*Several Uses of Airphoto Interpretation to the Soils Engineer**

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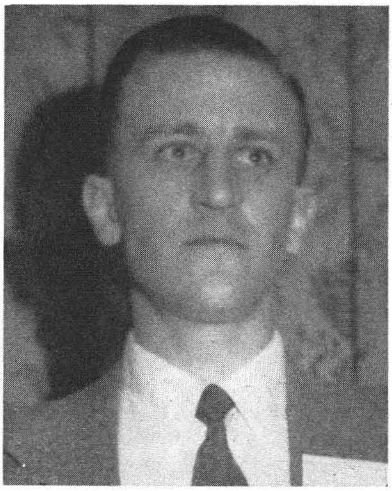
ABSTRACT: *The soils engineer can make use of airphoto interpretation in many of the various types of problems with which he becomes concerned. Three of these uses or applications are: highway location and design; reconnaissance and soil evaluation of a proposed industrial area; and in the foundations investigation for a group of heavy structures. Each of these uses is discussed, as applied to specific engineering projects.*

AIRPHOTO interpretation is rapidly becoming one of the more useful tools of the soils engineer. Formal courses in soils engineering now include at least a brief description of the methods and procedures of the photoanalyst. The more recent texts on soils usually point out the advantages to be gained by using airphoto interpretation. In addition, there have been numerous recent bulletins and papers describing specific engineering projects and how the results of airphoto interpretation have been applied in each instance. Aerial photographs will not displace drilling equipment nor will they replace the soils laboratory. However, they will serve as a valuable supplement in certain soils investigations by uncovering additional facts that can be considered in the evaluation of a soils problem.



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The soils engineer is concerned with all of the problems associated with the materials upon which a foundation is constructed. In addition, the geologic history of the area and its numerous boundary conditions are of importance in his work and usually have a direct influence upon the recommendations he makes. Problems of area reconnaissance, site investigation, foundation design, and structural maintenance are within the scope of soils engineering. It is understandable, therefore, why airphoto interpretation is used in so many different ways.

The following are three of these uses as applied to specific engineering projects; namely that of highway location and design, reconnaissance and soil evaluation of a proposed industrial area, and in the foundations investigation for a group of heavy structures.

1. HIGHWAY LOCATION AND DESIGN

In 1952 plans were being formulated for the location and construction of another section of the Garden State Parkway in New Jersey. This 165-mile long, four-lane divided tollroad now runs the length of the State, close to the Atlantic shore line. The then proposed 34-mile section, in Middlesex and Monmouth Counties, was to have a 500-foot right-of-way with an allowable speed of 60 miles per hour.

Monmouth and Middlesex Counties are mostly in the Inner Coastal Plain of New

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Jersey. The natural materials present in this area consist of a series of unconsolidated beds of marine sediment each bed consisting of various proportions of sand, silt, and clay. Some of the more than 15 beds or formations are of dense uniform medium to coarse quartz sand, whereas other formations are of soft to firm micaceous clay. Overlying this wide assortment of materials are more recent formations of intermixed gravel and sand. These more recent or Quaternary deposits are present as scattered outcrops; however, their value for use as base, subbase, and quality fill makes even the smaller deposits sought after.

Because of the narrow, meandering pattern of the formation exposures, and also the spotty and random occurrence of the more granular materials, the soil conditions could justly be considered as complex with regard to highway engineering. A detailed soils investigation is of paramount importance in such areas; however, time was definitely not available to make an extensive soil survey by drilling, soil sampling, and testing. As a result, the New Jersey Highway Authority requested of the Joint Highway Research Project of Rutgers University the preparation of a soils strip of this 34-mile section of parkway, using the airphoto interpretation method.

Previous investigation by the Project staff in this physiographic province of New Jersey was only of limited extent. A number of reconnaissance trips had been made in the area in addition to a series of hand auger borings for soil classification purposes. Soil testing consisted of grain size analyses, consistency limits, and optimum moisture-standard density relationships. No airphoto interpretation of the area had been performed.

