A TRAINING COURSE IN PHOTOGRAMMETRY

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Abstract

This paper is a report on the second five-week training course in photogrammetry that has been sponsored by the Mississippi State Highway Department. It was concluded in February 1953 and the first course in January 1951. A third course is being planned.

The need of such schools is pointed out. A general description is given of the course outline and of the principal topics taught.

The scope of the course was planned to give highway engineers the basic know-how for fuller use, for highway engineering purposes, of the identification of images on the aerial photographs and their interpretation by stereoscopic examination, and by making measurements by elementary photogrammetric methods for reconnaissance purposes.

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Introduction

How can the highway departments of the nation develop engineering talent, and make the best use of professional and subprofessional personnel to cope with the ever-increasing shortage of highway engineers? This question has been a lively topic of discussion at recent meetings of AASHO and other technical engineering societies, and the subject of numerous editorials and articles in trade and technical publications in recent months.

In-Service Training Schools have been proposed as one approach to solving this problem, and many highway departments have established schools covering various phases of highway engineering. One way in which the Mississippi State Highway Department is seeking to solve the problem is by instituting an In-Service Training School on Aerial Photogrammetry. The officials and administrators of the Department have long recognized the advantages and savings resulting from the application of the science of Photogrammetry to highway engineering work, but in the past the opportunity has not been exploited to its fullest extent because of the shortage of personnel trained in this field.

The first school of this nature was conducted in January, 1951, and was so enthusiastically received that it was decided to continue this training periodically, or as often as considered necessary to keep a sufficient number of trained personnel in the organization. The second school, with an enrollment of twenty students, was recently concluded and it too was considered highly successful. Plans are already under way for conducting a third school in the very near future.

The Aerial Photo School was planned and has been directed by Mr. I. W. Brown, who is State Manager of the Traffic and Planning Division and recognized nationally as an authority in this field of Photogrammetry. Mr. Brown spent the better part of three years in preparing and developing this short course. In the opinion of many experts in this field it is one of the most extensive courses of its kind conducted by a highway department.

Purpose of School

The primary purpose is to train personnel from the various divisions of the Highway Department in the basic fundamentals of aerial photo interpretation work and its application to highway engineering. In the past many engineering functions necessary to highway location work have entailed costly field surveys. Some of these can be handled faster, more accurately and less expensively through utilizing aerial photogrammetry. Thus it was believed that the Department could operate more efficiently and save many dollars of the taxpayer's money by training personnel in this field of science.

Another purpose is to impress on the students the advantages of doing certain phases of highway engineering with vertical aerial photographs by having them solve practical problems and make comparative time and cost analyses of doing the same job with and without using aerial photographs.

Scope of the Course

The school is designed as a short course study for beginners in aerial photo identification, interpretation, stereoscopy and photogrammetry. Five weeks are required to complete it and the maximum number of students that can be accommodated is thirty. The training is intended primarily for the young highway engineer who may have never seen stereoscopically and knows nothing about third dimension as applied to the use of vertical aerial photographs.

The schooling includes six phases of work considered especially essential to the highway location and design engineer. To satisfactorily complete the course creditable handling of the following is required:

1. Identification and interpretation required in the average problems of the highway location engineer.
2. Location of drainage network; division of ridge drainage areas; computation of watershed areas and structure openings; and determination of the type of drainage structure for the location in question.
3. Stapled index; accordion, uncontrolled and semicontrolled mosaics unmounted and also mounted on stiff and flexible back material suitable to the highway engineer's needs.
4. Ground form line sketching, form line contours and contour mapping.
5. Field altimeter elevation surveys suitable to the needs of control levels for contour interpretation and height finder work.
6. Elevational difference determination on vertical aerial contacts suitable for preliminary highway center line locations.

The course is designed to cover a full five weeks involving at least 220 hours of classroom work and supplemented by outside reading in order to obtain the full value of the course. The material covered in this period is equivalent to that which under average conditions in a college or university would be included in a year's work consisting of two 1-hour lectures and one 4-hour laboratory period per week. During the training period each student works some eighty or more practical problems covering all phases of the course. This practical academic study-laboratory application is considered sufficient to train the beginner and to give him sufficient practical work to build confidence in his ability to do the work.

