New Mexico's Semiannual Condition Surveys Effect Changes in Geometric and Structural Designs

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•POST-CONDITION inspection trips are made in New Mexico semiannually to gather data on changes occurring with usage, and to determine results of design variations on recently constructed projects. Conditions are evaluated at identical locations from year to year.

The idea of making continuing surveys on new construction work developed from routine inspections of experimental projects F-051-1(8) and I-010-1(8)6, on which comparative studies of various combinations of treated and untreated bases and subbases were being conducted. It was believed that information gathered from completed projects would be equally as valuable as the experimental projects for future design determinations. The post-condition surveys started in 1960, and generally have continued with the same key personnel from the New Mexico State Highway Department and the U. S. Bureau of Public Roads.

Comparisons are made yearly at identical locations of rutting, U. S. Bureau of Public Roads roughometer readings, and cracking patterns. At selected locations Benkelman beam deflections are measured and test samples lifted to supplement routine information. W. L. Eager, regional materials engineer for the U. S. Bureau of Public Roads, documented all inspections with written reports and photographs pertinent to developing conditions. He used measurements made to calculate the PSI value by the Illinois formula (1). Comparison of readings on the same project from year to year gives a more significant measure of deterioration than the condition of the project at any one time. It may indicate the need for corrective measures such as overlays, plant mix, seals, or slope flattening before there is pronounced distress. Also, these measurements are used as the basis for special recognition to contractors and engineers doing especially good work.

A problem has evolved concerning the number of new construction projects added to the list each year. Inspection trips are made semiannually and cover approximately one-half of the state each trip. We do not feel justified in allotting more than a week for each trip. The number of projects under surveillance has already passed the two hundred mark. About one hundred projects a week are all that can be adequately covered. It will be necessary in the future to be more selective and to drop some projects that past surveys indicate are duplications or informationally nonproductive.

PAVEMENT CRACKING

Because cracking is so prevalent in flexible pavements, highway engineers are prone to accept it as a normal development. Transverse, shrinkage, or aging cracks usually appear from 2 to 4 yr after construction in New Mexico. Transverse cracking has occasionally occurred during the first winter, for instance on the following two projects: FI-143(5), located in the southwestern part of the state, and F-053-1(6), located in the northern part of the state. On both projects a basalt gravel was used in the hot mix. Laboratory tests indicated an almost unbelievably high volumetric change in the mix due to temperature changes. It was calculated by the laboratory that within the normal expected temperature ranges, lineal volumetric change for 1 mi would vary up to 7 ft.

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Figure 1. Pavement constructed with crushed limestone, showing little cracking 3 yr after placement.

In contrast, a 12-mi project constructed in 1958 was found on a post-condition survey to be in excellent condition, without any cracking, 7 yr after construction. The coarse aggregate used in the hot mix was crushed limestone; it indicated a very low volumetric change due to temperature. Although cracking is widespread in New Mexico, this project indicates that through careful control of material and placement, cracking can be greatly alleviated. Comparison of pictures taken at the same location (Alamogordo Orogrande) 4 yr apart shows little change (Figs. 1 and 2).

Joint cracking at a point adjacent to a preceding hot-mix lay is probably due to internal stresses, and develops frequently in the Southwest. Past practice in New Mexico was to lay the shoulder more or less vertical. Present practice is to lay the longitudinal joints on a slope and leave the slope uncompacted until the adjacent lane is placed. With this procedure a more homogeneous mass is produced, instead of a potential cleavage plane (Fig. 3).

It appears that so-called shrinkage cracks are caused by aggregate volumetric changes due to temperature rather than by aging of the asphalt. Whatever the cause, cracking has developed through internal stresses within the asphaltic pavement for this type of cracking.

Reference has been made to cracks caused by internal stresses within the asphaltic pavement. There are other types of cracking; one is cracking occurring from repeated wheel loads. Traffic is generally channelized, and rutting is the first indication of distress. It may be slight during the first year, but if it continues to progress, cracking will eventually appear. During our post-condition surveys, hundreds of rutting measurements were taken. The critical point appears to be from $\frac{3}{8}$ to $\frac{1}{2}$ in. in depth.

Once rupture of the surface has developed due to rutting, the condition becomes very serious as channelizing of surface water feeds moisture into supporting foundation materials which, under traffic, become oversaturated. Complete failure is imminent.

