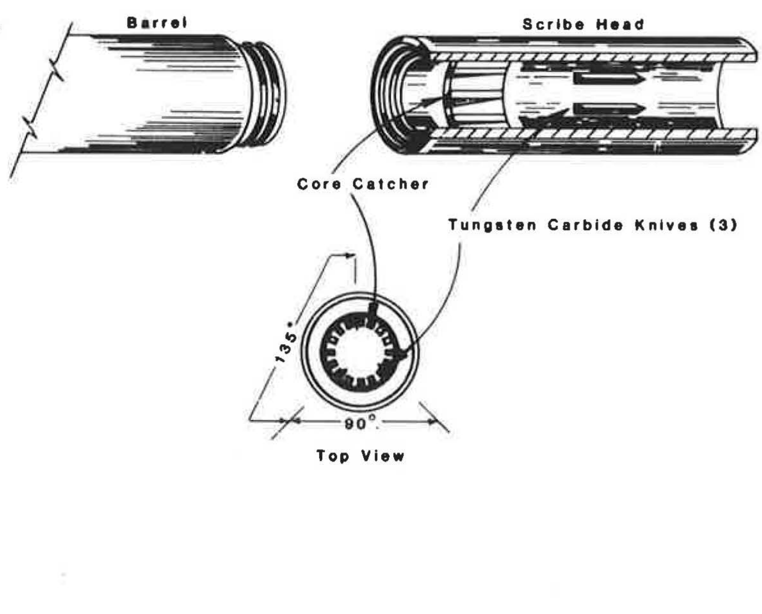


Figure 4. Data recording sheets for oriented core.

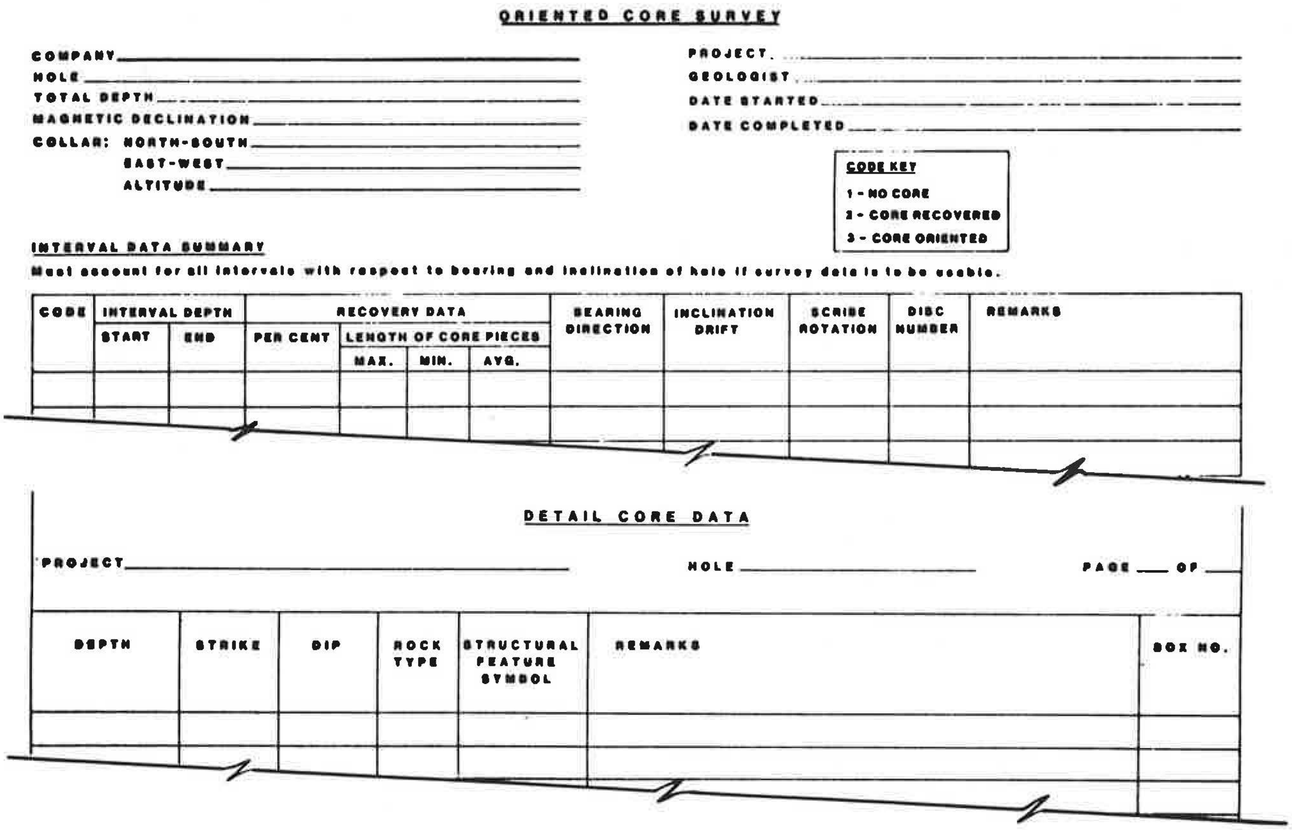
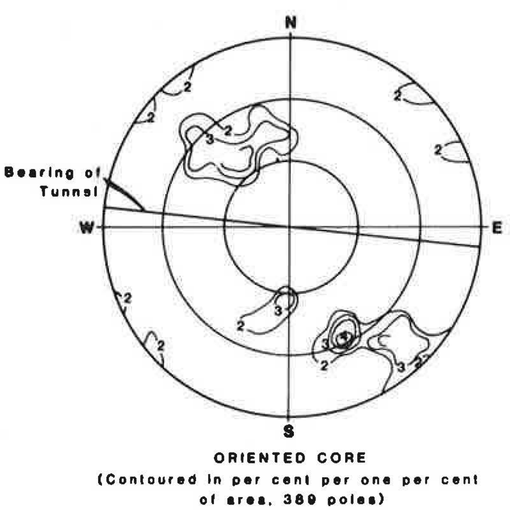