In approximately three weeks an Engineering Soils Strip Map to a scale of one inch equals one-half mile was prepared, together with a 50 page report describing the various materials present along the proposed right-of-way. The strip map, which delineated the various soil types and their drainage characteristics, was of an area three miles wide, and borrow materials were shown of a strip six miles wide. This soils strip map was compared to existing conditions in the field following the rough grading operations. The accuracy of the map was most encouraging.

Some of the more important items considered in preparing this soils map were speed, accuracy, and clarity. A team of five engineers and geologists worked together to prepare the necessary data. Reference literature was investigated; the logs of previous borings together with test results were correlated with the geologic formations in the area; a rapid examination was made of the airphotos to note major soil patterns and to determine those areas which would require field investigation; several reconnaissance trips were made to clarify confusing airphoto patterns; and finally the soil types were assigned map units and the final airphoto interpretation was performed. In several areas the outcrop pattern of the soil types was so intermingled that only general mapping information could be presented in the time allotted. Clarity was assured by using mapping designations which were not complicated and by omitting highly technical terms and long discussions in the written report.

The more important uses of this Engineering Soils Strip Map were as follows:

A. *Area Familiarization.* For initial reconnaissance, such a map provides general soil information concerning the entire area surrounding the right-of-way. The locations and the in-place relationships between the various geologic deposits and soil types are determined for the soils engineer. This is important in planning future phases of soil study, and such information would normally not be available until the completion of an extensive field survey based on borings, soil sampling, and laboratory soil testing.

B. *Alignment and Profile Selection.* Sufficient soils information is presented for the selection of both preliminary alignment and a general profile. Where several alignments are under consideration, the soil and foundation problems of each can be evaluated and a final selection can be made using the soil strip map as a guide.

C. *Establishing Additional Field Work.* In areas where more involved foundation problems occur, the soil map and report help in organizing a more worthwhile boring program. Borings are not necessary at definite intervals along an alignment to determine the soil types that may be present. This general information is shown on the strip map. Subsequent detailed borings in critical areas can be obtained at a minimum cost and, of equal importance, such information will be available for use in the early stages of highway design.

D. *Locating Borrow Material.* The locations of the various types of borrow material for use in highway construction are shown on the soil map. A field party does not have to "scout around" for such materials, but can quickly check on deposits as indicated on the map.

E. *Pavement Design.* By correlating past performance of several types and designs of highway pavements with various soil areas, it is possible to arrive at a pavement type and design that best fits the soil conditions in a certain area. For this section of the Garden State Parkway, a definite flexible pavement thickness (surface, base, and subbase) was established for the major soil areas according to the soil strip map. In addition, variable thicknesses of selected borrow material were established for the critical soil areas. Modifications in this design were made as the subsequent field work progressed.

For an economical, rapid, and accurate reconnaissance soil survey in highway engineering, an engineering soil strip map prepared by airphoto interpretation is ideal.

2. Reconnaissance and Soil Evaluation for a Proposed Industrial Area

In Cuba, this coming year, there will be considerable construction of oil refinery facilities. Oil products are in demand in Cuba, and also there is much activity in the fields of prospecting and drilling for natural petroleum deposits. Soil and foundation studies were made for at least two proposed refinery sites in 1955 and aerial photographs were instrumental in both investigations.

The geologic deposits at the proposed refinery sites are mostly of sedimentary origin. These materials consist of calcareous sandstones, shales, and conglomerates; limestones, chalks, and tripolite. As a result of subsequent folding, uplift, and erosion, the dips of the various interbedded strata are nearly vertical. To add to this relatively complex bedrock condition, masses of serpentine were intruded up through the sedimentary country rock which further obscured the continuity of the structure. In addition to these consolidated formations, there are soft alluvial deposits in former gully systems which were developed in the area, and organic tidal marsh deposits.

The soil developed in the area is a lateritic material and is much different from the majority of the soils present in the U.S.A. The process of laterization is typical of tropical regions where the heat and the moisture appear to carry the ordinary process of rock disintegration and decay somewhat farther than in more temperate climates.

The present soil is mostly a silty clay which is usually dried out or desiccated. Surface cracks to three inches wide are present in many places and vertical fissures, seams, and fracture planes extend deep into the profile. The depth of the soil is extremely variable as a result of the steep bedrock dip and of the differential rock weathering. In many places the steeply dipping beds of calcareous bedrock are interbedded with clay or silty clay soils which were developed from the weaker sediments. Much of the bedrock is so soft and weathered that it can be broken into numerous small pieces by finger-tip pressure.

