

PHOTOGRAMMETRY AND HIGHWAYS

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The Kentucky Department of Highways has utilized photogrammetry since 1954. At that time, a small photogrammetric unit was established, patterned after an experimental photogrammetric section in the Ohio Department of Highways.

Until 1957 the Photogrammetric Section made surveys of rural secondary highway routes and bridge sites. These particular surveys were not accomplished as economically by photogrammetric methods as they might have been by conventional methods on the ground because the available equipment was, in many cases, antiquated and impossible to maintain properly. Aerial photography was available only through contract with commercial photographers. The unwieldy contract procedure required that a program be prepared preferably 2 yr before the design phase of each highway location was to start.

In July 1957, following passage of the Federal-Aid Highway Act of 1956, the department acquired an aircraft, aerial camera, pilots, and photographers, and commenced an expanded aerial photographic program. The staff of 14 employees was enlarged to 50, three Kelsh double-projection stereoscopic plotters were added to make a total of five; four more darkrooms were added to the original one; a 24-in. copy camera was replaced by a 41-in. one; a precision, distortion-free aerial camera was acquired; a personnel training program was instituted; a part-time field survey party was expanded to two full-time parties, and all equipment was modernized.

All planning for this launching was based on glowing predictions and advance reports that proclaimed vast money savings and tremendous time reductions to be gained by the use of photogrammetry in highway surveying and design. Unfortunately, the reporting was done by men who assumed conventional design procedures were to be scrapped or revised to the extent photogrammetry could readily be used to gather all design data, without any of the usual survey methods being employed. This was not the case. It soon became apparent design procedures were not to be altered appreciably. Photogrammetry could not be used without a complete conventional field survey of the exact roadway centerline, precise field measurement of each highway location profile, and physical soil examination and rock soundings on staked centerline stations.

Under these requirements, it was soon learned that any benefit to accrue from photogrammetry could come only through measuring of the ground across the highway route corridor and compiling cultural details by photogrammetric methods. The advantage of photogrammetry in these operations is substantial, but is somewhat offset by the necessary ground surveying.

One definite advantage with the photogrammetric method is the greatly increased amount of information of all types available with no increase in cost. As a result, the roadway design engineers are given much more pertinent and accurate data on which to base their design. The end product must necessarily be better design and reduced construction costs, the latter being probably the largest single benefit.

During the period from July 1957 to March 1961, the roadway design was done from photogrammetrically made surveys accomplished by the Kentucky Department of Highways Aerial Engineering Section on a wide front, encompassing surveys throughout the whole State. Results of these surveys were quite varied: some were excellent, some were ordinary, and some were indeterminate.

Although costs of engineering work based on photogrammetrically made surveys were rather indeterminate as compared to costs based on surveys made by conventional methods on the ground, they were quite low in comparison with the typical engineering consultant fee prevalent during this period. Considering only limited-access highways on Interstate routes, the Aerial Engineering Section located, surveyed, and completed design on 51.7 mi of 4-lane, divided, limited-access highways. Also completed were 11 interchanges. This work includes 11.0 mi of Fayette County, I-64, 3.2 mi of Clark County, I-64; 5.0 mi of Clark County, I-64; 13.7 mi of Fayette County Lexington Relief Route; 3.3 mi of Jefferson County, I-71; 3.5 mi of Carter County, I-64; and 12.0 mi of Daviess County, US 431. The completely designed interchanges were on the

Lexington Relief Route intersecting US 421, Old Frankfort Pike, US 60, US 68, US 27, Bates Creek Pike, and US 25. Other completely designed interchanges were on I-64 in Fayette and Clark Counties, including the intersections at US 227, Van Meter Road, and Haley Road. Combined interchanges and road mileage designed represent an estimated construction cost of approximately \$40,000,000. A reasonable consulting engineer's fee for this work would be \$1,600,000. Figuring liberally, the survey and design cost incurred by the Aerial Engineering Section would not exceed \$700,000. This logic should illustrate the Kentucky Department of Highways benefited financially to the extent of nearly a million dollars in design alone. This work was carried out entirely by the Aerial Engineering Section with the other Kentucky Department of Highways design offices functioning undisturbed and without interference.

The construction savings can only be estimated and will never be absolutely known. An illustration, however, can be made of the portion of the Fayette County Lexington Relief Route, from US 421 to US 60, approximately 2.5 mi with an interchange proposed at each end. This road was surveyed, designed, and construction cost estimates were prepared for the entire project. A revision was requested for an interchange to be added at Old Frankfort Pike. Using aerial surveys, it was not necessary to return to the field, except for staking and making soundings of the proposed additional interchange ramps. The field work required only 2 days. The entire length of the grade was adjusted by a combination of photogrammetry and electronic computation. The centerline gradients were established, yardage computed, and grades adjusted to secure the most efficient distribution of material. The newly estimated construction cost (including complete cost of the additional interchange) was below the original construction cost estimate.

