

USE OF INFRARED PHOTOGRAPHY TO IDENTIFY FAULTING IN PIERRE SHALE

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ABRIDGMENT

•SOIL expansion and the accompanying pavement distress in roadways constructed on the Pierre formation have been a serious problem for the South Dakota Department of Highways for many years. Because of the distribution of the Pierre formation, most highways in the western half of the state have been affected. In the past decade, a great deal of research has been carried out by the highway department and other agencies to find a suitable design for primary roadways that would eliminate or at least minimize roadway heave and the subsequent breakup of the pavement. The investigation summarized in this report has been a continuation of this major research effort.

Along Interstate 90 from Wasta west to Rapid City, there are many sections of portland cement concrete pavement that have buckled and broken. Various post-construction treatments were attempted (1, 2), but eventually those areas required extensive overlays and patching. In 1968 and 1969 an investigation of pavement distress in roadways in western South Dakota was carried out by Hammerquist and Hoskins (3). These investigators were able to correlate severe pavement distress with faulting and jointing in the underlying Pierre shale. They also observed that pavement heave was still possible in sections of the primary roadway in which the subgrade had been lime-treated prior to paving. Moisture apparently could get down through the subgrade (or come up if the water table rose) into the faulted and jointed material under the subgrade and cause swelling along the strike of the faults. When the strike of a fault crossed the roadway at approximately a right angle, a prominent sharp bump in the surface resulted.

It follows that one of the key problems associated with the design and construction of smooth, maintenance-free highways in western South Dakota should be the identification of faults and joints as well as seasonal variations in the depth of the water table in the Pierre shale prior to the design and construction of existing routes. If these potentially troublesome areas can be identified beforehand, it might be possible to relocate the route to avoid those areas; or, if relocation were not feasible, a more extensive (and more effective) design and construction procedure might be used in just the faulted and jointed areas to secure better highways and eventually lower overall costs.

The purpose of the investigation we now report on was to try to identify faults and joints and water table depths in the Pierre shale from terrestrial and low-altitude aerial photographs. We used a multispectral photographic approach with black and white panchromatic, natural color, and infrared color film. The areas selected for photographic coverage were 3 test sites east of Rapid City previously investigated (trenched, with the faults and joints mapped in detail) by Hammerquist and Hoskins (3). The terrestrial photographs were taken at intervals of approximately 1 month for 1 year. Our initial premise was that the color infrared film would show relative changes in the health of the vegetation growing in the faulted zones compared to that growing on the undeformed shale. The fault and joint zones should serve as areas where more moisture is available to plant roots. Areas with a permanently higher water table should similarly be covered with more luxuriant vegetation.

We took the photographs at regular intervals for a full year to find out whether these differences in plant vigor were easier to identify at any particular time of the year. Terrestrial instead of aerial photographs were used initially for 2 reasons.

1. We were looking for lineaments whose total width was known from our previous work to vary from a fraction of an inch to a maximum of 5 to 6 in. We felt that it would be difficult to reliably identify such narrow features from conventional aerial photography.

2. It was much less expensive to take the photographs from the ground. Because this was a preliminary investigation we were not sure at the start what combination of filters and films and processing tricks would be required to give us the most useful display of information. With a limited amount of money available we could try many more combinations and repeat them if necessary under different lighting conditions with ground-based photography than we ever could have accomplished with commercial aerial photography.

Toward the end of the project we did contract for 2 flights of low-altitude (500 to 1,500 ft) coverage; one of the principal investigators rode on the flight to take the photographs.

The 3 areas selected for detailed study in this investigation are all located in the Pierre shale in 25- to 40-ft deep cut sections along Interstate 90 in Pennington County, South Dakota. These are sites 5, 6, and 8 (3). All 3 sites were in clay shale with field moistures of approximately 30 percent and liquid limits between 70 and 100. The concrete pavement was badly warped and broken by differential swelling of the shale along the strike of the faults at all 3 sites. The roadway has subsequently been patched and repatched several times at each location. The area is in rolling terrain with ridges approximately parallel and trending northwest to southeast. The highway grades in the road cuts are low angle to almost level, and the drainage in the cuts is generally poor.

The following cameras, film, and filter combinations were used for the terrestrial photography: Kodak Panatomic-X black and white film with no filter on the camera, Kodak Ektachrome-X reversal color film with a UVa (ultraviolet absorption) filter, Kodak Ektachrome Infrared Aero film No. 8443 with a No. 12 (minus blue) filter, and Kodak Ektachrome Infrared Aero film No. 8443 with No. 12 (minus blue) and No. 80B (light blue) filter used together. All of the Ektachrome and Ektachrome Infrared photographs were taken with 35-mm hand-held cameras. The Ektachrome and Ektachrome Infrared films were developed in our laboratory by using Kodak E-3 processing solutions. We also processed the black and white film. Both types of color film yield positive color transparencies. These are difficult to interpret even when projected, and so several different techniques were used to make prints. Color prints were made of a few of the transparencies; however, inasmuch as we produced more than 1,000 color transparencies, it would have been prohibitively expensive and time-consuming to make color prints of them all. Accordingly, we made negative black and white prints of the color slides on panchromatic enlarging paper (Kodak Panalure). To attempt to enhance the data presentation, we also selectively filtered the color slides during the printing process with No. 47 (dark blue), No. 64 (deep green), and No. 29 (deep red) filters on the enlarger. Each color slide (normal and infrared color) then yielded 4 different black and white paper negatives, one with no filters used on the enlarger, one with the dark blue filter, one with the green filter, and one with the red filter. These paper negatives were then used to make positive prints on ordinary photographic paper.

In general the terrestrial photographs were about as effective as we had anticipated. They show a wealth of detail with good resolution, and they are simple and inexpensive to take. However, they are very low angle obliques and are difficult to quantitatively interpret. Also, because these are photographs of artificially cut hillslopes, they should not be expected to show as much information as photographs of a natural hillslope where time has allowed the slow evolution of plants, each dependent on subtle soil-moisture changes. However, the fact that fracture traces are visible on the artificial slopes serves to indicate the usefulness of the techniques.

The low-altitude (500 to 1,500 ft), high-resolution aerial photographs yielded the most useful and easiest to interpret display of information. Most of the fine-scale

lineaments were still visible, and they are relatively simple to interpret. Conventional higher altitude aerial photography was only of limited use to us. The lineaments visible on conventional air photos are mostly the major drainages, and these are the fill areas on the highway and so are not directly related to the problem of pavement roughness in the cut areas.

We have recommended that a small project be started in which low-altitude aerial color infrared photographs are taken of a section of a highway route in Pierre shale prior to construction. Lineations found on the photographs should then be checked by a geologist on the ground during the excavation of the cuts. Once the lineations are identified and mapped, the performance of the pavement in these areas would be checked and recorded by highway maintenance personnel for several years. In this way a direct relation between the presence of the lineaments and the ultimate maintenance costs would be found and the cost effectiveness of the aerial photography as an investigative tool established.

REFERENCES

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