The primary objectives, when initiating a foundations study in a comparatively new area, are to become familiar with its geology, the normal process of soil development in that particular climatic zone, and the over-all conditions at the site. All of these items could be termed area familiarization. Prior to the performance of actual field work, such familiarization was facilitated greatly by the interpretation of aerial photographs. For the sites in question a materials map was prepared which delineated: the soils of greater strength; areas in which the more resistant limy bedrock was close to the ground surface; former gully systems since filled with soft soils; man-made fill areas; organic tidal marsh deposits; and outcrops of the resistant serpentine bedrock.

To a soils and foundations engineer, each of these items is of utmost importance. The soils of greater strength can readily withstand the loads imposed by oil storage tanks, process units, and other refinery structures. Foundations are relatively inexpensive and construction can proceed rapidly. In areas where bedrock crops out or is close to the ground surface, particularly where the hard more resistant rock is interbedded with weathered strata or soil, foundation settlement will not be uniform. Such differential settlement can over-stress a flexible structure and the resultant strain could throw the structural frame out of line and possibly even lead to complete failure. This settlement can be avoided, but special foundation designs are necessary. Soft, poorly drained sediment and strata of organic materials dictate the use of either costly construction procedures or of expensive foundation types. These construction procedures could be preloading the area and thus pre-consolidating the soft soils, or completely removing the objectionable material and replacing it with suitable well-compacted fill. The expensive foundation types could be deep footings, piles, and drilled piers.

The materials map prepared by airphoto interpretation was constantly referred to as the actual field work progressed. In some places corrections were necessary, whereas in other areas additions were warranted. There were places where the map indicated conditions that would have gone unnoticed by only a cursory field inspection. In one particular area, through a proposed tank farm, a former inland extension of marine tidal marsh was obscured by recently placed fill material. From the ground surface, it was impossible to detect the boundary of the former tidal area with sufficient accuracy. However, by airphoto analysis, the lateral extent of the organic soils was closely defined as well as the discovery of several areas where sandier soils were present rimming the tidal marsh. Borings and soil sampling to explore all soil types could then be directed and planned with a greater degree of efficiency.

Following the field work, the soils engineer gathers all of the facts together and analyses each set of conditions to arrive at the most suitable foundation recommendation for each structure. The airphotos again were useful for they helped the engineer visualize the site better than any other available reference. Each area was reviewed, misinterpretations were corrected where necessary, and a final materials map was then prepared. Such a map was useful in the present foundations study, and its cost will be repaid many times over for it can be referred to for all subsequent work in the area.

For area reconnaissance of a proposed extensive industrial site, airphoto analysis is practically a necessity. Not many items can remain over looked once the airphotos have been studied.

3. Foundations Investigation for a Group of Heavy Structures

The final use of airphoto analysis to be referred to in this paper concerns the foundations investigation for a group of heavily loaded structures. A large corporation wished to expand its production facilities by building a new plant area consisting of shops, furnaces, warehouses, and other expensive units. The site was chosen, purchased, and plans were completed for the plant layout. A few foundation borings were made which indicated dense granular soil to a depth below the practical zone of induced soil stress. From all indications, comparatively inexpensive foundation types could be utilized, even considering the proposed high unit loads. As a routine safety measure, airphotos of the area were referred to and a startling fact was revealed.

About 12 feet beneath the level ground surface, and running diagonally through the proposed plant area, was a former narrow stream. This drainage path had developed some 5 to 10 feet of soft organic soils which were subsequently filled over with more recent granular deposits.

Additional borings were made and the airphoto analysis was verified. Part of the proposed industrial plant was moved away from the former stream, whereas other parts were redesigned so as to overcome the presence of the weak and compressible subsurface stratum. The end result in this case history was success; however, it could very well have been failure.

Not all of the uses of airphoto interpretation can be brought to light as vividly as the preceding ones. Nevertheless, each engineering use is just as important to the soils engineer: a better job can usually be accomplished in less time when airphotos can be put to use.