Another striking example of assumed construction savings occurred on the Fayette-Clark I-64 from Hume Road in Lexington, eastward to Van Meter Road in Winchester. On the preliminary engineering report, this approximately 16-mi section contained, by estimate, 2,600,000 cu yd of earthwork excavation, whereas after combined photogrammetric-electronic grade adjustments, the yardage estimated on design was 1,208,418 cu yd. This represented construction savings of approximately \$900,000.

From July 1957 to March 1961, the Aerial Engineering Section completed the following projects: US 31W in Warren County, 10 mi field survey completed, 15 mi staked in field and photographed in Warren and Edmonson Counties; US 227 in Clark and Bourbon Counties, 16 mi centerline staked in field and aerial photography taken and controlled in field; US 68 in Todd, Christian, and Logan Counties, 25 mi centerline staked in field, aerial photography taken and controlled, and design quantities obtained; and Ky. Rt. 15 in Perry and Letcher Counties, 7.5 mi of aerial photography taken, controlled, and design data obtained. Altogether these projects total approximately 70 mi of completed photogrammetric and field surveys for roadway design. The total cost of salaries and expenses on these projects was less than \$75,000 or approximately \$1,000/mi, which also includes preliminary evaluation of route alternatives in nearly all cases.

During this same 3-yr period, the section also produced 126 mi of detailed topographic maps of topography strips along major Interstate and Federal-aid primary routes for advance route determination purposes. Total survey costs were less than \$500/mi for rural and \$800/mi for highly congested urban mapping. All of this mapping has been accurately and promptly completed, often at a cost of less than \$200 per highway mile. Miscellaneous detail topographic mapping was also completed, including three lake site maps totaling 4,158 acres, 11 roadside park sites and 19 highway interchange sites.

The Aerial Engineering Section exposed 80 rolls of aerial film negatives, comprising 15,200 individual negatives. More than 30,000 contact prints and 16,000 photographic enlargements have been produced and distributed, principally to the Divisions of Design, Right-of-Way, and Planning.

The entire length of the proposed Kentucky Interstate System has been photographed (more than 800 linear miles, considering revisions), and more than 1,000 linear miles of Federal-aid primary and secondary routes. The Aerial Engineering Section has produced and delivered more than 10,000 copies of existing maps, photographs, and

engineering drawings using the 41-in. overhead copy camera. This copy work has been distributed to all divisions of the Kentucky Department of Highways, and also to other departments of Kentucky governmental agencies.

Concurrent with these events, the Aerial Engineering Section has carried on an accelerated experimentation program to develop and refine photographic and photogrammetric techniques applicable to the improving of highway engineering methods. Some of the more important applications of photogrammetry are:

1. On current aerial photography, the Right-of-Way Division has been able to identify pertinent data properly and easily in order to establish quickly the comparative value of land parcels. Use of photographs has also been made for liaison between the Department of Highways and the individual property owners for improving public relations and for speeding land acquisition. As an aid to the Department of Highways in court suits, use of aerial vertical and/or oblique photographs has often been instrumental in securing swift and reasonable judgments.

2. Aerial photography has proved to be the most satisfactory means of displaying proposed highway routes to the general public.

3. Highway system planning operations and highway route location have been greatly facilitated by the use of current aerial photography. Proper use of this photography enables the planner to see type and intensity of both urban and rural land development. Also, the photographs, fully used photogrammetrically and by photographic interpretation, provide pertinent dimensions and qualitative data about the land use, topography, soils, ground conditions, and drainage for determining the best highway routes.

4. Photographs are useful in correlation of traffic origin and destination studies. Traffic studies and their probable solutions are more quickly accomplished through the use of currently taken aerial photographs. Studies can be made of traffic congestion and traffic bottlenecks to determine the type, nature, and time of peak traffic in areas of known congestion. Also, aerial photography properly used will reveal the deterioration of roadways, paint striping, etc.

5. Road location and design operations make many applications of photographic materials and procedures practicable, beginning with small-scale strip mosaics of aerial photographs (scale, 1,000 ft to 1 in.) for reconnaissance surveying and highway route determination, and continuing through the preliminary survey and design procedure to the preparation of detailed construction plans, often supplemented by large-scale photographic mosaics assembled from large-scale aerial photographs. These mosaics may reveal even individual clumps of grass, giving highway design engineers more complete information than any other feasible method.

