*Photographic Interpretation– Its Significance in the Highway Program**

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ABSTRACT: *The impact of the new highway program will require development and utilization of time-saving methods to obtain information required for planning, location, design, and construction.*

The use of airphoto interpretation to evaluate soil and materials is a proven method that will save much time. Illustrations show the application of the technique to specific engineering uses, such as soil surveys and material prospecting. The use of airphoto interpretation and carefully planned field work should go hand in hand.

There are several ways to develop utilization of information gained by this technique. Many photogrammetric engineering firms could develop a staff capable of supplying a "package deal" to the highway departments. Highway departments should develop and encourage a staff of trained personnel. Cooperative research programs with colleges could develop the technique for a geographic area, and aid in training personnel. In addition, qualified consultants could be contracted to supply the information desired.

BEFORE the American Public and the highway engineers lies an almost staggering public works program. The impact of this 41,000 mile highway program, called the greatest construction job conceived by men, will create a terrific strain on an already too small engineering force. That this is realized by those in the highway field is indicated by the recent emphasis on time-saving methods in many publications and at many highway conferences. At the recent ARBA conference in Chicago two separate sessions were devoted to development in the use of two of these time-saving devices—photogrammetry and electronic computers. These time-saving devices will relieve the designers of many tasks connected with topography, cross-sections, earthwork computations, and many other tasks normally performed by technicians, engineering aides, and junior engineers. It has been well demonstrated that the use of photogrammetry and electronic computing devices can result in great savings of time and money.

There is, however, one very *important phase*† of highway location and design where the photogrammetric methods and the electronic computing machines cannot supply information. This is in the *realm of soil surveys, materials location, and general site and route evaluation* based on the interplay of the natural environmental factors. Here also the airphotos can be used to save time and money in the planning, design, and construction phases.

By the time-worn procedures of the soil auger and samples taken at evenly spaced intervals along the route, how much time would be required to sample soils along this 41,000 miles of highway? In addition many miles of preliminary routes would have to be investigated before the location of the 41,000 miles could be finally established. Also during this time these same

† I am responsible for the italicizing in this paper.—EDITOR.

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highway departments would be working on many other miles of highway not included in this inter-state program. It can be appreciated that this would be a staggering, if not an impossible job in the time required to accommodate the demands of the rapid growth of traffic. The driving public will not be satisfied to wait for this development to take place by time-consuming procedures. The need is now! Different procedures and new methods are needed, must be found and used.

The use of airphoto interpretation techniques to evaluate soil and materials conditions is not new, but has been developed over a period of 15 to 20 years. This has been largely on a research basis, but a few progressive highway organizations and contractors have used such methods for several years with excellent results. In the light of this, it is appalling to note in a recent survey of time-saving methods that *only eighteen state highway departments* gave positive statements that they were *employing airphoto interpretation methods for soil surveys. Five other states* indicated that they *were experimenting* with its use. (11)

The purpose of this paper is to discuss photo interpretation and how it can be used in this highway program.

Uses

Airphoto interpretation will save time and promote better highways in several ways. Several of the uses of the technique are:

1. *Preliminary interpretation of soils and other natural environmental factors during the planning, reconnaissance survey and preliminary location survey stages.*
2. *Engineering soils maps along proposed locations.*
3. *Location of construction materials close to the route.*
4. *Determination of potential engineering problems, such as hard rock cuts and landslides.*

To obtain the full benefits of airphoto interpretation, it should be started with the initial planning and reconnaissance survey stages. There are *several environmental factors*, determinable by interpretation, that *control the economics of a location.* Four of these environmental factors are discussed below.

Grade and Alignment

In many instances the topographic features will exert predominant control over the location. The use of airphotos, under stereoscopic study, will aid in evaluating a location that will provide the most desirable features. Figure 1 illustrates an area where the topography very strongly controls location. The river shown in the photograph has cut a serpentine path more than 1,000 feet deep in hard basalt rock. The slopes are steep and the highway must cut into the edge of the valley to maintain an easy grade. Airphoto interpretation can determine where the roadway must be cut out of hard basalt rock and where it will cross deposits of coarse talus. Unstable or problem areas can be located readily. Here the choice exists between the two sides of the river and both possibilities can be evaluated.