Figure 2. Pavement constructed with crushed limestone, showing little cracking 7 yr after placement.

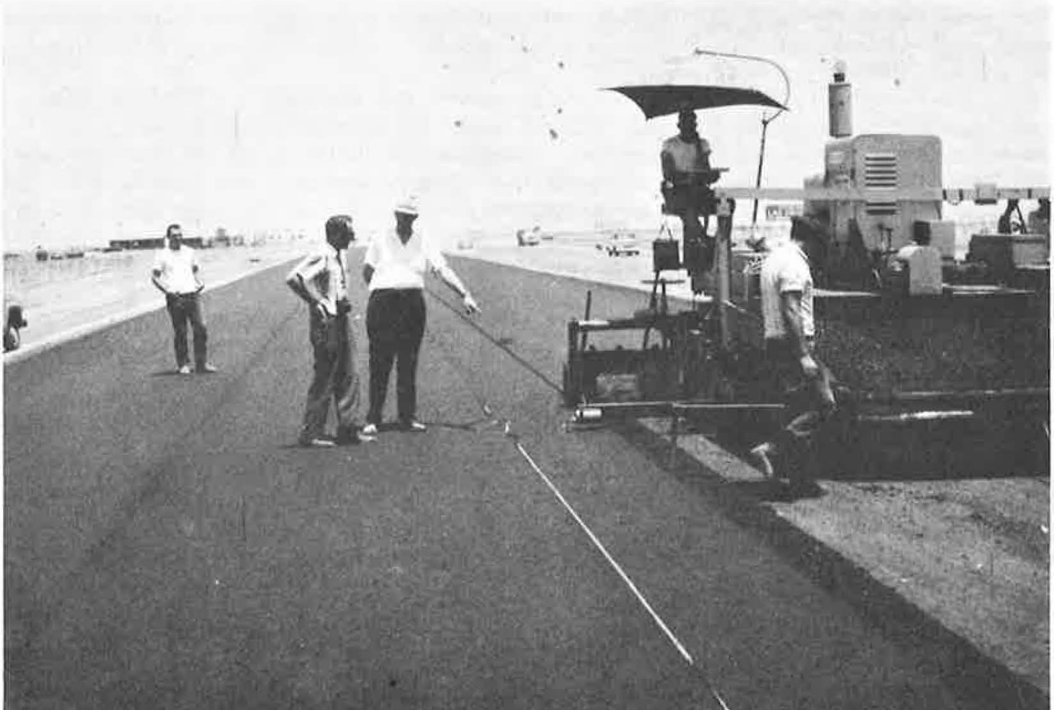

Figure 3. Longitudinal shoulder joints being laid on slope which is compacted after adjacent lane has been placed.

Excessive rutting indicates instability either from an underdesign of the total pavement or from construction deficiencies. Common contributing factors may be insufficient compaction in the pavement, base, subbase or subgrade; materials used in the pavement structure may not have the inherent stability needed for durability or to support the applied loads. Some rutting is to be expected, and most pavements stabilize before they become critical.

Safety experts contend that one eye is dominant in driving patterns. If the left eye prevails, the driver tends to hold close to the center stripe. If the right eye dominates, the driver tends to hold close to the shoulder stripe. My personal observations lead me to believe that this is true.

Rutting on New Mexico highways develops in the travel lane, and seldom in the passing lane, when the shoulders are striped. We believe that a wider traffic lane would disperse wheel loading over a greater area and reduce the tendency toward critical rutting. Certainly, wider traffic lanes would enhance safety and driving comfort. It is also logical to believe that the pavement's life would be prolonged.

We striped several projects in New Mexico, using 12-ft passing lanes, and 14-ft driving lanes where the pavement extends shoulder-to-shoulder. The cost is no greater, as the stripe uses a part of the shoulder. These projects will be observed closely, and measurements taken during post-condition surveys.

The post-condition surveys indicate that most of the cracks, and the most damaging, occur through external forces to the mat. Often overlooked by highway engineers as inconsequential is early shoulder cracking outside the traffic lanes. The condition is general in embankment areas with relatively steep slopes. A good example of progressive deterioration occurred on I-010-1(8)6, Road Forks East, a project built with experimental features and closely watched. In Report No. 1 (state) dated November 5, 1956, station 400+00 reads: "A few longitudinal cracks were also found about one foot from the left edge of the driving surface."