Instructional Material and Equipment

Although many good books have been prepared and any number of articles written on using and applying vertical aerial photographs, it was believed that none of these on photo interpretation has been presented in a complete, concise and logical manner for teaching the rudiments of the science of photogrammetry. To fill this need three manuals, or textbooks, were prepared for instructional purposes in connection with the course and for later use by the students as references.

The first of these entitled *Manual of Classroom Instructions in Aerial Photo Short Course of Study* was written primarily as a lecture manual and reference handbook. It covers quite thoroughly the first five of the six phases of work previously enumerated. A separate manual entitled *Drainage Structure Development* was prepared from sections of the *Manual of Classroom Instructions* and from other sources to simplify the solution of drainage structure design problems which play an important part in the Short Course School.

The third manual entitled *Essentials of Elementary Photogrammetry* was prepared as a supplement or an advanced study to follow the Identification, Interpretation and Stereoscopy course. The material covers elevational difference determination on vertical aerial contacts suitable for preliminary highway center line locations—the sixth and final phase of the course.

In addition to the material in the manuals, other information and instructions in the use, care and study of aerial photographs are included in the problems. This material is thereby readily available to the student while working with the photographs; also the likelihood of his damaging or otherwise misusing the prints is reduced.

The photographs used in the school concluded last February were furnished by the Mississippi State Highway Department, agencies of the Federal Government and several well known aerial survey companies. Without cooperation of this kind it would be difficult and expensive to carry out certain phases of the work, particularly the construction of mosaics. Mosaic work requires large quantities of prints which are completely destroyed as regards future use, and if prints were not donated for use in the training, the cost would be almost prohibitive.

In addition to this donation for mosaic work, several aerial survey companies loaned items of equipment that added much to interest and value of the instructional work, particularly the phase dealing with elevational difference determination. Representatives from these companies also appeared as guest lecturers to discuss various phases of photogrammetric engineering. The courtesies and assistance given by these companies are greatly appreciated.

The Training Course

The training course, as previously stated, consists primarily of solving practical problems. Short lectures are given as the course progresses and the instructor is available at all times to answer questions and offer assistance.

The course is divided into six different phases.

Perhaps the best way to explain the extent of the training is to describe briefly what was covered in each of these six phases. The sixth and last—Elevational Difference Determination—was added to the five in the first school. This addition in this and future courses is considered necessary because this training in photogrammetry is essential for satisfactory handling of problems arising from the use of aerial photographs for location and design purposes.

Airphoto Interpretation, Identification and Stereoscopy

As an insight into aerial photography, the methods and equipment used in making aerial photographs are explained at the beginning of the course. This instruction covers the type of cameras used including the specifications for a precise aerial mapping camera and the necessary accessories for the camera and plane. The type of airplane best suited for certain kinds of surveys, the scale to which photographs are made for various uses, how to determine the scale of prints, the amount of overlap required for stereoscopic work, and other factors and steps that must be considered before a successful job of securing aerial photographs can be accomplished are discussed and explained.

Following this lecture, the technique of photo interpretation is discussed in a lecture on identification and interpretation. It is explained that interpretation requires the study of four different qualities in the prints—tone, light and shadow, shape and size and shadows cast by objects—and that boundaries of man-made objects or areas are usually straight or curved lines, while boundaries of natural areas are usually irregular. The features and objects of primary interest to the highway engineer and how they appear on photographs are discussed and explained in detail. This is preparatory to the first practical problems to be worked by the students. Before assigning any problems considerable time is taken to explain and demonstrate the care that must be taken in working with aerial photographs.

The first eight problems deal with interpretation and identification. Students are given photographs, a work sheet containing a list of objects that appear on the prints and a grid made on transparent positive film. The objects on the list are located on the print and their grid positions recorded on the work sheet.

Next the students are taught the "Theory of Stereovision." A minimum of four hours is spent by each student on four exercises which are designed to teach them to see relief using a pair of overlapping photographs and without the aid of an instrument. While the ability to see relief with the eyes unaided has numerous advantages and enhances the interest in stereoscopic study, many hours of training are required by most individuals before they master this art of stereovision.

