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Color Photos for Highway Engineering

The various aerial color recording media can now be applied to materials surveys, topographic mapping, etc.

(*Abstract on next page*)

INTRODUCTION

AERIAL COLOR AND false-color films have been in production for over 30 years. Yet it has only been in the past few years that significant progress has been made in the use of either of these types of photography for highway engineering purposes. Use of aerial color photography in geologic mapping, such as that reviewed by Fisher[6] and Minard[10] led directly to utilization of this medium in highway engineering. Minard and Owens[11] were among the first to forecast the role of aerial color photography for making highway materials surveys.

The U. S. Bureau of Public Roads, Region 9† has made extensive use of aerial color photography in areas such as Yellowstone National Park[1,2] and Rocky Mountain National Park. In 1966, Stallard and Biege[12] reported on the use of aerial color photography by the Kansas Highway Commission on specific highway engineering problems.

Aerial infrared color photography has achieved moderate success in forestry, agriculture, and camouflage detection[4,5] but its possible use in highway engineering is still a matter of conjecture. In 1960, Winkler[14] briefly discussed the use of aerial false-color photography in conjunction with other types of aerial photography for interpretation of glacial drift in Indiana, a purpose closely akin to use in highway materials surveys. Colwell[4] points out the haze-penetration properties of infrared color photography and notes its benefits in identification of vegetation; both of these properties can be of help in photographic interpretation as a tool in making engineering materials surveys.

† Includes Colorado, New Mexico, Utah, and Wyoming.

APPLICATION OF AERIAL COLOR PHOTOGRAPHY TO MATERIALS SURVEYS

Aerial color photography has seen considerable use in highway materials surveys conducted by the Federal Highway Projects Office, Region 9, U. S. Bureau of Public Roads. In 1958 the Federal Highway Projects Office contracted to have experimental aerial color photography taken in Dinosaur National Monument in Colorado and Utah. The results of this trial were promising, and the possible advantages of using such photography for soil and materials surveys were recognized.

In 1961 the Federal Highway Projects Office entered into an agreement with the U. S. National Park Service whereby the Bureau of Public Roads agreed to inventory highway construction materials in Yellowstone National Park, Wyoming.[2,3] Aerial color positive transparencies (Kodak Ektachrome Aero Film*) at a scale of 1:6,000 were taken in single flight strips along the major road system and in other selected locations in the Park. Over 400 flight-strip miles

* Replaced in 1962 by an improved product called Ektachrome Aero-Film-Process E-3, now called Ektachrome Aero, Film Type 8442.

were photographed using color film during the summers of 1961 and 1962.

In 1964 and 1965 the Bureau of Public Roads extended its highway materials inventory work to Rocky Mountain National Park. Aerial color photography was taken in flight strips along 150 miles of highways and secondary roads and in other selected areas of the Park. This photography was taken at a scale of 1:9,600. Agfa color negative film was used from which 9-inch by 9-inch color prints were produced.

As a result of these investigations, the writers are of the opinion that color photographs have many advantages over black and white photographs for making materials surveys. The use of aerial black and white photographs for interpretation of specific ground conditions, soils, or geologic materials involves the interpretation of various photographic tones. The number of such tones or shades of gray which can be differentiated is extremely limited and many different types of soils or geologic materials may have about the same tonal expression. Since the human eye can perceive under ideal conditions up to 10 million color tones[11] interpretation of color photographs is considerably easier and more reliable than interpretation of black and white photographs. Identification of materials deposits can be based partially on color rather than relying on photographic gray tones as must be done when black and white photographs are used. As an example, in the Yellowstone National Park materials survey it was often extremely difficult to differentiate on black and white photographs between soil or rock and certain low-growing types of vegetation because both produced identical gray photographic tones.

Organic soils can be recognized due to their brown colors. Wet soils, boggy ground and seepage zones can be recognized by a distinctive dark green color of the lush vegetative growth in these areas. On black and white photographs such conditions are expressed as gray photographic tones and identification or delineation is not as positive as for color photographs.

Various vegetative types can also be more readily identified on color than on black and white photographs. In some cases correlation can be made between types of vegetation and specific types of materials or ground conditions; in such cases color photography is superior to black and white. For example, in Bureau of Public Roads surveys in southern Colorado, aspen growing on alluvial fans clearly outlined these deposits which contained granular construction material.

The identification and delineation of such rock types as granite, rhyolite, basalt, limestone, shale, and sandstone are greatly facilitated by use of color photography. In the area investigated the color of granite rock appeared as a light reddish brown; rhyolite as a grayish brown; basalt as black; limestone as a light brown; shale as dark grey to black; and sandstone as yellowish brown. Color photographs are particularly helpful in identification of rock types in instances where fracture patterns or other distinctive features are not present and cannot be used as a means of identification on aerial photographs.