Soil Conditions

Photographic interpretation provides the means for rapid evaluation of soil conditions along possible routes during the location stage. All too often the soil conditions have not been investigated until after the location has been determined. Adjacent soil areas may have wide differences that affect the design thickness of the pavement or the construction procedures. It is important to utilize the soils that provide the best results for the least expenditure. Figure 2 shows a typical example where the evaluation can be determined by interpretation of the soil conditions as pictured on the aerial photograph.

One soil area is composed of glacial till, which often contains seepage areas along slopes. Adjacent is a terrace composed of gravels with good internal drainage (Note workings along face). The remaining area is composed of recent alluvium with poor drainage and poor strength characteristics. The alluvial soil will require considerable pavement thickness and, due to its characteristics and low position, can be worked only during dry periods.

The till in this area has good strength characteristics but contains enough poor materials to prevent construction work except during dry periods. The terrace has the advantage of providing the highest strength foundation and also has the advantage of being workable during wet

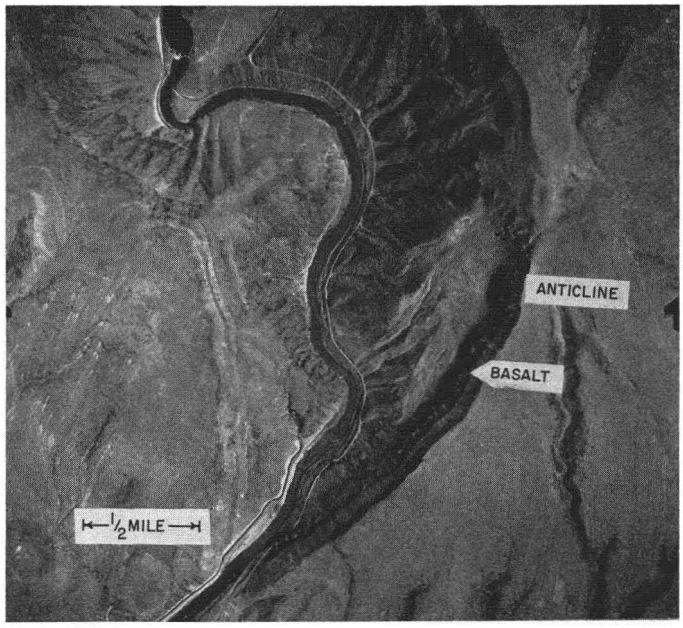


FIG. 1. An area where the topography strongly controls highway location. Bedrock conditions and type can be analyzed to estimate design and construction problems.

periods, which is important as this area is located in a region where there are many rainy days throughout the year. Delays due to wet soils can be costly and this terrace will aid in reducing these costs if the route is located upon it rather than the adjacent soil areas. A similar evaluation of the soil conditions along a route can aid a contractor in programming his work. Thus, an airphoto evaluation can mean savings for the contractor as well as for those concerned with design and location.

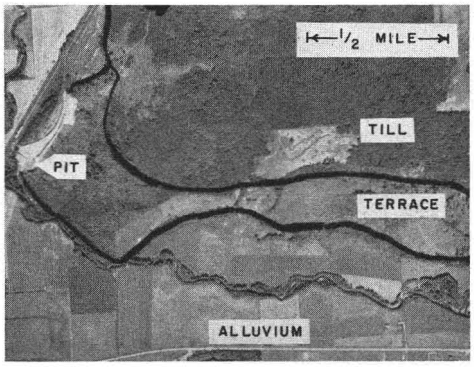


FIG. 2. The airphoto provides a means for readily evaluating soil conditions. The gravel terrace in this area provides a good area for highway location or a source of construction material to be used elsewhere.

MATERIALS LOCATION

It is important that highways be located to take advantage of available construction materials when possible. The cost of construction increases rapidly when construction materials must be hauled great distances. The terrace shown in Figure 2, which was readily identified on the airphoto, would provide a valuable source of base course material for any nearby highway.

CULTURAL FEATURES

Many miles of the highways in this new program will be located by the influence of cultural features on right-of-way costs. Where possible, the highway will have to be located to avoid going through the most expensive land in vast urban and industrial areas. The airphoto can aid in carefully selecting a route that takes advantage of strips of lower cost property through these areas. The problem exists even in rural areas where farmers are already concerned about the wide strips of valuable agricultural land being consumed for our complex transportation network. By the airphoto alone, locations can be determined that take advantage of the least productive areas when other factors do not control. Figure 3 shows an area with two distinct cultural patterns. One side of the

river has an intensive agricultural pattern, whereas the other side shows no agriculture and, therefore, lower land values.