Figure 5. Equal-area diagram of the attitude of joints in core from the Wheeler Junction hole.



Orientation was lost when the pieces in the box could not be matched--for instance, when drilling through a fault zone. The procedure for orienting the core was then repeated. Orientation runs were made whenever orientation was lost or at least every 20 m.

RECORDING GEOLOGIC DATA

The core was logged geologically, and structural data were recorded based on the assumption that the fiducial scribe line and the axis of the core defined a plane that passed through the center of the core. The plane was assumed to strike north and dip vertically. Figure 4 is an example of the data recording sheets.

The standard information (company, hole number, total depth, geologist, date started, date completed, coordinates of collar, and magnetic declination) are recorded in the heading of the first sheet. In addition, a code is used to specify whether core was recovered and whether the core was oriented. The interval drilled, data on core recovery, and in-hole survey data are tabulated.

The geologic data are recorded on a separate sheet (lower part of Figure 4). Rock type and the attitude of structural features such as the foliation, joint, or veins are recorded in reference to the orientation plane. A code system for different types of structural elements has been developed to facilitate computer input of data. The code used is designed for each geologic environment.

DATA REDUCTION

At the time when the horizontal hole at Wheeler Junction was drilled, the only technique used to determine the true attitude of geologic features was the use of a core goniometer. The goniometer consisted of three graduated circles of right angles and a core holder. An oriented piece of core is placed in the core holder and the three graduated circles are rotated until the core is in its surveyed position. The planar features can then be measured in relation to true bearing and horizontal plane by a compass or protractor.

The data for this project were reduced by using a Schmidt equal-area net. A data point, such as the attitude of a joint, was plotted as a pole on a Schmidt equal-area net and the net rotated to the bearing of the drill hole. The true attitude of the joint could then be read and correctly recorded. The true attitudes of foliation, joints, faults, and veins were then compiled on equal-area diagrams. Figure 5 is the resultant equal-area diagram of the joints in the core.

In present practice, the data reduction has been greatly simplified. Survey and geologic data are now punched on cards, and a program has been developed to plot a plan and profile of the drill hole, to correct the attitude of planar elements to their true position, and to plot and contour the equal-area nets.

HOLE DEVIATION

Each time that a core orientation is taken, the bearing and plunge of the hole are known. When deviation in the bearing or plunge of the hole

Figure 6. Standard 1.5° wedge, orientation assembly, and drilling assembly.