Several scales of aerial color photography have been used for the Bureau of Public Roads materials surveys. The scales used were 1:4,800, 1:6,000, 1:9,600 and 1:12,000.

Of these scales, the 1:6,000 was found to provide optimum results in the areas investigated for the ordinary materials survey; however, the 1:9,600 scale is to be preferred in areas of considerable relief such as Rocky Mountain National Park. Although slightly greater detail can be seen on the 1:4,800 than on the 1:6,000 scale photographs, this

ABSTRACT: *Results of the use of aerial color transparencies and prints in engineering materials surveys by the Federal Highway Projects Office, Region 9, U. S. Bureau of Public Roads, show that they have many advantages over black and white photographs. A photography scale of 1:6,000 seems to provide optimum results for materials surveys. Preliminary investigation of infrared color photographs show that although it does have some advantages over conventional color photographs for engineering interpretation, it can be best employed as a supplement to color film. The development of the Stereoimage Alternator system and technological advance made by the film industry make it possible to use color photographs for topographic mapping with double projection anaglyphic plotting instruments as well as for interpretation.*

advantage is not significant in terms of materials identification and delineation. The larger photography scale limits the areal coverage per photograph thus requiring more photographs to cover a given area. This increases the cost of the photography. In addition, the greater image displacement occurs at this larger scale in areas of great relief significantly affects the ease of interpretation. The 1:12,000 scale photographs provide insufficient ground detail for optimum use although the smaller scale does provide greater width of coverage. Interpretation of photographs at this smaller scale is more difficult, time consuming, and less reliable than for the 1:6,000 and 1:9,600 scales.

In the Bureau of Public Roads investigations, aerial color transparencies were used in the early surveys; for the Rocky Mountain National Park survey, however, a change was made to aerial color prints. Both of these media provided excellent results in terms of quality of photographic interpretation obtained. The color prints proved much easier to work with, however.

As color transparencies must be viewed by transmitted light, a suitable illuminating source is necessary. This requirement has generally not handicapped office use of color transparencies, but it can be somewhat of a problem when they are used in the field. A portable light box powered by an automobile electrical system was used for this purpose, but proved rather awkward.

The necessity for transmitted light for viewing transparencies means that a mirror stereoscope must be used instead of the simpler lens stereoscope which is satisfactory for work with prints. A mirror stereoscope is particularly awkward to handle in the field; therefore, color prints are considerably more practical than transparencies for field work. Also, if a color transparency is lost or damaged, it cannot be replaced as would be the case for a print. As a result, considerably more care must be exercised in handling of transparencies as compared to prints. To prevent damage and to allow annotation, it is necessary to encase the transparencies in plastic envelopes.

Possible Application of Aerial Infrared Color Photography

One type of recording medium in which highway engineers have recently expressed an interest is aerial infrared color film.* IR color film has a near-infrared sensitive layer† which replaces the blue sensitive layer of color film.[7,13] The yellow filter layer present in conventional color film is missing in the IR film, therefore, the latter must be exposed using some type of yellow filter over the lens.

The Bureau of Public Roads recently experimented with aerial IR color photography in conjunction with surveying for location, design and construction of highway I-64 by the Virginia Department of Highways.[3] Photographs were taken from a flight height of 1,500 feet with a 35 mm. camera having a 100 mm. focal length lens. Photography was obtained in early spring before new vegetative growth had occurred. Infrared reflectivity from vegetative growth at this time was near minimum. A light meter was not used because it is not sensitive in the near infrared region. Acceptable IR aerial oblique color photographs using a 35-mm. Canon camera were taken with an exposure of 1/250 second at f/8 using a Kodak Wratten No. 15 filter.‡ The infrared focusing index was used, although this appears not to be essential in taking acceptable IR color photographs.[7] Since two of the three film layers are light sensitive, fixed focal length aerial lenses of high quality can be used for this purpose. This is not true, however, for black and white infrared film having only one layer sensitive to both visible and near-infrared radiation. For adjustable focus lenses, the lens-to-film distance can be increased slightly to insure proper focus of the infrared rays. Specially designed aerial lenses are also available for infrared photography such as the Wild Infragon or Zeiss Pleogon. In all cases the smallest lens opening that light conditions will permit should be used.

Pilot experiments conducted on Virginia I-64 and in the Washington, D. C. area confirmed the fact that IR color film does have a rather narrow latitude of exposure, and that serious color shifts can occur when the film is either over or underexposed. On the other hand, the IR film has greater color contrasts and better haze penetration than conventional film. These are desirable characteristics from the standpoint of photographic interpretation.

The colors that are produced by IR film do not represent the actual colors of the scene photographed, hence the name *false color*

* Kodak Ektachrome Infrared Aero Film, Type 8443.

† Top layer sensitive to infrared (720 to 900 mμ); middle layer sensitive to green (500 to 570 mμ); bottom layer sensitive to red (640 to 680 mμ).