The orientation in Stereoscopic Study covers the subject very thoroughly. It is explained that there is a correct way to set up aerial photographs and to adjust the stereoscope, and that unfortunately too few people really understand and appreciate this and the benefits to be derived therefrom. Two outstanding advantages are cited: (1) obtaining the full value of the three-dimensional view, and (2) eliminating eye strain even when the stereoscope is used constantly over long periods of time.

The instruction covers the steps considered necessary for undertaking stereoscopic study work: (1) locating the principal point on an aerial photograph; (2) transferring this point to an adjacent print in the same flight line, by both the visual and stereoscopic methods; (3) locating the base flight line; (4) orienting and placing prints, and (5) proper adjustment of the stereoscope.

In highway planning and research activities, a stereoscopic study is employed chiefly for interpretative purposes, affording a three-dimensional view of the terrain and permitting a far more accurate and detailed analysis than is otherwise possible. Such a study proves exceedingly valuable where interpretation, classification or detailed examination of ground features is the prime objective.

The lecture and instructions on stereoscopic study are followed by nine practical problems on stereoscopic interpretation. These are similar to the first eight problems in identification, except that in identifying the objects the stereoscope is employed.

Twenty-one practical problems are solved by the students in this first phase of training. This requires forty hours or more of classroom work, and when satisfactorily completed the students have become familiar with vertical photos and have acquired sufficient skill to identify and interpret the objects and features of primary interest to the highway engineer.

Drainage Structure Development

The portion of the course dealing with drainage structure development might be called one of the primary phases because it involves thirty or more problems and requires approximately seventy hours of classroom work. This phase of training the highway location and design engineer is particularly emphasized because watershed drainage area determination is one of the most important aids obtained by use of vertical photographs. Without any doubt aerial photographs furnish the highway location and design division with the most accurate, economical, efficient and rapid means for making the determination of drainage area so necessary in the correct design of highway cross-drainage structures. Examples of actual field operations indicate that by using stereoscope and aerial photographs, drainage areas can be determined at a cost of from 2.65 per cent to 14.3 per cent of the procedure by field party survey—as an average less than 10 per cent of the cost by the field method. This not only saves some 90 to 95 per cent of the field drainage area survey cost but the measurement is more accurate due to the ability to follow the dividing ridge more closely.

The training in Drainage Structure Development is fourfold in purpose and is designed to teach the student to:

1. Run out drainage network and watershed areas.
2. Run out drainage divides and compute watershed areas.
3. Compute the required waterway openings.
4. Recommend size of structure for each location.

Empirical formulas are employed in determining the opening which will be neither too large nor too small. The formula used should cover a wide range when a number of unknown factors influence the runoff and should take into account the size of drainage area, the shape and slope of the area, and the assumed intensity and frequency of rainfall. The students are cautioned such formulas should be considered as supplementing other methods of estimating the required openings. For each proposed structure location they are urged to take the following action:

1. Make a dividing ridge watershed area drainage survey for use in determining the expected amount of runoff during heavy rainfalls.
2. Investigate the structure site for evidence of the magnitude of heavy floods at earlier times. A detailed check at the site of other structures on the same water course will often give valuable information.
3. Check available U. S. Weather Station records for as many years as records were kept. River gauge recording stations are located at a number of places throughout the country, especially on large rivers and navigable streams. Local residents who have lived for a number of years in the vicinity can often provide valuable information on the extreme high water.
4. Investigate the watershed area and determine the characteristic surface; that is whether flat, rolling, hilly, mountainous or a combination of two or more. Indicate the surface vegetation features—the per cent of heavily wooded, open land, pasture and cultivated areas. Note the type of soil—

clay or gumbo, lime or dense prairie soil, loose loam, sandy silt, sandy gravel, or rocky.

It is clearly explained to the student that while it is impracticable to conduct all these investigations on the problems solved in the short course, the final computation of watershed areas and the structure openings in the field should embrace the thorough study above stated.

The "Table of Standard Culvert Quantities" employed by the Department is used in selecting the size of culvert for the location after the waterway area has been determined. Students are cautioned to exercise care in selecting the design standard and take into consideration the height of fill or difference in elevation between the culvert flow line and roadway grade.

