KENTUCKY'S USE OF AERIAL PHOTOGRAPHY IN HIGHWAY LOCATION AND DESIGN

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At the present time, there are a great many persons making a great many claims and statements as to the tremendous advantages obtained by doing highway location and design by aerial photogrammetry. These statements and claims are to a large extent true, which fact is quite surprising when you consider the lack of definite practical experience available upon which to base such statements.

While Photogrammetry, as a science is very well advanced and thoroughly practical and aerial photogrammetry has been applied with tremendous success to various fields of mapping and surveying, yet there have been only a very few years in which low level aerial photogrammetry has been widely used, so few years in fact that low level aerial surveying can be said to be in its infancy. Every day new and startling discoveries are being made in the photogrammetric field and new applications are being found for the present machines and products of photogrammetry.

To obtain satisfactory results from Photogrammetry, in the past, it has been the custom to strive for a higher degree of accuracy than required in order to get an accuracy which is usable and this same practice probably should be applied to Aerial Photogrammetry for Highway Design. However, this is not the case. As a matter of fact, after the flight elevations have been lowered to 1,200' above ground elevation (which is probably the very lowest practical flight level at present), it is still not possible to guarantee vertical elevations any closer than 0.4 of a foot and to secure elevations of even this accuracy requires constant dedication by all persons involved in the various processes which must be employed to utilize photogrammetry. The field surveyor must secure all measurements, both horizontal and vertical to at least third order accuracy. The office engineer must plot this field information on the base maps to the same accuracy and on paper or board which will not shrink or expand beyond third order tolerance.

The photographer must work under the most adverse conditions positioning and cycling his camera every six seconds or less while flying in extremely rough air due to the presence of very bad thermal air currents which nearly always prevail at altitudes below 2,000 feet. Also, he is limited as to exposure setting since the low altitude increases image movement during exposure. Actually, a camera which is a very good instrument for high altitude photography can be worse than useless for low altitude flying simply because its cycling time, shutter speed and light gathering ability are all geared to high level photography. The danger involved in photography of this type is that of getting photography nearly good enough, which of course presents a very strong temptation to the photogrammetrist.

The pilot of a survey aircraft for low altitude photography has possibly the most thankless task of all. He is required to fly a path directly over his ground control, correcting for drift, at a speed of less than 100 miles per hour in an aircraft designed to fly at speeds in excess of 150 miles per hour. All this, in spite of the fact that he must use full flaps and sacrifice 50% effectiveness of control surfaces and usually is unable to see the ground any nearer than two or three miles ahead of the aircraft.

Processing of the film is just as important and as demanding as are all the other phases of photogrammetry. There must be just the right amount of chemicals used and the precise amount of developing time employed. In drying the film,
the proper film tension combined with the correct amount of temperature and humidity controlled forced air must be used to guard against stretching or warping of film base or emulsion. With the film dried in good condition the image thereon must be transferred in exact detail to glass plates with an optical flatness tolerance of one thousandth of an inch.

Using these glass plates, the operator of the photogrammetric plotting machine can secure elevations and horizontal measurements to the accuracy of 0.1 to 0.5 foot on individual points if his plotter is in perfect adjustment and if he dedicates himself to his task.

If all the aforesaid conditions are met, then we can safely say that photogrammetric surveys are as good and in some cases better than conventional field surveys.

If we assume that all the previously named processes have been done correctly, then we are forced to face the fact that field surveys should be replaced by photogrammetric surveys wherever possible and supplemented by photogrammetric processes in all other cases.

When this change is made, we can be sure of gaining several very distinct advantages; for instance, we can select a position or elevation 800' from centerline with the same speed and accuracy as we can select a point which is exactly on centerline; also, we can make any road revision or approach survey in a minimum of time at any point during the design period. In order to make any sort of revision during design stage, it is necessary only to calculate the different alignment and reset the stereo models to secure extra details or cross sections.

In fact, the photogrammetric survey method has such an appeal to the design engineer and his draftsmen that they will soon become spoiled and will protest heartily any attempt to get them to return to road design using conventional field surveys. By simple-visual inspection of photographs under stereoscopes, it is possible to solve many difficult design problems and a quick check of individual photographs will often eliminate glaring errors which would not be found normally until the construction stage.

There have been advanced two basic methods applying photogrammetry to road design. The first being the development of design data from contour maps which are photogrammetrically made and the second being the direct reading of cultural detail and point elevations from the stereo plotter thus getting information in much the same form as field survey notes directly from the plotter, each method has its own obvious advantages and disadvantages.

