COMPILING PRELIMINARY FOUNDATION DATA FROM EXISTING INFORMATION ON SOILS AND GEOLOGY

Gene O. Johnson, Ohio Department of Highways

The production of foundation data simultaneously with topographic control for highway location and design is created by researching, processing, and presenting the geologic and soils information along a proposed highway location at the same time photogrammetric maps are being plotted. The foundation data are researched from existing field surveys on geology, soils, and hydrology. Photo interpretation is used to detect foundation problems such as landslides, collapse of mine voids, peat bogs, and wet zones. A field check verifies the remote-sensing and foundation data and provides additional first-hand information in critical areas. A written geologic evaluation of the proposed location, with accompanying maps, covers the foundation and slope problems by explaining the geology, soils, and hydrologic controls in the terrain. The cost of this program ranges from 50 to 100 man-hours per mile of proposed highway.

•HIGHWAY foundation problems, such as peat bogs, landslides, wet zones, soft subgrades, and coal mine collapses, are becoming more catastrophic and expensive to solve as modern design and construction practices expand highway involvement in natural and man-made terrain features. Many foundation problems are discovered too late in a highway's development to be able to economically avoid the problem areas. This necessitates the introduction of design changes or expensive corrective measures during the final design or construction.

A few examples of engineering problems that confront current highway programs are the rearrangement of design geometrics due to the discovery of a deep peat bog under a proposed centerline, the delay of the opening date for a new highway because of a landslide triggered by construction, and a pavement collapse into an abandoned coal mine.

Published and resource data on foundation information applicable to the early location and design of highways are available in Ohio from several earth-oriented disciplines. These data have the potential of producing preliminary foundation information throughout Ohio, with as much as 70 to 80 percent ground truth that can be used to make critical location decisions while the highway design is still in the formative stages. Soils, bedrock, hydrology, geomorphology, and mineral industry history are some of the composite data sources that can produce a preliminary stability evaluation along a proposed highway route.

The presentation of the evaluated data is most effectively produced simultaneously with the topographic mapping for highway location and design. This is the first stage of highway development in which the relation of the proposed route is tied to the landform with relative certainty. Through this topographic control, evaluations can be made with a minimum of extraneous effort. Foundation data can be collected, reviewed, and interpreted during the photogrammetric compilation of topographic mapping of highway sites; a report with geologic profiles, cross sections, and stability evaluations can be produced to define problem areas and to suggest engineering advantages such as local aggregate sources or disadvantages of the natural and man-made features.

Sponsored by Committee on Exploration and Classification of Earth Materials.

The geological engineering unit of the aerial engineering section has been producing evaluations of highway foundation stability simultaneously with the compilation of photogrammetric maps for highway corridor studies, location, and design. The system of landform evaluation is organized into three modes of development: (a) review of all resources for available foundation information, (b) compilation and interpretation of the data, and (c) production of the written report describing the engineering features of the landform. This paper is a compendium of the system of producing preliminary foundation data from existing information on soils and geology for the Ohio Department of Highways and is designed to disseminate the sources, techniques, and results of that system.

COMPILATION OF FOUNDATION DATA

The research of previously composed data available along the highway location has a tenfold return on the time invested. An example of the time element and manpower savings is the measured rock section performed by a field geologist. A detailed measured section in the field may take up to 6 hours to complete with sufficient integrity to allow interpretation for highway locations. However, several times this amount of data can be compiled in less than an hour from the files and literature of the Ohio Geological Survey along with interpretations of the past engineering performance of individual rock members. The example demonstrates the time savings available in all seven of the research areas explored by the geological engineering unit.

The seven primary sources of information utilized are Ohio and U.S. Geological Surveys, Ohio Division of Oil and Gas, Ohio Division of Groundwater Resources, Ohio Division of Lands and Soils, United States Department of Agriculture Soil Conservation Service, Ohio Division of Mines, and photo interpretation and field checks. The agencies noted are the major depositories of foundation data within the state of Ohio, and similar agencies exist in many other states. Photo interpretation and field checks verify the validity of the other information and aid in collecting new and specifically oriented data pertaining to the interrelation of the rock, soil, and water constituents of the landform.