All these factors can be evaluated and an analysis made for a route location considering them from the advantage of a comprehensive viewpoint that the airphoto gives. The airphoto records the natural environment and the interpretation provides an analysis of their effect upon the highway location and design.

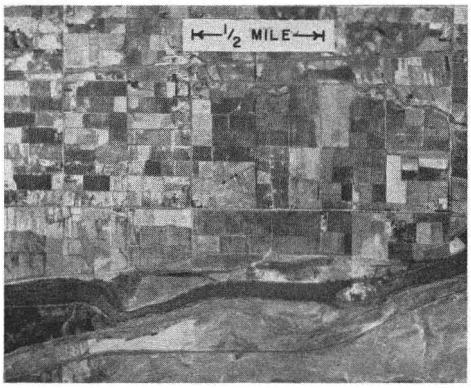


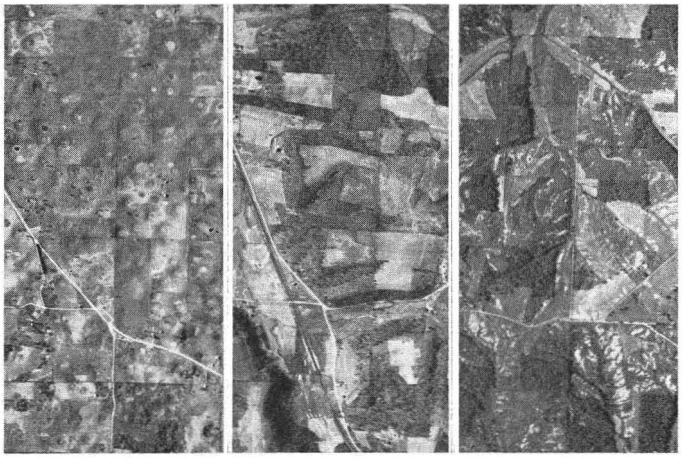
FIG. 3. An area with two distinct cultural patterns. The upper portion has an intensive agricultural pattern, whereas that below the river shows no agriculture and, therefore, lower right-of-way costs.

TECHNIQUES

The principle of airphoto interpretation has been explained many times and will be mentioned only briefly here.* The basic principle is that *materials under similar topographic and climatic conditions will exhibit similar airphoto patterns, and unlike materials will create different patterns.*

The pattern can be described as the combination of certain *recognizable elements* as recorded upon the airphoto. These elements that singly or together form a significant pattern are: *landform, drainage system, erosion characteristics, photo tones, vegetation, and land use.* The basic principle and the pattern concept are illustrated in Figure 4. Dissimilar materials under similar climatic conditions have given the airphotos contrasting patterns. Figure 4a illustrates the airphoto pattern developed in areas where flat-lying limestone and its residual soil are exposed under a semi-humid climate. Here the soils, consisting of plastic clays, will be found to be six to ten feet deep and only infrequent, shallow rock excavation will be necessary for highway construction. Figure 4b illustrates another rock type in this area, that of massive sandstone beds. The topography consists of flat, blocky upland areas with steep valley walls. The soils are shallow upon the uplands and highway construction here will require large cuts and fills to obtain good grade and alignment. Figure 4c illustrates the airphoto pattern developed in areas of flat-lying

* Several references in the bibliography explain the principles and the techniques in detail.



(a) (b) (c)

FIG. 4. Three contrasting airphoto patterns in southern Indiana created by different types of sedimentary rock. (a) The sinkhole pattern identifies residual soils over limestone. (b) Steep escarpments, angularity and blockiness of the pattern identify massive sandstone. (c) Rolling topography, intricate drainage and erosion pattern indicate residual soils over shales.

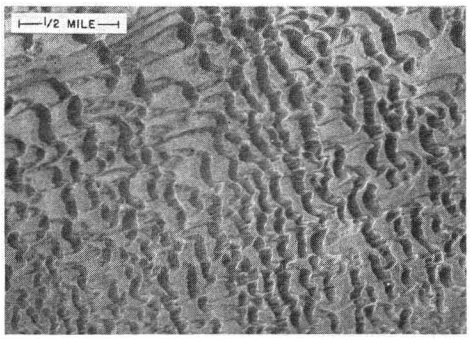


FIG. 5. An area with a uniform airphoto pattern. One sample site is all that is required in such an area since uniform soil conditions are indicated. The airphoto pattern identifies the material as windblown silt.