The first method certainly would be the simplest from the standpoint of the photogrammetrist, since he is not required to know anything about road location or design; it is simply necessary for him to make a good topographic map of the general area showing all cultural detail (roads, fences, houses, etc.) and all topographic detail (contours, drains, spot elevations, etc.). Once this map is compiled, it is given to the design engineer who extracts design data from it for the roadway design by superimposing the road alignment on the contour map and scaling and reading the contours to develop profile and cross sections. The plan information is traced or transferred by scaling. The main advantages of this method are of course, that the photogrammetrist need not be familiar with highway design practices which facilitates the training or conversion of plotter operators considerably. Another advantage, worthy of consideration is that the road alignment need not be located precisely until after the contour map is completed which would be a definite aid in locating precisely the most economical route within the limits of the contour map. The disadvantages of this method are that it is difficult to maintain accuracy for the entire length of a contour line and while the contour is generally accurate, it is not usually specifically accurate; also, it is very difficult to show variations in the ground elevation which do not exceed the contour interval. Usually, on a contour map the break point of ground slopes are not defined and cannot be recovered for plotting thus introducing additional error in cross sections and profiles. It is not generally thought that cross sections and profile
taken by this method will be accurate enough to use for computing pay quantities.

The second method, that of obtaining design data directly from the stereo models, has been used with success also, and the advantages and disadvantages are practically the reverse of the first method. Of course, the alignment must be determined before the photogrammetric plotting can be commenced and possible before the route is photographed. In the latter case, it is possible to signalize the actual road centerline which is of tremendous benefit to the plotter operator since it supplies good horizontal and vertical positions which he can check as he works the stereo models. Also, it is much easier to compile accurate cross sections and profile elevations, since the operator can determine elevations at all breaks in ground grade where they actually occur. This operation will eliminate also some error normally caused by paper shrinkage and expansion which is encountered in the contouring method. Obtaining cross sections directly from the stereo models will also be as saving of time, since it is not any more trouble to take cross sections from stereo models than it is from contour maps. The disadvantage of the second method lies in the fact that the precise road centerline must be determined from preliminary maps and studies before the plotting is commenced. This is not much of a drawback considering the increased benefits derived.

Cross sections taken directly from stereo models should be accurate enough for the computation of pay quantities of roadway excavation.

The Kentucky Department of Highways has generally adopted the latter method of determining design data and we are well satisfied with the results. We find that we are able to determine a large percentage of elevations to within 0.2 foot of true elevation and at least 90 to 95 percent of elevations to within 0.5 foot with the remainder being within ±1.5 feet of correct elevations.

Our general procedure in the development of a road survey using aerial surveys has been to photograph each route at least two times. The route is first photographed at a scale of 1"=1000' which on a 9"×9" negative gives us a strip coverage of 9,000 feet. This photography can be used two different ways. In the case where the terrain is flat, the photography can be mosaiced directly into maps which are excellent for preliminary maps on which the proposed route can be projected with some precision. The scale of these mosaics is usually set at 1"=400' which is a very good for determining the route of least Right of Way damages.

The second method of using the 1"=1000' photography is generally used where the terrain is relatively rough and the photography contains too much relief displacement for mosaicing. The treatment here consists of running field control surveys and making a topographic map by stereo plotter which will be at a scale of 1"=200 feet. This preliminary map will be very accurate and will provide elevations in the form of 5' interval contours for grade studies.

Either method of preliminary is very good and should be the cheapest possible way to secure preliminary data.

After the precise route is determined, then the route is flown at low level altitude of 1,500 feet which will be suitable for use in the stereo plotters to secure plan and profile information. These flights are controlled by signals or cloth panels which are placed previous to photographing on points of known position and elevation. These photographs are then controlled by field surveys on identifiable points on the photograph.

The contact scale of these photos will be 1"=250' which will be magnified to 1"=50' in the stereo plotters. This scale used in either of the previously discussed methods for securing design data is generally adequate for determining design data of sufficient quality for road design.

Using the presently available cameras and techniques, we have not been able to determine elevations to the necessary precision of curb and gutter projects, that is where there is a high concentration of close buildings and sidewalks. This is one type of survey that we do not attempt at present. However, we find that we are able to do very accurate plan work in our stereo plotters on this type of project.
We have actually done a considerable amount of plan work in highly developed areas with the stereo plotter and have found it to be very good and much faster than plain table mapping.

Recently, we were asked whether we could work stereoscopically in evergreen thickets to which question the answer is obviously no. Also, we cannot secure stream or drain profiles in weed choked ditches. On nearly every aerial survey, we encounter a certain amount of terrain which requires supplementary field surveys for one reason or another. Actually, there is little chance that aerial surveys can ever be used to do all field work, but it will soon be developed to the extent that the majority of surveys will be made cheaper and faster through the use of Aerial Surveys.

In summation, we can say that Aerial Surveys should not be regarded as a separate field of surveying to end all surveying, but should be regarded as a very simple and very accurate method of enlarging and developing conventional field surveys to realize the full advantages of field surveys without the drudgery usually involved.