The Ohio Geological Survey has produced several reference works to facilitate the rapid location of applicable reference information. These include the list of publications of the Survey's literature and the Bibliography of Ohio Geology. From these two sources the published and unpublished data including these and in-house reports applicable to the project area are located and then gleaned for points of information relating to the foundation. The survey also has on file maps and measured sections with specific rock units delineated and defined as to type, color, thickness, composition, and relative strength.

The oil and gas division is the state depository of oil and gas well locations and logs. The files and maps of this division have information on wells dating back to the 1900s. The well locations are organized by political coordinates and are surveyed at the time of drilling. The well logs contain pertinent information relative to the completion or abandonment of the individual wells. Data available on the completion logs include location, initial oil or gas production, subsurface stratigraphy, and aquifers encountered in the well. The abandoned well logs record the location, subsurface stratigraphy, aquifers, and the plugging record of the well. By Ohio law, abandoned wells must be plugged between formations to prohibit interformational leakage and also plugged at the surface to avoid collapse or artesian water leakage. If these plugs are improperly set or if wooden plugs are used and rot out, the abandoned well may become a sinkhole for subsiding soil or a source of contaminated artesian water. These data give the highway engineer the knowledge from which he can plan construction practices to avoid destruction of the surface plugs and release of subterranean water, oil, or gas.

The groundwater resources division has on file the records of all the residential and industrial water wells drilled in the state since the 1950s. The water well data are recorded by the individual operators at the time of drilling and sent to the division. The water well's location, owner's name, depth to rock, total depth of the well, and pumping test water-level drawdown are some of the well data recorded on the logs. These data define the location and quantity of the aquifers along the highway corridors and contain information that is another source of stratigraphic control supplementing the measured rock sections from the Ohio Geological Survey. The diverse background of the well drillers makes quality control a problem in this data source. As a result, much of the information must be interpreted as to the real geologic significance. Nevertheless, this is a valuable source for obtaining the main control for the definition of the hydrologic setting in the project area including water flow, direction, and quantity. The definition of this natural phenomenon allows the highway geologic engineer to predict the sources and influences of lubricating groundwater in the proposed back slopes and fill areas. Other data available from this division include published reports and maps of county-wide hydrology, water quality, and top of bedrock.

The lands and soils division and the soil conservation service have been mapping the soils of Ohio in detail since the 1930s. At present, approximately 70 percent of the state is covered by county soils survey reports. Numerous spot maps of individual farm plots are available in the counties where whole county coverage has not been completed. These maps are produced by an experienced soil scientist who determines the type of soil of every lot and landform. By definition of a prescribed set of rules, each soil must fall within a set of characteristic limitations. The soils mapping of Ohio and other states includes the soil series, topographic slope, and erosion factors (how much topsoil has been lost). Also, the tables in the text of the report include the average qualitative and quantitative engineering characteristics of each soil series to a depth of 5 ft or more. The qualitative characteristics include engineering soil type (AASHO, Ohio, or Unified), engineering recommendations for embankment stability-bearing value-subgrade rating, drainage and seasonal high water table, shrink-swell, corrosivity, depth to bedrock plus location, origin, general agricultural use, and other pertinent miscellaneous information. The quantitative characteristics include the physical and mechanical analysis of the individual horizons in the average type of soil. These characteristics include soil texture, engineering classification, group index, liquid limit, plastic index, optimum moisture, maximum dry density, soil pH, and mechanical sieve analysis with silt and clay percentages. From these data, an accurate, representative engineering picture of the individual soils along the highway project can be developed and used to estimate the effect of the proposed highway on the landform's soils and vice versa.

The mines division has on file many of the mine maps of abandoned mines in Ohio and is a data source when a proposed highway is to enter the coal-bearing regions of eastern Ohio. The maps are drawn to a scale of 1 in. equals either 100 or 200 ft, and some date from as far back as the turn of the century. The mine maps show the entries, manways, and pillars of the mine, elevations of the mine floors, and the relation of the mine to section corners on the surface. These maps are integrated with the photogrammetric maps and indicate the relations of mine voids, groundwater from the mines, and remaining mineral resources in the terrain to the proposed highway location.