Report No. 3 (Eager) dated August 16, 1960, B-condition of project, reads: "The project is in excellent condition. Transverse cracks are less in evidence than at previous inspection, February 25, 1960. Rutting (in outer wheelpath of traffic lane) is more pronounced. Longitudinal cracks, particularly in paved shoulders and in passing lanes, are pronounced in fill sections across light fill sections across flats (station 326+15. 4 to 800+00)."

The first cracks to appear in the paved shoulders are probably the result of soils movement in the subgrade. In the Southwest there are alternating cycles of moisture and extreme drought which in turn cause a swelling and shrinkage of the soils beneath the pavement. The susceptibility of the soils to moisture varies over a wide range; consequently, cracking patterns vary accordingly. When cracks begin to open up they permit entry of surface water and the condition becomes progressively worse (Fig. 4).

It is quite noticeable that the worst conditions are more pronounced in fills with relatively steeper side slopes. The westbound lane adjacent to the project under discussion was constructed in 1943 with much flatter slopes. There is no indication of similar distress, although the embankment was constructed of the same type of borrow and traverses the same terrain.

GEOMETRICS

Early in 1965 the New Mexico State Highway Department changed the standard design of slopes from a mininum of 4-to-1 to a minimum of 6-to-1 for a distance of 9 ft beyond the paved shoulder (Figs. 5 and 6).

Although our new geometric standards were originally discussed on the basis of additional support for the shoulders, there are a number of other advantages that may be even more valid.

From my viewpoint, the new geometrics are only the first step in constructing safer highways. They provide for an additional 9 ft on each side of the shoulder as a possible recovery area. This is not enough. The recovery area needs to be from right-of-way fence to right-of-way fence. General Motors has proven that anything less than a 6-to-1 slope is unsafe when a car is out of control. It is time highway engineers faced the facts.