‡ Wratten Filter No. 12 which is commonly employed in aerial photography can also be used.

film. Because of this, interpretation of ground details in photographs is somewhat more difficult and uncertain unless positive ground correlation or comparison with conventional color film has been made. The range in number of colors that can be recorded is more limited for IR than for conventional film because of the missing blue sensitive layer. This is a distinct disadvantage for photographic interpretation of soil and ground conditions.

Shadow details in most IR photographs are obliterated because the film does not record the blue light that is scattered into shadows as does conventional color film. Shadows of clouds are usually very dark since clouds are quite effective in filtering out infrared radiation from sunlight.

Green grass and other vegetation show up a bright magenta color due to the high infrared reflectivity. In many areas lush green grass is an indication of the presence of water. This suggests the possibility of detecting areas of water seepage which might go unnoticed on conventional film. Exposed water courses, lakes, and ponds appear as deep blue colors and are relatively easy to delineate.

Black asphalt patches on concrete pavement showed up clearly with great contrast. There is a possibility of use of IR film for pavement performance evaluation studies even with use of 35-mm. format.

Exposed limestone bedrock photographed from the air tended to appear blue and appeared in sharp contrast with adjacent soil which appeared dark green. Ground IR photographs of freshly exposed bluish-gray limestones tended to be light colored and generally overexposed. Some soil and rock materials such as dark colored shales and brownish alluvial soils can be identified more readily on conventional color photographs.

Coniferous trees can be more readily distinguished from deciduous trees on infrared than on conventional color film.

In summary, IR color film has the following advantages over conventional color film for interpretation for highway engineering purposes: (*a*) shows greater color contrasts in recorded natural features or cultural objects; (*b*) has increased ability to penetrate haze; (*c*) enables a more positive differentiation of coniferous from deciduous trees; (*d*) records areas of water seepage and boggy ground more positively; and (*e*) hydrologic features such as streams and lakes can be more readily detected and delineated. These advantages however do not seem sufficient to economically justify its general use because of the difficulty in correlating false colors with actual ground conditions. It does, however, however, provide a good supplement for interpretation purposes when used in conjunction with conventional color film. One should realize that the foregoing are conclusions based on rather limited experiments.

Use of Aerial Color Photography for Topographic Mapping

In the past, color recording films have not been used extensively by highway organizations for mapping by photogrammetric methods for the following reasons: (*a*) most highway organizations are equipped with double projection instruments based on the anaglyphic principle; (*b*) substitution of polarized light for the complementary colors in the anaglyphic system has not been entirely successful; (*c*) color films have not been dimensionally stable; and (*d*) color diapositives have not been available.

The present situation is somewhat different in that dimensionally stable negative color film* and color diapositive plates† are now available for topographic mapping. The current development of the Stereoimage Alternator system[8] offers a potential breakthrough for the use of color photography for highway mapping. Highway organizations having instruments equipped with the Stereoimage Alternator kit have the option of mapping with either black and white or with color photography. Those with anaglyphic double projection systems can do their mapping with black and white diapositives printed from aerial negative film and use color prints or transparencies for the qualitative aspect of their work. Color diapositives can also be used for conventional aerial triangulation using optical train analog instruments or for analytic triangulation using comparators.

Economic Considerations

In terms of the entire photographic operation, including flying costs, the cost of procuring and processing aerial color transparencies is greater than the cost for panchromatic film. The possibilities for use of color transparencies for highway engineering are limited as compared to the newer color photography products such as the Kodak Aero-Neg System from which color prints, color diapositive plates, color transparencies, black and white prints, and black and white diapositives can all be produced. With this multiplicity of

* Kodak Aero-Neg. Color System
† Kodak Special Plate, Type 083-01.

finished products, the total cost has of course risen. However, the cost of procurement of the color negative material for these new processes is only slightly higher than that of the Ektachrome transparencies. To this cost of procurement of the color negative material must be added the costs of producing prints, plates, and transparencies as desired.

Compared to the completed cost of the highway, the cost of procurement of photography is very small, if not insignificant. The man-hours saved in examining color photographs and in field verification as compared to hours required for similar use of black-and-white photographs should not be overlooked in economic considerations.

Outlook

Almost all highway organizations now employ aerial methods in one form or another. In the future more extensive application will be made of aerial photogrammetry and photographic interpretation in the preliminary highway engineering phases of location and design.

As a result of recent technological advances and an increasing awareness of the potential benefits, greater use will be made of aerial color recording media by engineers concerned with photogrammetry, soils and materials, planning, location, design, right-of-way and traffic studies. The various color media available will provide a more efficient tool for those in need of aerial photography in their work. A variety of aerial color products are now commercially available from both foreign and domestic sources that will meet the most demanding requirements of highway engineers. Continued research and experimentation is certain to pave the way for new applications in highway engineering.

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