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A BRIEF GEOLOGICAL REPORT ON THE STRAIGHT CREEK TUNNEL

BY JOHN O. POST, RESIDENT GEOLOGIST

The Straight Creek Tunnel is a twin-bore vehicular tunnel located 55 miles west of Denver. It will carry Interstate Route 70 traffic under the Continental Divide in the Rocky Mountains in central Colorado. The tunnel, at an elevation of about 11,050 feet, is the highest ventilated tunnel in the world, and it is the largest Federal-aid highway project ever to be let as a single contract. The tunnel is 1.7 miles long and has a maximum overburden of 1,450 feet. Each bore will be excavated roughly 48 feet wide and 50 feet high and will carry two lanes of traffic. The Straight Creek Tunnel is of special interest to engineering geologists as it affords them the opportunity to compare the results of a tremendous amount of pretunnel investigation to the results as now found in the north tunnel bore.

East Portal of Straight Creek Tunnel, showing approach road and regional terrain.

The geology of the site for the Straight Creek Tunnel was mapped in the summer of 1962 by U. S. Geological Survey personnel. They found that bedrock was 75 percent granite, and 25 percent metasedimentary gneiss and schist that occurred as migmatite inclusions. The bedrock was cut by numerous shear zones, faults, and joints that would affect the construction of the tunnel. In conjunction with the geologic mapping, several coreholes were drilled, and a seismic survey was run along the tunnel alignment.

The information obtained from surface coreholes was limited as the holes were at right angles to the tunnel. They made up for this in that they provided a third dimension to the surface geology. Fracture density was one of the most important structural features affecting tunnel construction, and the coreholes were among the best ways to obtain this information. The electric logs that were run in the coreholes showed that resistivity and gamma-ray logs were of value in locating fracture zones and delineating the metasedimentary rock, which was carrying or saturated with water. Horizontal coreholes would have been useful, if driven from the portals, to provide information on the geologic conditions along the tunnel alignment through the critical "turning under" interval of the tunnel.

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1971-COMING EVENTS-1971

October 3-6: Society of Petroleum Engineers of AIME, annual meeting, New Orleans (O. L. Oucate, 6200 North Central Expressway, Dallas, Texas 75206).

October 4-5: Seminar on Geologic Atlas of the Rocky Mountain Region and Symposium on Stratigraphy and Exploration, by Rocky Mountain Association of Geologists, Denver (J. E. Luken, PetroLewis Corp., Denver, Colorado 80202).

October 4-6: International Society for Rock Mechanics, symposium, Nancy, France (Rene Houpert, Symposium de la SIMR, E.N.S.G., BP452, 54 Nancy, France).

October 8-9: American Institute of Professional Geologists, annual meeting, Denver (R. M. Lindwall, USGS, Denver Federal Center, Denver, Colorado 80225).

October 19-22: Association of Engineering Geologists, annual meeting, Hilton Hotel, Portland, Oregon (R. K. Dodds and J. L. Holland, Co-Chairmen, P.O. Box 8708, Portland, Oregon 97208). The program will include symposia on "Instrumentation — Practical Applications and Results" and "Rock Support Systems — Underground and Open Excavations" as well as papers on other aspects of engineering geology.

November 1-3: Geological Society of America, annual meeting, Washington, D. C. (Also associated societies: Geochemical Society, Geoscience Information Society, Mineralogical Society of America, National Association of Geology Teachers, Paleontological Society, Society of Economic Geologists, Society of Vertebrate Paleontology.) GSA Headquarters, Box 1719, Boulder, Colorado 80302.

November 8-9: Remote Sensing of Earth Resources and the Environment, seminar, North Hollywood, California (Society of Photo-optical Instrumentation Engineers, Box 288, Redondo Beach, California 90277).

December 6-9: Underground Waste Management and Environmental Implications, by U.S. Geological Survey and American Association of Petroleum Geologists, Houston (H. R. Gould, Esso Production Research Co., Box 2189, Houston, Texas 77001).