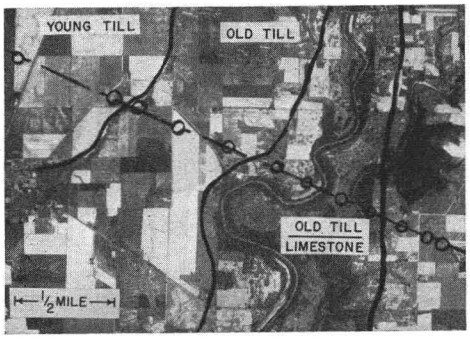


FIG. 6. An area where the airphoto pattern varies considerably from one part to another. Within major soil type units significant differences also can be noted. Extensive soil sampling will necessarily be required in such an area, and the airphoto provides a means of planning where sampling should be conducted. Circles along a theoretical route indicate where samples would probably be required in this area.

shales in the same general region. Here the topography is rolling, and highway construction will require frequent cuts through troublesome shales.

Rather than explain the step-by-step procedure of photo interpretation, the technique will be shown by the use of several illustrations. These will illustrate the technique and the significance of airphoto interpretation for the specific applications of soil surveys and materials prospecting.

SOIL SURVEYS

Airphoto patterns vary from those that are simple and easily interpreted to those that are complex and identifiable only by close scrutiny. Also there is a difference in uniformity; some soil areas are uniform over large expanses but in other areas soil conditions vary greatly. In an area such as shown in Figure 5 there is no need to employ extensive field sampling since the simple uniform airphoto pattern indicates uniform soil conditions. Not only will this observation save time in field surveys, but it will reduce the number of samples sent to an overloaded soils laboratory.

Figure 6 illustrates an area where the airphoto pattern varies considerably from one portion to another with irregular boundaries between different soil areas. Within each major soil unit are found depression soils and soils developed on high areas. Where the pattern is different, it is logical to expect a different soil condition. Sampling in the field will necessarily be more extensive than in Figure 5 since soil characteristics must be established and the boundaries of each soil unit carefully checked. The airphoto provides a means of locating the different soil units and their boundaries. Thus, before going into the field, the field exploration can be planned and organized. This can reduce undersampling an area as well as reducing oversampling.

Not only can soil units be mapped and an engineering evaluation given, but also underlying rock types can be established, as illustrated previously in Figure 4. Also unstable conditions such as landslides leave their tell-tale mark upon the airphoto, aiding in avoiding such areas. In Figure 7, the characteristic topography of a landslide area shows up clearly on the airphoto, indicating an area that should be avoided.

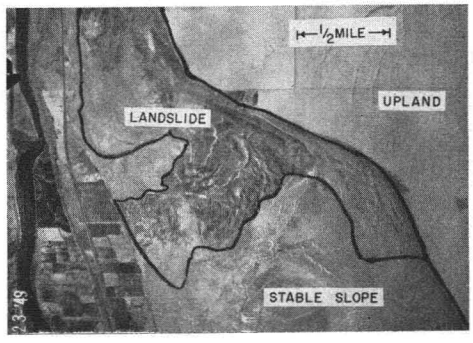


FIG. 7. The characteristic topography of a landslide area shows up clearly on the airphoto, indicating an area that should be avoided.

MATERIALS SURVEY

The location of construction materials such as sand, gravel, and quarry rock close to the site is essential in highway construction; these materials are in short supply in many areas today. In the past, many sources were located by word of mouth, and by chance. In today's highway program this method will not suffice. In a recent publication the closing instruction for materials prospecting was as follows:

"Much walking and hard work are necessary for making an intensive materials survey. A prospector must be alert and efficient and he must keep on looking for materials with a view of finding a source just 100 yards beyond where he desires to turn around. Instances are on record where good material was found just over the hill from where another prospector got tired and stopped. One should not exchange hard work and walking for the comfort of riding, if he expects to be a good materials man." (7)

These were good instructions once upon a time. But now the prospector can exchange endless walking for a method that does locate the material that is "just over the hill" while not leaving the office. The use of *airphoto interpretation will reduce much time in locating materials* where required, and will *find many sources that have eluded discovery by "hard work and walking."* By photographic interpretation the search is not confined to a narrow width as it is on the ground.