Drainage Structure Development, in the opinion of many taking the short course, is one of the most interesting phases covered. This is probably due to the tremendous savings in time and expense being so obvious, even after this limited study of photogrammetry.

Mosaics and Mosaic Making

For the average problems in highway engineering mosaics may be limited to three kinds: index stapled mosaics, uncontrolled mosaics and semicontrolled mosaics. Of these three the semicontrolled mosaic is perhaps the most important. Mosaics may also be divided into four types depending on the method or kind of mounting—stiff back, flexible back, unmounted and accordion. The instructions include these various kinds and types. The building of controlled mosaics is explained but actual construction is not undertaken. It is explained that controlled mosaics are required for more exact mapping needs than are ordinarily encountered in highway location and planning work, and that if need for a controlled mosaic should arise, the job of preparation in all probability would be contracted.

Twenty-three mosaics are constructed by each student, and forty-four hours are allotted for this work. The students are taught the proper way to select, assemble, layout, trim, featheredge and mount the prints to make a complete mosaic. At the conclusion of the school, students are given the mosaics they made for subsequent use by themselves or for showing to their associates in highway work.

Form Line Contours and Field Altimeter Surveys

These two phases of the short course will be discussed together as they are directly related, and are conducted simultaneously in the course. The instructions in Field Altimeter Surveys are included to train the students in one of the methods by which elevation control points, for use in locating form line contours, can be established through using a stereoscope with vertical photographs.

A form line contour may be described as an elevation contour form line drawn on a vertical aerial photograph showing the configuration of the surface of the earth at a relative known elevation. The elevation may be said to be known in its relative position since only the control elevation points throughout the area are determined.

The students are taught that for the average problems encountered by the highway location and design engineer the configuration of the earth's surface may be shown by:

1. Form Lines.
2. Form Line Contours.
3. Contours.

The above may not be in agreement with the terminology of the photogrammetric and topographic engineer, but for the highway location and design engineer they serve quite well.

The classroom instruction in form lines, form line contours and contours with aerial photographs involves the solution of ten problems requiring twenty-two or more hours. To many students this is the most difficult phase of the training; it is apparent to all that to become proficient in the art of drawing form lines much practice is required.

Three field problems in the use of the altimeter to spot check elevations over an area are carried on in conjunction with the training in form line contour work. Prior to actual field work with the altimeters, detailed instructions are given on the preliminary preparations necessary to a successful survey, the use and reading of the altimeter in the field, the methods of altimetry to be employed in the various problems, recording the field data, and office computations. Field training with the altimeter involves twelve or more hours, making a total of forty-four hours of training in these two phases of the short course.

Elevational Difference Determination with Stereoscopic Coverage Photographs

This is the sixth and final phase of the short course. It is an introduction to the "Essentials of Elementary Photogrammetry," and is necessarily covered last because the student must have a working knowledge of Identification, Interpretation and Stereoscopy before undertaking a study of Photogrammetry.

This phase is designed to teach the student the more or less simple methods and instruments used in determining the heights of objects and the variation in the heights of terrain features covered by overlapping vertical aerial prints. The outlined studies are limited to the engineer's scale, the height finder and the simple, or more aptly described, portable contour finders.

The first method used in determining values for the elevational difference computations is an engineer's scale with 100 divisions per inch and a magnifying or reading glass. It is explained to the student that very good results may be expected from this kind of equipment on low altitude photographs provided sufficient care is exercised in preparing the prints and scaling the distances.

A number of companies make instruments for use in height determination work and form line contours that may be termed simple equipment. This statement is not intended to imply that the instruments will not do suitable work for any number of requirements. In a series of thirteen problems requiring approximately forty-eight hours of classroom work, students are trained in determining elevational differences suitable to the needs of the highway engineer with the following types of devices and equipment in addition to the engineer's scale:

1. Parallax Scale
2. Height Finder
3. Parallax Bar
4. Stereo-Elevation Meter
5. Contour Finder
6. Stereo-Comparagraph

The advantages and disadvantages of each of these are discussed and it is pointed out that in many cases they would be preferred to more elaborate equipment even for highly important purposes. The advantages cited are:

1. Low cost of the equipment.
2. Short period and the ease of training necessary for the beginner.
3. The speed of determining elevational difference when accuracy of a lower order is satisfactory.
4. The stereoscopic principles of this equipment are similar to the more elaborate instruments, thereby training the beginner in a step-by-step progression.
5. This equipment is portable thereby facilitating field use.
6. The original low cost makes the parts less expensive when repairs are necessary.