December 6-9: National Water Well Association, annual meeting, Las Vegas, Nevada (J. H. Lehr, National Water Well Association, 88 East Broad Street, Columbus, Ohio 43215).

EARTHQUAKES THEME FOR AIME SAN FRANCISCO MEETING

CALL FOR TECHNICAL PAPERS IN GEOLOGICAL ENGINEERING

The 1972 AIME Annual Meeting will be held in San Francisco, February 20-24, 1972. The general theme of the geological engineering sessions will be consideration of earthquakes and earthquake-related phenomena in design. The Annual Meeting will be attended by several thousand engineers and geologists from the mining, metallurgy, and petroleum fields.

If you would like to submit a paper for consideration, please send the title and a very short summary of the paper to me. If you are aware of other papers, or authors who may have papers worthy of consideration, please submit their names and I will contact them directly.

Henry Klehn, Jr., Program Chairman
American Institute of Mining,
Metallurgical and Petroleum Engineers
Society of Mining Engineers
Geological Engineering Unit Committee

ASCE PLANS JUNE CONFERENCE

A Conference on Performance of Earth and Earth-Supported Structures, sponsored by the Soil Mechanics and Foundations Division, American Society of Civil Engineers, will be held at Purdue University, Lafayette, Indiana, Monday, 12 June, through Wednesday, 14 June, 1972.

Papers will include the results of site studies, analyses (or predictions) of behavior, and performance measurements. Comparison of predictions with performance, and conclusions therefrom, are encouraged.

Session leaders will prepare a historical review of the session topic, critically analyze papers submitted to the conference, and lead panel discussions. Panel members will discuss the session leader's report, establish areas of agreement, and debate conflicting viewpoints. A reporter is assigned to synthesize panel deliberations and discussions from the floor.

The technical sessions and session leaders are:

I. EMBANKMENTS ON SOFT GROUNO: L. Bjerrum, Oirector, Norwegian Geotechnical Institute. Total, neutral, and effective stress distributions — and corresponding strain distributions — initially and as a function of time, in the embankment and its foundation; stability and stabilization measures.

II. EARTH AND EARTH-ROCKFILL DAMS: J. Lowe, III Partner, Tippetts-Abbett-McCarthy-Stratton. Stability and integrity of embankments; settlements and their effects; cracking of impermeable cores and membranes. Measures to control and monitor seepage, including rapid drawdown; stability of reservoir slopes.

III. SHALLOW FOUNDATIONS: D. C. Moorhouse, Principal, Woodward-Moorhouse & Assoc. Isolated and combined footings and rafts in shallow or deep excavations; stabilizing measures, including preloading, compacted bearing strata, etc.; tolerable displacements of structures.

IV. DEEP FOUNDATIONS: B. McClelland, Principal, McClelland Engineers, Inc. Oriven and bored piles, piers, and caissons; construction problems. Behavior of individual piles considered only in relation to over-all foundation performance.

V. SOIL-STRUCTURE INTERACTION: R. B. Peck, Professor, University of Illinois. Tunnels and conduits; locks and cantilever walls; braced and tie-back walls, slurry trenches; anchored bulkheads, and cofferdams.

Extensive exhibits of laboratory and field measuring devices are planned at the conference. Further information may be obtained by writing to Prof. G. A. Leonards, School of Civil Engineering, Purdue University, Lafayette, Indiana, USA 47907.

NOTICE OF COMMITTEE MEETING

The Committee on Construction Materials, under the chairmanship of Erhard M. Winkler, has made arrangements to convene at the GSA annual meeting in Washington on Monday, November 1, from 7 to 8 p.m. Time and place will be published in the program for the meeting. The following topics will be discussed: an annual, short annotated bibliography of recent papers, liaison with other committees, needs for applied research, and a closed session at the annual meetings. The presence of interested people will be welcomed.