Construction materials are frequently hard to find in areas of residual soils underlain by sandstone or shale, and the search for materials in these areas is most important. Figure 8 illustrates an area where the major features indicate an area of intensely eroded shales. The bedrock in such an area would certainly not provide suitable materials for highway construction. Yet within the area illustrated is a source of gravel that is easily identified on the airphoto and would be a very valuable find in this area. Even the thickness of the deposit, which is a remnant of an old outwash plain that mantled the shales, can be estimated.

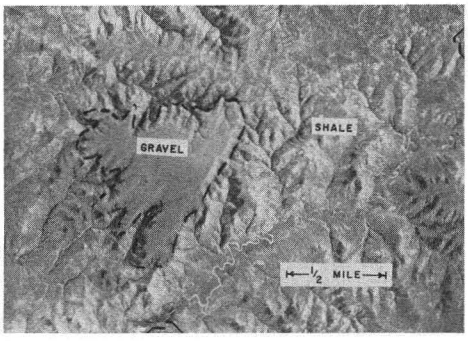


FIG. 8. A gravel outwash remnant that clearly shows on the airphoto within an area of intensely eroded shales. This gravel could be an important source of construction material.

FIG. 9. An isolated area of limestone within an area of sandstone and shale mantled by loess.

The location of isolated good bedrock materials within an area of generally poor materials can also be determined from the airphoto. This is illustrated in Figure 9, where a small area containing the sinkhole pattern, which was shown in Figure 4a, indicates an outcrop of limestone. The area is otherwise devoid of construction materials as the bedrock is largely sandstone and shale mantled by loess. Such a find could be very important.

River terraces which are good sources of sand and gravels are usually sharply defined upon the airphoto. Figure 10 shows terrace remnants standing out in sharp contrast to the glacial debris surrounding it. Such terraces provide a source that can be easily and cheaply worked.

How To Develop Use

As pointed out earlier, many highway departments have not taken advantage of this reliable and time-saving technique. Why? The answer is largely inertia—the lack of interest in changing from the use of old methods. The time schedule and the work-load will not allow this to continue. Another reason is a lack of adequately trained photographic interpreters in the engineering profession; successful inter-

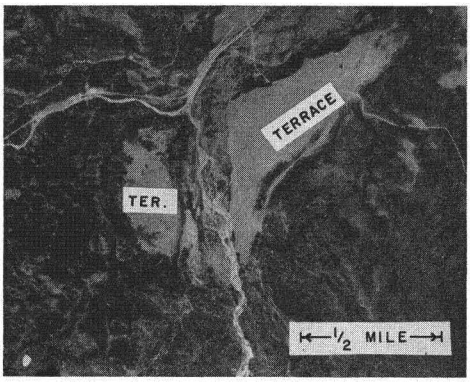


FIG. 10. Terraces defined by characteristic landform and lack of vegetation stand out in sharp contrast to the glacial debris surrounding them. The lack of vegetation indicates rapid internal drainage.

pretation and analysis cannot be obtained by handing an improperly trained engineer a volume of photo-keys and asking him to evaluate soil conditions. Cost certainly is not a factor, since aerial photography, taken for photogrammetric and planning purposes, is available on most projects where photographic interpretation is necessary today. In addition, photography of adequate scale and quality for interpretation is obtainable at very low cost from many organizations, such as the Commodity Stabilization Service, U. S. Department of Agriculture.

There are several ways to develop utilization of information gained by photographic interpretation of soils and other environmental conditions. *Many firms now supplying topographic maps made by photogrammetric methods could develop a staff to supply an engineering analysis of the environment as part of their job.* These contracting firms would have to develop a staff adequately trained in engineering and the processes of geology. Thus, these firms could supply a "package deal" to the highway department.

Highway departments should at least develop a minimum staff that can analyze conditions from photographic interpretation. They would derive many benefits if all those responsible for soil and material surveys were able and encouraged to use the technique.

Where will the highway organizations find these men? They should enlist the aid of the colleges and universities. *Engineering analysis of soils and materials by photographic interpretation should rate high on the research plans of these schools*; the highway departments that encourage it with cooperative research grants will obtain good returns on their investment. The schools can train students while developing techniques applicable for the type of soils and geology found within their region. Much research could be done on the significance of certain vegetative patterns in terms of the engineering characteristics of the materials it often obscures. The students so trained could then be offered opportunities to join the highway soils and materials staff. Once employed, they should be encouraged to apply their skills by assignment to specific projects and not be used as common technicians. Highway departments also can encourage their present personnel to take advantage of short courses offered and to utilize the technique on specific projects.