The component parts required to an elementary elevation measuring and contour device are explained as follows:

1. A stereoscope for bringing out relief of the stereoscopic coverage prints.
2. A floating mark system capable of being either attached to the stereoscope or built into it as a unit.
3. A drawing arm attachment designed for attachment to the floating mark system.
4. A parallel drafting arm designed for combination with the floating mark drawing attachment.
5. Photogrammetric computer.
6. Carrying case.

The first four are essential to the device while the last two are additional features for convenience.

When a beginner in the art or science of aerial photo studies becomes sufficiently familiar and interested in the use of the simple stereoscope, he is well on his way to explore the fields of photogrammetry. This phase of the training is intended to be the stepping stone for that part of aerial photo study considered as the most important as well as interesting. The primary purpose is to teach the beginner the rudiments of elevation determination by the principle of the floating dot instruments. It is realized that this short course of training will not be adequate to make well grounded photogrammetrists. It touches rather lightly on the theory of photogrammetry, but it is believed that sufficient fundamental principles are explained for assuring no difficulties for the student provided they are mastered.

The novice who masters this elementary course will be qualified to do a creditable job in using aerial photographs for highway location and design work.

CERTIFICATES AWARDED

Thirty-eight students have been graduated from the "Short Course in Photogrammetry." Eighteen from the first school conducted in 1951, and twenty from the second school. Thirty-five were employees of the Mississippi State Highway Department, one from the State Forestry Department and two from the Arkansas Highway Department. It is planned to give other States the opportunity of sending students to schools to be held at future dates.

At the conclusion of both schools each student was awarded a certificate stating he had satisfactorily completed the Short Course of Study in Photogrammetric Engineering. The certificates were signed by the three Commissioners of the State Highway Department, the Director, the Chief Engineer and the Instructor and bore the State Highway Department Seal.

A DISCUSSION OF "A TRAINING COURSE IN PHOTOGRAMMETRY," by W. J. Crecink, Jr.

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IN-SERVICE training courses in photogrammetry for highway engineers are not only advisable; they are essential. To my knowledge, no college or university in the United States, or in other countries, has on its curriculum a course in photogrammetry specifically for highway engineers. Until this is done and graduating engineers possess the education and practical training in photogrammetry necessary for highway engineering purposes, it will be the task and responsibility of each highway department to conduct schools and provide such education and training for its new engineer employees as well as for its present staff of engineers.

It is not desirable, nor is it fully practicable, to employ photogrammetrists per se and expect them to be productive immediately in a highway engineering department. Before their photogrammetric knowledge and experience could be properly applied in the highway engineering field, it would first be necessary for them to learn the principles of highway engineering and to obtain practical experience in highway location, design and construction. Moreover, there are only a limited number of photogrammetrists who could be so engaged, too few to fill the needs of all highway departments.

Highway engineering has been broadened so greatly that each highway department has a staff of specialists, each particularly adept in a certain phase of highway engineering; together these specialists form a team which now does the engineering essential to providing us with modern highways.

The highway engineers of today are confronted with an especially large number of complex, inter-related, inter-dependent problems that have to be solved cooperatively to provide safe, convenient, comfortable and serviceable highways for modern day motor vehicles of passenger automobiles, trucks, and buses. The problems are being multiplied daily by the rapid manner in which the number of those vehicles, of all kinds, is increasing. As more and more people travel by motor vehicle, highway engineers cannot cope with the rapid increase in complex highway engineering problems without first obtaining sufficient information of the kind and amount as needed about topography and land-use. Otherwise, the team of specialists on the many cooperating highway engineering staffs, who contribute to the planning and location, design, construction and maintenance of the vast system of highways throughout the United States (also in other countries), can not work effectively or efficiently to attain the goal —the best highways and services possible for the funds available.

It has often been stated that photogrammetry is the modern means of reliably obtaining a large portion of the information and data required by highway engineers which must be in the form of topographic maps (dimensions of the topog-