NOMINATIONS FOR BURWELL AWARD

The E. B. Burwell, Jr., Memorial Award of the Engineering Geology Division is made to the author or authors of a published paper of distinction which advances knowledge concerning principles or practice of engineering geology or of the related fields of applied soil or rock mechanics where the role of geology is emphasized. Although the paper shall have been published not more than five years prior to its selection, there is no restriction as to the publisher or publishing agency. The author or authors of the selected paper need not belong to the Engineering Geology Division or the Geological Society of America and need not be residents or citizens of the United States. A certificate and cash award will be presented to the recipient at the annual Engineering Geology Division luncheon.

The recipient of the award is selected by a six-member committee appointed by the Management Board of the division. However, any member of the division may nominate a paper or papers for consideration by the Award Committee by sending the name of the nominee, the title of the paper, and its publication source not later than January 15, 1972, to the Secretary of the Engineering Geology Division.

PLANNING NEW TOWN'S ENVIRONMENT DISCUSSED AT AIPG CONFERENCE

The American Institute of Professional Geologists, with funding by the National Science Foundation, sponsored an interdisciplinary conference on "Planning a New Town's Environment" March 14-16, 1971, at the Airlie House, Warrenton, Virginia. Attendance, by invitation, was limited to 55. Although not directly involved in planning the conference, GSA and the Engineering Geology Division were well represented at the conference. Dr. Richard H. Jahns, President of GSA, presented the keynote address. Then, four papers on geologic topics relating to environmental problems were presented. The speakers and their topics were James E. Slosson, Terrain Analysis; Phillip E. LaMoreaux, Water Supply; Robert L. Bates, Mineral Resources; and Paul L. Hilpman, Waste Management.

Both Paul Hilpman and James Slosson are members of the Engineering Geology Division; Paul is also a member of the Division's Joint Committee on Engineering Geology with ASCE. Two other members of this committee, Richard E. Gray and Harry F. Ferguson, were present as ASCE representatives. Other members of the Division present were Emery T. Cleaves, James Dunn, Peter T. Flawn, 8ruce M. Hall, John B. Ivey, Richard W. Lemke, and Henry H. Neel. Following presentation of these papers, the geologists and representatives from the disciplines of architecture, landscape architecture, civil engineering, and planning divided into interdisciplinary teams, which then worked on planning a new town in central Pennsylvania. It was the general consensus of those attending that the conference demonstrated the value of geology in environmental planning. The interplay of the various disciplines in the team planning process was instructive to all.

GSA-ASCE COMMITTEE MEETING HELD AT PHOENIX ASCE MEETING

The Joint GSA-ASCE Committee on Engineering Geology met during the Phoenix ASCE Meeting in January 1971, at which it sponsored a technical session on the topic of "Geologic Aspects of Subsurface Waste Disposal." The following three papers comprised the session: "A Deeper Look at Deep Well Disposal," by Neilson Rudd; "Underground Disposal of Radioactive Wastes," by William C. McClain; and "Sanitary Landfill: Scientific and Engineering Criteria," by George M. Hughes and Keros Cartwright.

With respect to technical sessions at future meetings, members of the Committee on Engineering Geology were assigned to (1) investigate having a session at a GSA meeting on environmental mapping techniques, (2) investigate holding a session at an ASCE meeting on fine-grained sedimentary rocks, and (3) organize a joint session, with ASCE's Committee on Pipeline Location, on geological problems affecting pipelines.

Committee members are R. E. Gray, Chairman, T. C. Kenney, Secretary, F. D. Patton, R. E. Olson, N. Twelker, E. B. Waggoner, H. Ferguson, and P. Hilpman. The latter two are the Engineering Geology Oivision's appointees.

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The surface refraction seismic work was an experimental program that attempted to reproduce geology as shown in the coreholes. The program produced little useful information.

The depth of the proposed tunnels in a complex geologic setting made the prediction of other than major structures nearly impossible. The projection of major shear zones and estimated percent of rock types proved very good. Predictions on tunnel support, water volumes, lagging, grout, and rock loads all had to be revised considerably.