Aerial photo interpretation is one of the best methods of obtaining information for the foundation evaluation of highway locations when used in conjunction with stereoplotted topographic mapping. Wet zones, peat bogs, potential sites of soft foundation, mine void collapse, and active and potential slide areas are only a few of the foundation problems revealed by this technique. Areas of foundation advantage, such as good fill material sites and zones of definite foundation stability, can also be delineated by photo interpretation. The spatial relation of the individual foundation features are described on the highway location map via the mapping model in the stereoplotter. This topographic control enables the correlation of the foundation problems to the geologic and soils factors causing the instability. With this knowledge of the problem areas in the terrain, the potential foundation problems and associated extra costs can be evaluated.

The field check is performed after most of the data have been collected from the sources. It is used to check and evaluate the information and to gather additional data. The photo interpretation of the area is checked for the ground truth and any additional developments in those features since the flight date of the photography. The previously measured sections are reviewed to associate the exposures with the office data. Additional rock sections can be measured and used to expand the data bank of geologic information. A soil tube is used to analyze the soil profile and investigate the slides, wet zones, and other pertinent foundation features along the corridor. Geophysical investigations, such as seismic or resistivity surveys, can be used to define top of rock elevations and depth to specific materials at critical points. The field check usually requires only 1 day on the project location for a representative 2- to 4-mile job.

PROCESSING INFORMATION

The procedure for processing the foundation information includes correlating stratigraphic terms to the exposed rocks, extending the stratigraphy through the area along the highway corridor by using water wells and photo interpretation, cross-referencing the soil's parent material to the terrain, and correlating foundation problems with specific units. The photogrammetric map usually serves as the best base for this procedure and ultimately provides the compiler with a three-dimensional plan of the topography and geology from which he can produce diagrams and demonstrations for the report.

Bedrock is the basement of all landforms and is the prime factor controlling terrain evolution and stability. With a detailed understanding of the bedrock, all the other superimposed materials, such as soils, alluvium, and colluvium, are easily defined and evaluated. The bedrock correlation throughout the project areas is developed with the geologic discipline by compiling the measured sections with other geologic data on profiles or maps and then correlating the stratigraphic terms to the rock unit. The stratigraphic names of formations and members used in geology have been assigned by geologists in order to facilitate definition and communication. By keying these names to the types of rock in the highway corridor, the discussion in the text of the report is easily organized and interpreted. After the major geologic units have been established by definition and location in the project area, the water well logs are used to extend the outcrop control into the subsurface and to define the hydrologic setting in the area. Photo interpretation is used to extend the surface control by studying the photo pattern at a known rock unit outcrop and observing the lateral extent of that pattern in the landform. Photo interpretation is also used to extend the control on the hydrologic setting by spotting local wet zones and springs.

The soils information, including the physical parameters of the parent material, are used to process the terrain by cross-referencing the substratum data. This extends the surface control, as defined by the soil type, into the subsurface control with the use of data from water wells and measured sections. The soils information also reveals the detailed engineering characteristics of the most important upper 5 ft of the terrain. An engineering soils map is compiled from existing soils mapping on a copy of the photogrammetric base map. This facilitates orientation and interpretation of the data and produces one of the most easily explained demonstrations of foundation potential for the report. The soils data are composed on engineering soils sheets to be used in the report appendix. The final product of the soils processing is a reasonably accurate estimate of the soil engineering capability and a detailed map of the geographic limits of those estimates.

The correlation of the foundation problems is produced most effectively while the photogrammetric map is being compiled in the stereoplotters. This enables the exact limits of the foundation problem to be defined and delineated on the highway corridor map. This map then becomes the base for the geology and soils maps. This provides a three-dimensional aspect to the problem areas for subsequent analysis and documentation and facilitates the correlation of the various foundation problems with the specific geologic and soils units causing the instability.

GEOLOGIC REPORT

The geologic evaluation is the written total of all the pertinent information revealed by the compiler during the research and processing of the foundation data. This report presents in an explanatory sequence all the influential factors that define the engineering characteristics of the landform components and foundation problems. The detailed topics of the reports are reviewed in the following general outline used by the personnel of the geological engineering unit.

Abstract

The abstract includes the location and topography of the project area with engineering soils, general geologic reasons, and controls of the foundation problems. The abstract also includes an explanation of the economic mineral resources of the area and the major types of foundation problems including the specific controls for the definite and probable foundation problems.