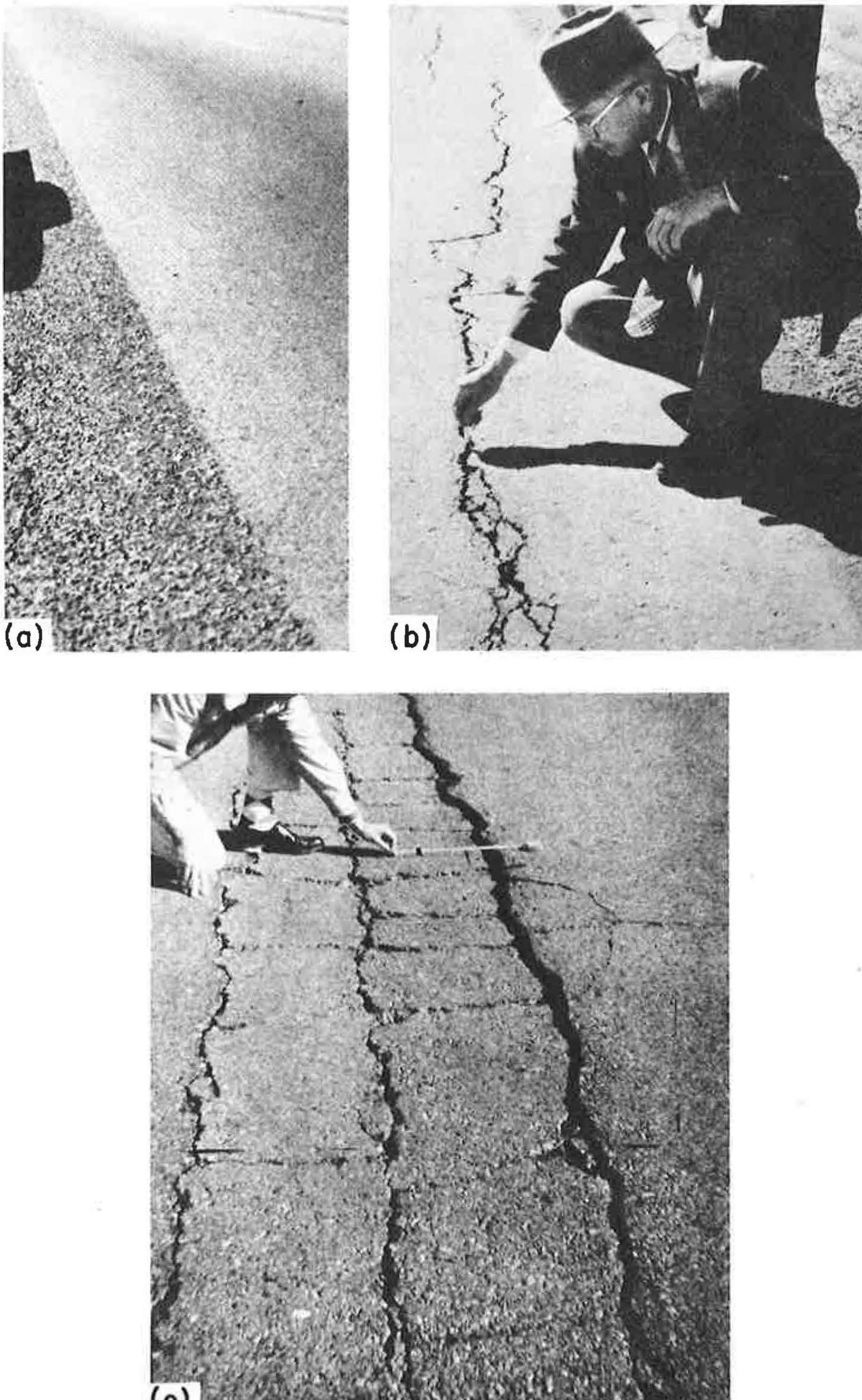

Figure 4. Typical progressive deterioration from shoulder cracking: (a) early shoulder cracking; (b) progressive cracking into driving lane; and (c) ultimate failure.

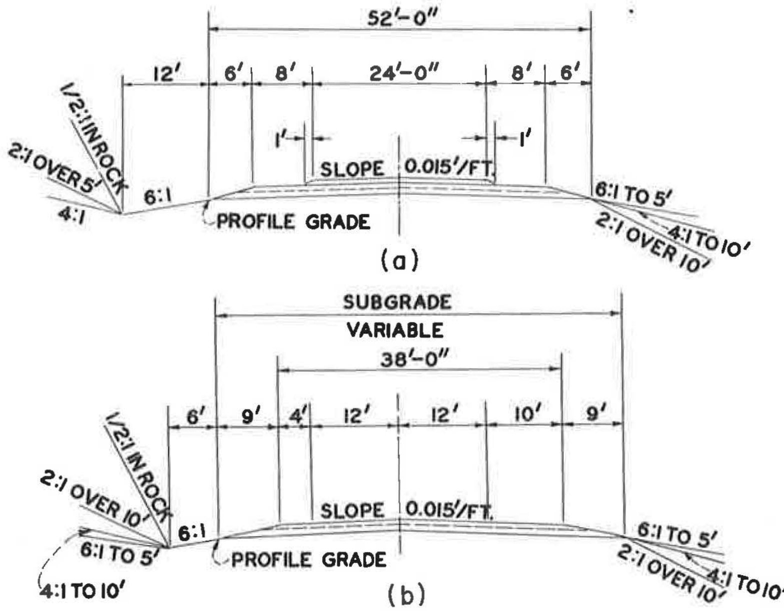

Figure 5. (a) Old and (b) new typical sections.

Not much can be done to prevent head-on collisions except to provide greater maneuverability. In rural areas, by far the greater portion of vehicles in accidents terminate off the pavement structure. In the process they strike some obstacle such as a curb, post, guardrail, or sign. These safety devices cause the accidents. It does not make sense.

When New Mexico obtained approval of the new geometric design, we planned to move the obstacles out to the 9-ft hinge point, but were unable to do so except on an experimental basis because the AASHO sign manual requires that these obstacles be placed within 2 ft of the shoulders (2). The WASHO Construction Committee, during our recent meeting at Salt Lake City, voted unanimously to request the WASHO Executive Committee to take the necessary action to permit moving the obstacles out.

We have read and heard much recently about safety, beautification, billboards, and junkyards. The most esthetic highway possible is one that gives the motorist a feeling of comfort and safety, with flat slopes and a minimum number of obstructions within the recovery area. Why are signs erected by highway departments within the rights-of-way more esthetic than billboards off the rights-of-way?

The flatter slopes are more conducive to better ground cover of natural vegetation and facilitate mowing and snow removal.