A slope stability study warned of a problem at the West Portal, and the ventilation building was relocated farther from the hillside. During the excavation of the East Portal, the toe of an unstable slope was cut out, and a two-million-cubic-yard landslide was set in motion. The pilot bore tunnel was realigned, and the grade was lowered to get away from the lower slip plane at the toe of the slide. The landslide largely stabilized itself, and a buttress fill was placed against the toe.

East Portal of Straight Creek Pilot Bore Tunnel

A pilot tunnel was driven along the alignment of the future South Tunnel Bore during 1963 and 1964 in order to obtain the engineering and geologic data required to design, finance, and construct the North Tunnel Bore of the Straight Creek Tunnel.

The Colorado Division of Highways and the U. S. Geological Survey performed geologic investigations in the pilot bore, which included mapping rock types, determining the degree of decomposition and alteration of the rocks, recording density and orientation of fractures, plotting foliation, and tracing shear zones and faults. Projection of rock types and geologic structures to the proposed alignment of the future north tunnel, at a distance of from 130 feet to 260 feet, was also undertaken. Related information recorded included initial and total water volumes, relative size of recommended support and spacing of sets, percentage of crushed timber, and the amount of floor heave. Laboratory studies performed on rock samples included triaxial tests and mineralogy, and volume changes of clay and fault gouge.

The pilot bore was highly instrumented under a rock mechanics program, the object being to gain information needed by the tunnel designers and the construction engineers. Load cells were placed in various arrangements in the steel supports to determine loads; multiple-position-borehole-extensometers (MPBXs) were used to measure the amount of movement and depth of the tension zone around the tunnel; and bar extensometers were installed to measure the inward deflection of the rock.

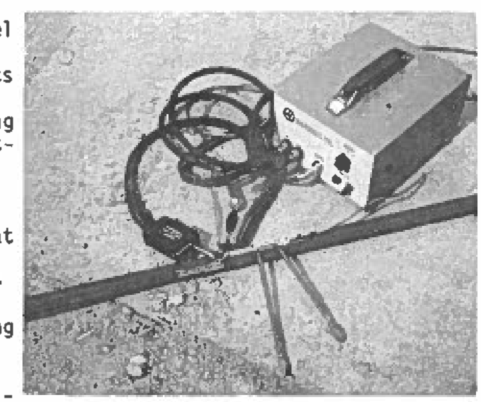
The instrument arrays were used during construction of the pilot bore to indicate where load buildups were occurring, and to indicate the relationship of horizontal to vertical loads. This information aided engineers in deciding the type of steel supports needed, their spacing, and if invert struts were necessary. Most of the load cell instruments had just been developed, and problems occurred because of improper calibration, eccentric loading, and the fact that they were not always waterproof. The MPBXs were often difficult and time-consuming to install, which interfered with the heading advance. Considerable time was required to reduce the MPBX readings and analyze the results.

The pilot bore was completed in January 1965, and the data were turned over to Tippetts-Abbett-McCarthy-Stratton Engineers and Architects for preparing the plans and specifications for the project. The design engineers relied heavily on the engineering-geological data. They were able to design the tunnel support and lining requirements for four different classes of rock, and estimate the quantities of materials accordingly. The plans and specifications were the primary source of information for interested contractors in determining their cost estimates for the bids.

The Straight Creek Tunnel contract was awarded to Al Johnson Construction Company, Gibbons and Reed Company, Western Paving, and Kemper Construction Company as joint partners, in November 1967, for $49,576,412, with three years to complete the construction. This contract was only for the North Tunnel, stubbing in the South Tunnel, and construction of the ventilation buildings and installation of equipment. The contractor chose the "Top Heading and Bench" method of excavation for most of the tunnel. The top heading operation worked well in the competent rock in the west half of the tunnel. The bench was removed by downhole drilling with airtracs similar to an open cut operation. The top heading in the eastern one-fourth of the tunnel was driven through more difficult rock, and considerable breast-boarding was done at the face. "Forepoling," with rebars and railroad rail spiling over the back of the heading, was used to catch the loose rock. Another problem in the east top heading was that, when appreciable load was exerted on the arch sets, the wall-plate footers did not provide enough bearing support and allowed the steel arch supports to settle.