Geology

Introduction—The geologic introduction includes the physiographic province, geologic formations, general structural features, general lithologies, and potential mineral resources along the proposed highway.

The second paragraph of the introduction contains the geologic history of the area including the depositional history of the bedrock, the erosional and weathering development, and the post-erosion depositional history of the area if any.

Bedrock—The bedrock text includes a description of the individual lithologic characteristics of each rock unit in chronological order. The characteristics include the most useful information, such as thickness, type of rock, color, texture, mineral composition, facies, structural features, and the engineering potential of each unit. Special emphasis is placed on the lithologic units causing the foundation problems and the processes involved.

Nonbedrock—The data on nonbedrock materials (glacial, alluvial, colluvial, and man-made land) are each described in a paragraph including the type, location, source, and composition of each unit. Special attention is paid to nonbedrock material involved in foundation problems along the route.

Economic Geology—The valuable mineral deposits are defined and described with references to information sources. Both potential and real economic minerals are evaluated. Other potential functions involved with mineral development, such as increased resource transport traffic, can be discussed.

Summary—The summary includes a brief review of the significant geologic points applicable to the foundation problems. The rocks with useful engineering characteristics and/or significant economic mineral resources within the right-of-way lines are also noted.

Soils

Introduction—The soils introduction includes sources of information, climate, precipitation, and general parent materials of the area plus the engineering evaluation of the soil associations along the proposed highway. A brief reference is made to the soils appendix.

Residual, Glacial, and Alluvial Soils—The information on residual, glacial, and alluvial soils groups includes the origins, thickness, occurrence, and engineering characteristics of the problem soils. The colluvial soils are included in the residual section. The engineering characteristics of the soil groups contain the engineering classification, foundation potential, agricultural value, and the probable groundwater influence (e.g., shrink-swell).

Special Materials—The special soils are the man-made soils and debris, i.e., dumps mine waste, fills, and so forth. The data on these materials contain the origin, thickness, composition, occurrence, age, and engineering characteristics. The specific engineering characteristics that are included are the engineering classification, foundation potentials, agricultural value, and probable groundwater influence.

Summary—The soils summary includes a review of the significant soil quality such as clay content and type, shrink-swell, slide potential, frost action, and any other characteristics that may be involved in the foundation problems. An evaluation of the potential engineering use of the soils along the right-of-way is included.

Foundation Problems

Introduction—The introduction begins with a general overview of the specific problems and the major causes of these problems. It also contains an explanation of the field observations and photo interpretation techniques used as methods of detection and the sources of geologic and soils information.

The definition of the system for the foundation stability potential is presented as the classes of definite problems, probable problems, and possible problems. The definite foundation problems are defined as active hazards within the right-of-way. The probable foundation problems are defined as the inactive hazards in the right-of-way plus the active hazards threatening the right-of-way. The possible foundation problems are defined as areas within the right-of-way that could develop into hazards.

Individual Foundation Problems—Each of the three classes is presented as individual foundation problems located by reference to centerline stationing. This sequence is taken from the photogrammetric map and can be demonstrated by single-page maps of each area plus a typical geologic profile of the area.

Summary—The summary includes a grouping of the associated foundation problems and a general explanation of their causes.

Conclusions

Introduction—The introduction to the conclusions includes the proposed location of the highway centerline, important geology of the area, and soil associations with engineering classifications.

Foundation Problems—The definite and probable foundation problems are presented in numerical sequence as plotted on the map with a concise review of the individual problems. This review includes the type, location, cause, and favorable engineering capabilities of each foundation problem. The total number of possible problems is included.

Evaluation—The conclusions will also include an evaluation of the project's overall foundation stability.

CONCLUSIONS

The compilation of preliminary foundation data from existing information on soils and geology is effectively created by researching the various sources of data available, processing the information through the geologic discipline, and producing a report with diagrams and text describing the foundation of the highway location. With this system of research, approximately 70 to 80 percent ground truth is produced during photogrammetric compilation of topographic maps to be used for highway corridor studies or location and design. The distribution of the report reaches the design and construction agencies in the Ohio Department of Highways almost simultaneously with their receipt of the highway plan map. At this stage of the highway plan development, critical location and design decisions can be made to solve the foundation problems along the proposed route. The cost of this program ranges from 50 to 100 man-hours per mile of proposed highway.