In the process of extending the 6-to-1 slope out to the 9-ft hinge point, normally crushed rock or gravel is used. The value of this material in controlling erosion became known to me as I was inspecting paved shoulders showing some distress, on New Mexico Project I-040-2(24), West of Gallup. Erosion stopped on the slope at the edge of the gravel placement (Fig. 7). The section greatly reduces the need for shoulder curbs and rundowns, which are potential accident obstacles. Also, I believe that gravel in side ditches would control erosion more effectively than check dams on grades up to 3 percent.

STRUCTURAL DESIGN

The conditions on some projects emphasized the need for, and brought about, some revisions in our structural design practices.

Although some cracking occurred on projects where untreated base course was placed directly under the asphaltic surface course, cracking patterns developed earlier

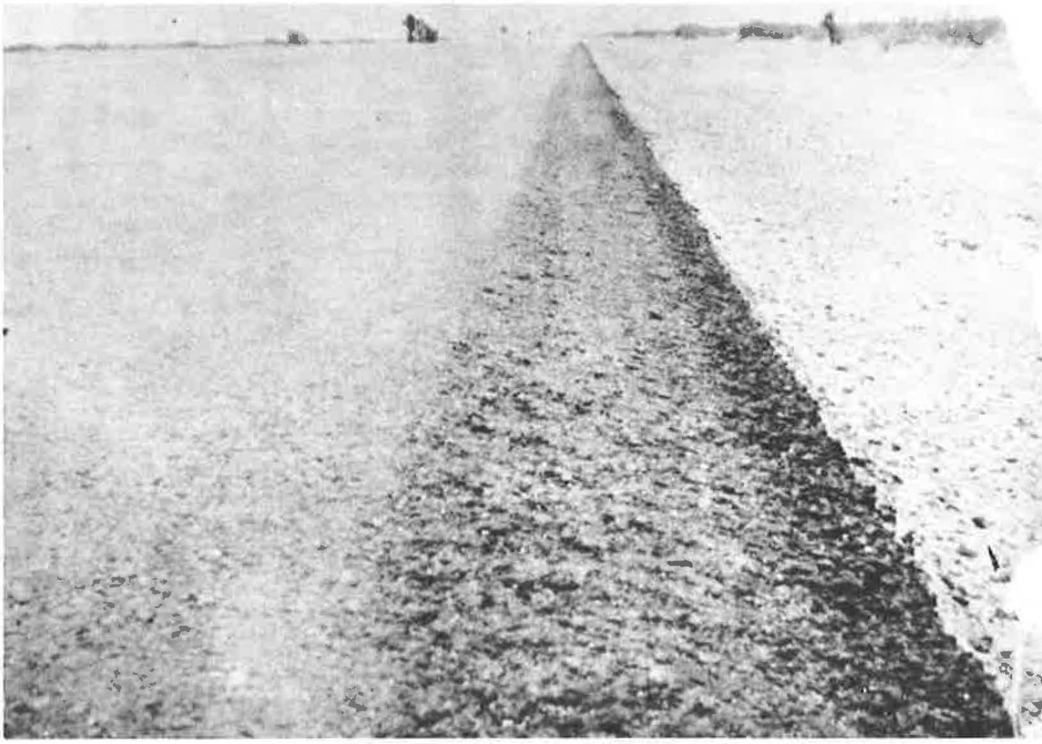

Figure 6. New design shoulder slope, June 21, 1965.