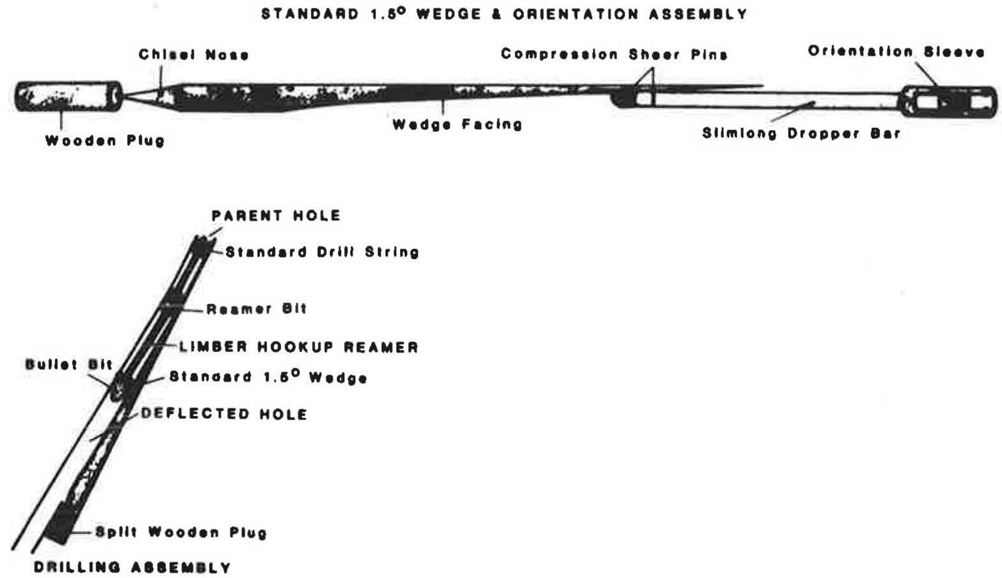
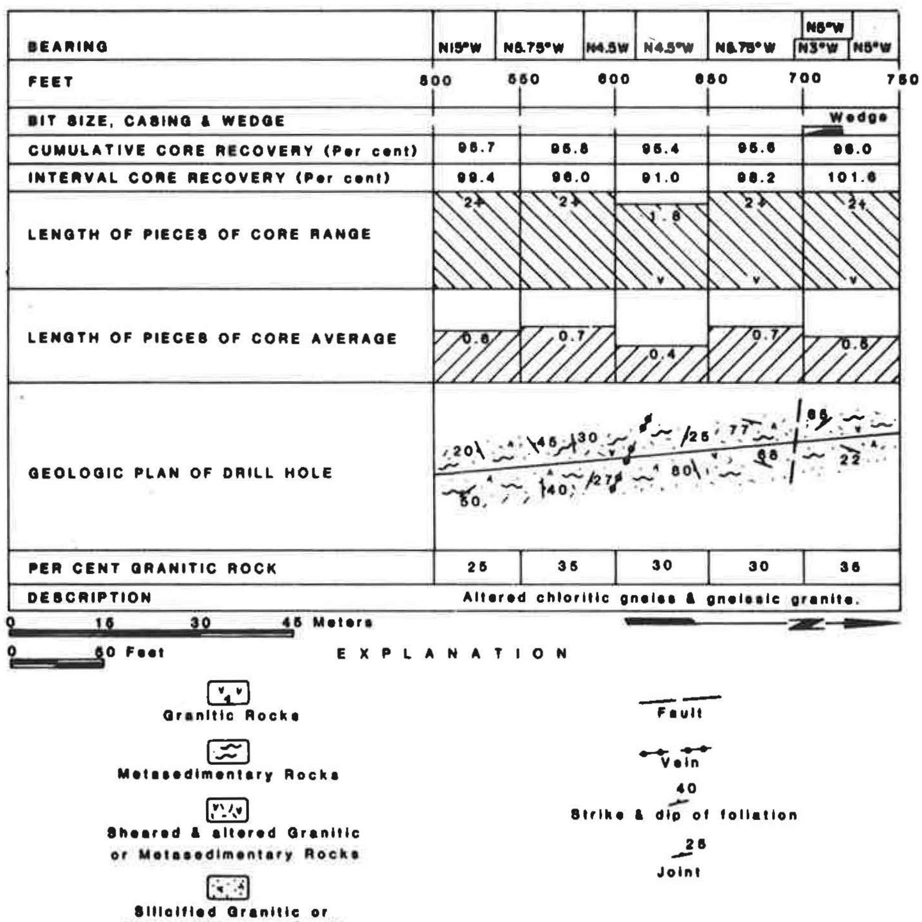


Figure 7. Portion of geologic map of drill hole no. 1, Wheeler Junction.



exceeded 1° from the planned alignment, the hole was whipstocked to the correct bearing and plunge by the use of a wedge. The wedge (Figure 6) is a carefully machined bar of steel. An NX wedge is 7.30 cm in diameter and 2.44 m long. The face of the wedge is machined to form a curved face with an angle of 1.5°. The nose of the wedge is a chisel point. The position of the wedge is fixed in the hole by a fast-swelling wooden plug that is split by the chisel point of the wedge.