6. Aerial photography, both vertical and oblique, has been used advantageously in recording and displaying roadway construction progress and as a check on construction techniques. Photography can be used also to record and display construction failures, earthslides, embankment failures, etc.

7. The use of photogrammetry for measuring cross-sections of constructed highways to determine earthwork pay quantities has been found to be practicable and probably desirable, particularly if cross-section measurements of the original ground have been punched into cards for use in the electronic computer. The constructed highway cross-sections are measured with the Kelsh stereoscopic plotter and an electronic digitizer to automatically punch the measured dimensions into electronic computer data cards. This procedure certainly saves manpower, time, and money for the Highway Department, and should greatly expedite payments to construction contractors.

The measurement of constructed highway cross-sections is a part of highway surveys more peculiarly adaptable to photogrammetry than any other type of highway surveying. Photography for photogrammetrically measuring construction quantities can be flown and taken at any time of the year and under varying weather conditions, thus there is unlimited possibility for mass production.

8. Aerial photography can show areas of proposed construction in a before-and-after sequence by artistic drawing directly on oblique photographs. This permits demonstration of proposed construction to interested groups before final decisions are made.

There are many other aerial photographic uses and techniques which may be realized by use of only a small amount of thought and imagination. It is certain that as

photographic techniques, films, cameras, and knowledge increase, the uses of photogrammetry will increase.

USE OF PHOTOGRAMMETRY IN MONTANA

After the advent of the Interstate System in 1956, a requirement of which was an estimation of the cost of constructing the highway in each State, a State-wide aerial mapping contract was entered into by the Montana State Highway Commission for topographic mapping of the entire system. A scale of 200 ft to 1 in. with a contour interval of 5 ft was chosen for the general mapping, with some sections being mapped at a scale of 100 ft to 1 in. with a 2-ft contour interval.

On completion of the contract and after use of the mapping for several months, the great value of photogrammetric products became evident to the engineering personnel and, as a result, it was decided to enter into the photogrammetric field. A small economical print-type stereoscopic plotter was purchased, along with mirror stereoscopes and parallax bars.

Because of Montana's inclement weather and the lack of private aerial photography companies in the State, it was decided in 1957 to purchase a Cessna 180 with aerial camera. Related darkroom equipment was also purchased. Because of continued utilization of photogrammetric products and the increased work load two Kelsh stereoscopic plotters were purchased by 1959. More accurate design mapping was the constant demand of design engineers, including structural designers.

In keeping with these demands, a LogEtronic automatic dodging printer was purchased and a specialist was trained in ground control. The regular field survey crews within the State are used along with the specialist who selects the finite image points, sets the targets, and trains other personnel in these techniques. By 1960 the original camera was replaced by a Wild RC-8 aerial camera.

The Photogrammetry Section is assigned to the Interstate Department because 99 percent of its work is performed on Interstate highways. Of the aforementioned personnel, two are supervisory, one is assigned to the field, two are part-time and also do work for other departments, and four are photogrammetric instrument operators and draftsmen.

From the fall of 1958 to 1961 more than 200 sq mi of reconnaissance topographic mapping was accomplished. More than 80 percent of this mapping is done at the scale of 200 ft to 1 in., with a 5-ft contour interval, and the remainder is done at the scale of 400 ft to 1 in., with a 10-ft interval. This work also includes approximately 50 sq mi of design mapping at scales of 50 ft and 100 ft to 1 in., with a 1- and 2-ft contour intervals, respectively. Another 100 sq mi of mapping is under way. Thus far no cross-sections have been measured photogrammetrically, other than extension of field measured cross-sections.

Other specialized work completed includes the assembly of an uncontrolled mosaic of every city, town, and hamlet in the State. These mosaics are to be incorporated into a book to complement the City Plat Book already produced by the State Highway Commission. The feasibility of furnishing the construction department monthly aerial photography of the highway construction projects to verify monthly progress reports and payments is being studied.

The Right-of-Way Department is furnished enlarged aerial photographs at a scale of 200 ft to 1 in. or larger of all Interstate projects to facilitate negotiations. This photography is acquired as near to the time of negotiation and purchase as possible to insure obtaining the most up-to-date information possible.

Research is being done on the utilization of various methods of ground control when surveying in very rugged mountainous topography for different mapping scales. This includes the use of electronic distance measuring devices alone and in conjunction with field survey crews utilizing conventional methods.