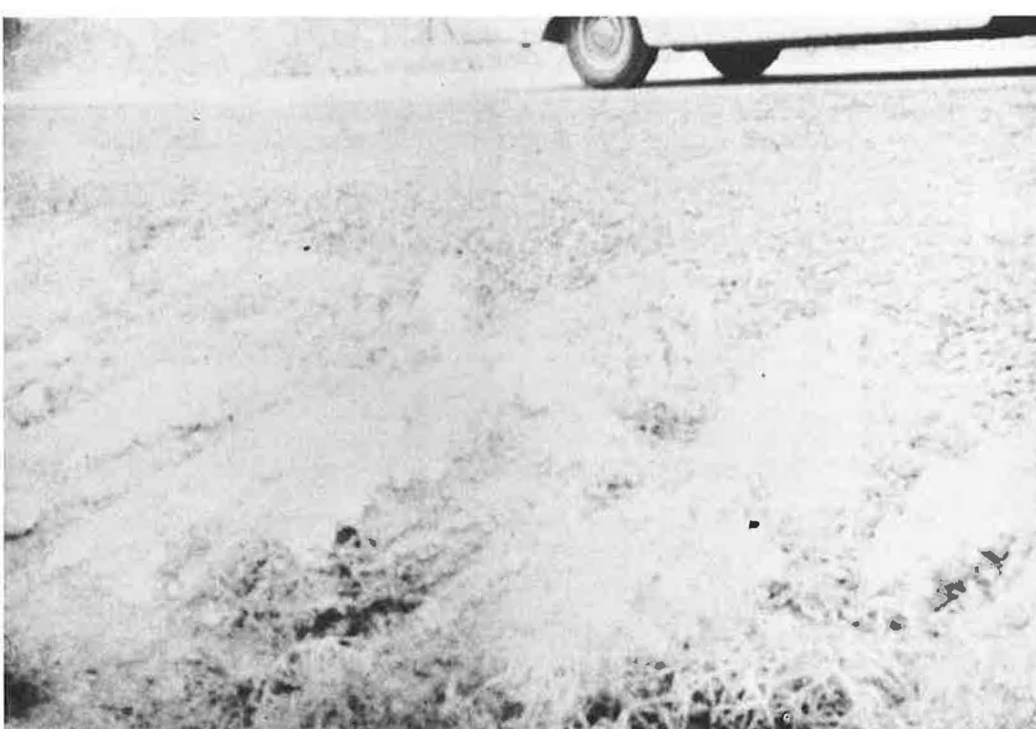

Figure 7. Four-to-one slope; slope erosion stops at edge of gravel placement.

and reached more serious proportions on those projects where the asphaltic concrete was placed directly over a cement-treated base course. To alleviate the problem caused by the transmittal of reflective patterns from the cement-treated base course through the bituminous pavement, the practice of placing cement-treated base course directly under the mat has been discontinued almost entirely and two alternate designs have been used. The first alternate design, which has been referred to as the upside-down design, consists of placing a cushioning layer of high-quality base course between the cement-treated base material and the asphalt concrete mat. Structurally, the upside-down design appears to be equal to and perhaps superior to the normal practice. As indicated by recent semiannual conditions surveys, the reflective cracking problem has been greatly reduced on those projects where the intermediate layer of cushion material has been used. The other alternate design consists of placing asphalt-stabilized base course material directly under the mat in lieu of the cement-treated material. Our limited experience has shown that the asphalt-stabilized base performs equally well; consequently, cracking problems of any appreciable degree have not been encountered on recent projects constructed using either design.

The aggregates available for highway construction in certain areas are instrumental in the design determination inasmuch as not all aggregates are equally suitable for stabilizing with cement or with asphalt. The choice of the stabilizing material, and consequently the design to be used is, therefore, influenced by the nature of the aggregate to be stabilized. Also, any type of design which results in shrinkage cracks over a plastic subgrade soil is highly undesirable, since the cracking patterns allow surface moisture to leak into the subgrade, resulting in reduced support, pumping, and swell.

Another problem noted during the course of the semiannual inspections was the development of alligator cracking patterns and deformation of the roadway structure in certain areas due to the inadequate stabilization and structural failure of the underlying courses. Benkelman beam tests performed in conjunction with post-condition inspections showed high readings in extensively cracked areas. As a result, the previous practice of using untreated base materials on high-volume roads has been discontinued, and it is the present policy to use stabilized bases on these types of highways. Benkelman beam tests taken on projects which were constructed with stabilized bases have shown readings well within the acceptable tolerances. Travis Cole, materials engineer for the New Mexico State Highway Department, recently made a comprehensive revision of our structural design criteria and procedures for flexible pavements. The new structural design criteria and procedures are based on the AASHO Road Test findings, and are given in the New Mexico Highway Department Bulletin No. 101, Structural Design Guide for Flexible Pavements.

Adoption of the new design criteria has permitted more versatility in structural design selection because more realistic structural strength coefficients are assigned the materials used in the construction of the flexible pavement structure. The inclusion of a regional factor, which permits an adjustment in thickness determination based on climatic and environmental conditions, is a realistic approach.

Rutting was generally attributed to the instability of the asphalt concrete mat. To provide more internal stability in the asphalt concrete surfacing, the requirement for the percent of fractured faces in the asphalt concrete aggregate was increased to a minimum of 60 percent of two mechanically fractured faces, and plasticity index requirements which presently call for sandy, nonplastic material have resulted in a cleaner aggregate with a corresponding increase in the stability of the bituminous surfacing.