The wedge is positioned in the hole by using the Eastman R Single Shot surveying instrument so that the face is in the required direction to deflect the hole. As in taking oriented core, the fiducial line of the instrument is aligned by using an orientation sleeve and a slimlong dropper bar. The slimlong dropper bar is aligned with the face of the wedge by shear pins. The wooden nose plug and the wedge and instrument assembly are inserted in the hole at the end of the drilling rods and the orientation of the face is determined by taking a survey. The face of the wedge is then rotated to the desired position and a check survey is made. When the correct position of the face of the wedge is obtained, hydraulic pressure is applied to the drill rods, the chisel point on the wedge splits the wooden plug, and the pins that hold the wedge to the slimlong dropper bar are sheared. The entire orientation assembly is then withdrawn from the hole.

The new hole direction is obtained from the face of the wedge by drilling with limber hookup. A bullet-nosed bit smaller than the desired diameter of the hole is put on the front of a small-diameter steel rod. A reamer bit the size of the desired hole and a short length of solid rod are attached behind the bullet-nosed bit and rod (Figure 6). The entire limber hookup is attached to the standard drill string.

RESULTS

Figure 7 is a portion of the geologic map (plan view) of drill hole 1 at Wheeler Junction prepared from the oriented core. Geotechnical data recorded included the bearing of the hole; footage; bit size, casing, and location of wedges; percentage of core recovery; and the range and average size of pieces of core recovered. The geologic data recorded included rock type and the attitude of the foliation, joints, faults, and veins.

CONCLUSIONS

Oriented-core horizontal diamond-drilled holes can be used to determine the geological and geotechnical data for the design and construction of tunnels in rock. Technology is available to drill and control the bearing of core holes and to obtain oriented core from which geologic data can be recorded. The cost of drilling oriented diamond-core holes is considerably less and requires less time than the construction of a pilot tunnel to obtain the same data. The apparent limit on the use of oriented diamond-core holes is length. Present drilling equipment is capable of drilling holes to about 1750 m.

REFERENCES

1. S. R. Wallace, N. K. Moncaster, D. C. Jonson, W. B. McKenzie, A. P. Bookstrom, and V. N. Surface. Multiple Intrusion and Mineralization of Climax, Colorado. In Ore Deposits of the United States (S. D. Ridge, ed.), Society of Mining Engineers of AIME, Salt Lake City, UT, 1968, Vol. 1, pp. 606-640.
2. J. C. Harding, L. A. Rubin, and W. L. Still. Drilling and Preparation of Reusable, Long-Range, Horizontal Bore Holes in Rock and Gouge. Federal Highway Administration, U.S. Department of Transportation, Rept. FHWA-RD-75-95, 1975, Vol. 1.

Publication of this paper sponsored by Committee on Engineering Geology.

Mississippi's Experience with Horizontally Drilled Drains and Conduits in Soil

WENDEL T. RUFF

This paper relates the experience of the Mississippi Highway Department (MHD) with horizontally drilled drains and conduits in soil. MHD has used horizontally drilled drains that had an inside diameter of 3.8 cm (1.5 in) and conduits that had an inside diameter of 12.7 cm (5 in) with interconnecting vertically drilled drains to effectively achieve subsurface drainage. The advantages of drilled drains and conduits over trench excavations (to eliminate the risk associated with the latter) are discussed. Two case histories are described. The first describes the use of large-diameter interconnecting vertically drilled shafts to create a drainable reservoir in a deep irregular formation. The second describes the use of long horizontally drilled perforated drains to reduce the water table in an active landslide.

The primary cause of landslides in Mississippi can usually be traced to inadequate subsurface drainage. Likewise, the correction of all stability problems generally includes some method of relieving subsurface hydrostatic pressures or controlling seepage. This paper describes the experience of the Mississippi Highway Department (MHD) in accomplishing subsurface drainage by using horizontally drilled drains and conduits.

Simply defined, horizontally drilled drains are small-diameter wells drilled nearly horizontally into a hill or embankment for the purpose of removing groundwater and controlling seepage (1). Their purpose and benefit is to lower the water table rather than to serve as a seepage cutoff wall, as would be the case in trench-excavated interceptor drains. The most common horizontally drilled drainage pipe is Schedule 80, type II polyvinyl chloride that has an inside diameter of 3.8 cm (1.5 in), which conforms to ASTM D-1785. The pipe has two rows of slots cut around the circumference of the pipe on two of the one-third points (120° apart).