For the excavation of an 800-foot zone of highly decomposed rock near the center of the tunnel, the contractor decided to use a massive drilling shield that would support the "heavy" ground as he tunneled through this area. The shield was built in California and was shipped to the Straight Creek Tunnel in sections and assembled inside the tunnel. It was large enough to advance the tunnel full-face, rather than by the top heading and bench method, as the major part of the tunnel had been excavated. More than a year was spent assembling the drilling jumbo and shield, at a cost of about two million dollars.

Late in 1969, the various parts of the shield were tested, and during the testing operations, the heading was advanced about 80 feet. A lubrication problem developed with the steel rollers on which the shield was to be moved, and these were replaced with a skid arrangement for moving ahead. For some reason the shield was not put into operation. Work continued in other areas for more than a year, and the shield remained in place, unused. Early in 1971, the contractor abandoned any plans for using the shield, and a multiple drift method for excavating through the bad ground was initiated. The center part of the shield, which contained the drilling jumbo and hydraulic equipment, was dismantled, and the shell of the shield was rock-bolted in place.



Strain Gauge Instrument equipment, showing a gauge installed on a rebar.

The North Tunnel holed through with several small drifts early in 1971, and the geologic mapping was completed shortly afterward. For the most part, the geology correlated quite well with that found in the pilot bore. The most important geologic factor in increasing the cost of construction was the degree of decomposition and alteration in the rock. There were long reaches of granitic rock where the feldspar had been altered to clay. In the gneiss and schist, much of the biotite and hornblende had been changed to chlorite. The degree of alteration was proportional to the density of fractures, although the fractures were often not recognizable in the most highly altered zones. The decomposed zones that were wet produced the highest loads. The shear zones were usually accompanied by high alteration in the rock. Fracture systems that were nearly parallel to the tunnel alignment and blocky rock that had fractures filled with clay gouge produced fallouts and quite often severe point loading on the steel sets. The rock type, foliation, and joint orientation seldom had any influence on the construction of the tunnel.

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No extremely heavy water flows were encountered, as had been found in many of the previous Rocky Mountain tunnels. At locations of low overburden elevations near the portals, however, fairly large seepages of water occurred, especially during the spring runoff from the winter snow. Several water flows on the order of fifty-gallon-per-minute have persisted throughout the year in the central portion of the tunnel.

A rock mechanics section was established in the highway department to develop and supervise an instrumentation program for the tunnel. The initial program used load cells incorporated in the steel sets, MPBXs, and Gloetzl pressure cells between the rock and the concrete lining in permanent arrays, as well as some in moveable temporary arrays. A new instrument program was later initiated using miniature electric strain gauges that were spot welded on the web of the steel supports and the reinforcing bars. Several hundred of these gauges were installed fairly quickly with leads easily strung to selected readout locations. Gloetzl pressure cells were still supplementing the strain gauges to provide a check on the load computations.

CONCLUSION

The preliminary geologic mapping gave a good indication of the rock type and major structural features that would be encountered by tunnels under the Continental Divide. Surface investigations, however, did not provide all the necessary facts that were needed to calculate construction costs and methods at the Straight Creek Tunnel.

The rock conditions in the pilot bore correlated closely with those found in the North Tunnel. The geologic mapping and investigations in the pilot bore proved very valuable to both the contractor and the owner during discussions over changed conditions. The highly instrumented tunnel, however, did not provide some of the critical rock load information that had been expected. It is now evident that rock loads cannot be extrapolated from a small tunnel to a large tunnel in this geologic setting with any consistent degree of accuracy.

The Straight Creek Tunnel was not completed within the three-year period, and it is now scheduled for completion in the middle of 1973 at a much greater cost. On completion, the North Tunnel will carry two-way traffic until the future companion South Tunnel is completed.

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