Comparison of pavement condition on identical projects on a yearly basis also revealed aging of the asphalt concrete surface course in certain areas. The aging process was retarded on projects which had received an early chip-seal treatment. Chip sealing did not prove satisfactory due to bleeding; it also chipped windshields and caused a general inconvenience to the traveling public, especially on roads carrying a high volume of traffic. Because of this, New Mexico eliminated sealing on most of the asphalt surface courses.

Recently a ½-in. plant mix seal coat was used on numerous projects with satisfactory results. The specifications require a minimum of 75 percent of the material retained on the No. 4 screen to have at least two fractured faces. The gradation requirements are as follows:

Sieve	Percent Passing
$^3/_8$ in.	100
No. 4	30-50
No. 10	5-25
No. 40	0-12
No. 200	0- 6

The key to a successful seal with this mix is the asphaltic content. New Mexico uses 6 ½ to 7 percent of 60 to 70 or 85 to 100 asphalt cement by weight of the total mix. It is necessary to lay the mix at lower temperatures than the usual asphaltic concrete mixes to retain a thick film over the aggregate particle. The asphalt flows gradually down to the surface of the mat and completes the seal. Warm weather and traffic are necessary to accomplish the best results.

For some unknown reason, surfaces constructed with this design and tested with the U. S. Bureau of Public Roads roughometer show a lower reading (by about 20 in. per mile of deviation) than the normal hot-mix surface. The mix when properly laid has a dense terra cotta effect and provides an excellent nonskid surface. Allowance is made for the ½-in. layer in the final thickness determinations (Fig. 8).

The post-condition surveys constitute a continuing research project, and permit adoption of improved practices. A vast pool of factual data has been accumulated. The questions are multiple and the answers are elusive, but through the process of analyzing the changes which are occurring we believe that better serviceability can be attained.

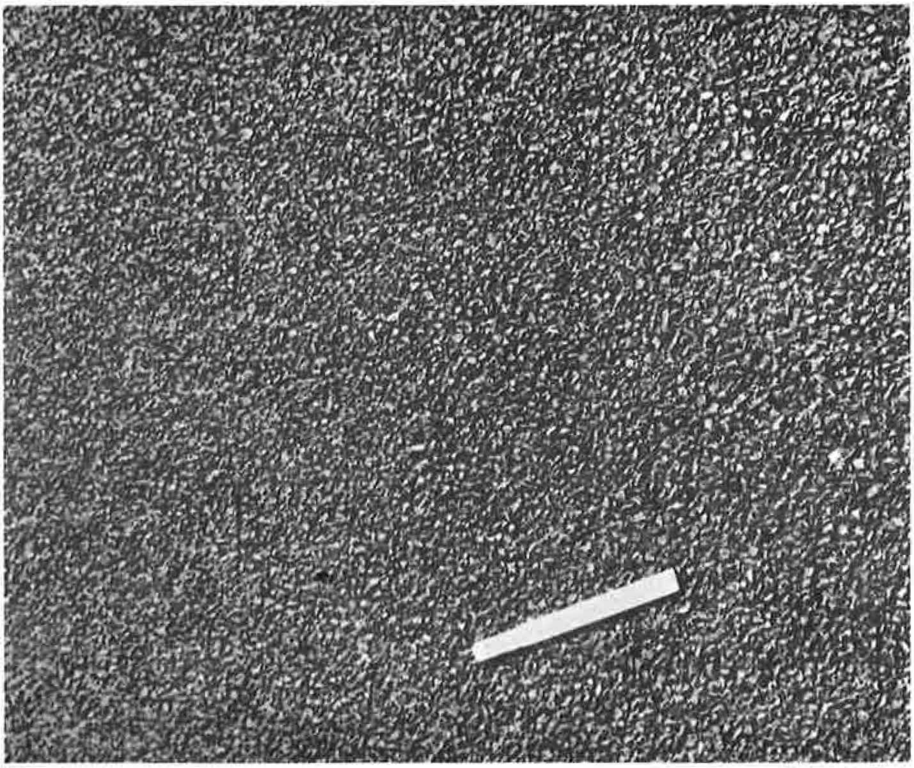

Figure 8. PI mix seal; Arizona state line-road forks.

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