In addition, the highway departments could derive many benefits by *contracting for the services of qualified consultants within the field.* Many construction contractors have successfully used this method to locate adequate materials for construction near a job site and have reduced their costs for these materials.

SUMMARY

In summary, the present huge highway program will require that old outdated methods be scrapped and time-saving methods be substituted to keep the program going on schedule and to obtain the most for the dollar spent.

Airphoto interpretation is not new, but has been developed over a period of 15 to 20 years. It can be and has been used to successfully evaluate the environmental factors that control the location and design of our highways. Illustrations have shown the application of the technique to specific engineering problems, such as soil surveys and materials prospecting. The airphoto is a valuable tool, but it is not suggested that it supplant all field investigation. It will not provide all the answers, but then neither does the soil auger. The *use of airphoto interpretation and carefully planned field work should go hand in hand.*

There is more than one way to develop the use of these time-saving techniques, but *highway departments should encourage research and initiative of their personnel and of engineering schools in their region to develop techniques for their area.*

BIBLIOGRAPHY

1. Belcher, D. J., "The Engineering Significance of Soil Patterns," *Proceedings of the Highway Research Board*, Vol. 23, 1943.
2. Frost, R. E., *et al.*, *A Manual on the Airphoto Interpretation of Soils and Rocks for Engineering Purposes*, School of Civil Engineering and Engineering Mechanics, Purdue University, Lafayette, Indiana, March 1953.
3. Frost, R. E., "Factors Limiting the Use of Aerial Photographs of Soils and Terrain," PHOTOGRAMMETRIC ENGINEERING, Vol. XIX, no. 3, June 1953.
4. Frost, R. E., and Woods, K. B., *Airphoto Patterns of Soils of the Western United States*, Technical Development Report No. 85, (Civil Aeronautics Administration) U. S. Department of Commerce, 1948.
5. Jenkins, D. S., *et al.*, *The Origin, Distribution and Airphoto Identification of United States Soils*, Technical Development Report No. 52, Civil Aeronautics Administration, U. S. Department of Commerce, Washington, D. C., May 1946. (See Appendix B).
6. Johnstone, J. G., "How Airphoto Interpretation Can Speed Highway Planning and Design," *Roads & Streets*, Nov. 1956.
7. Land, J. L., "Design of Flexible Pavements in Alabama," *Flexible Pavement Design in Four States*, Highway Research Board, Bulletin 136, 1956.
8. McLerran, J. H., "Airphoto Interpretation of Soil Conditions," 1954 *Proceedings Northwest Conference on Road Building*, University of Washington, Feb. 1954.
9. Mintzer, O. W., and Frost, R. E., "How to Use Airphotos and Maps for Material Survey," *Highway Material Surveys*, Highway Research Board, Bulletin 62, May 1952.
10. Smith, P. C., "Appraisal of Soil and Terrain Conditions for Part of the Natches Trace Parkway," *Public Roads*, Vol. 26, No. 10, Oct. 1951.
11. ———, *Time-Saving Methods in Highway Engineering*, Chapter 9, "Soils and Foundations," Highway Research Board, May 1956.

NOTE: The airphotos used in this paper were photographed for the Commodity Stabilization Service, U. S. Department of Agriculture.

*Contractors' Acceptance of Measurements Made by Photogrammetric Methods**

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ABSTRACT: *1. Statements made at prior meeting in Atlanta recently, relative to acceptance by Highway Engineers and Contractors.*

2. Adoption by engineers dependent on their conclusions of the comparable accuracy with prevailing methods.

3. Comparatively recent practice of furnishing contractors with plans containing limited information, thus requiring the contractor to do his own quantity take-offs and bidding lump-sum or on a mileage basis. Such a contractor would be equipped to handle the proposed methods of photogrammetry.

4. The highway departments and manufacturers should provide the advance education of the contracting industry prior to letting construction contracts under these new methods.

THE science of photogrammetry and electronic computing on highway work has not been applied to any projects in the area in which our company normally operates. Some use has been made of aerial photographs in the preliminary stages of highway location work in some of the states. But the preparation of the plans

* Presented at 23rd Annual Meeting of the Society. Hotel Shoreham, Washington, D. C., March 4, 1957. This paper is a part of the Panel on Photogrammetry in the New Federal Highway Program.