SHALE—ITS PLACE IN THE CONSTRUCTION OF ROAD BASES

By G A Rahn, *Research Engineer*
Pennsylvania Department of Highways

SYNOPSIS

As the result of a question raised in Pennsylvania in 1932 concerning the use of shale in bases on secondary and tertiary roads, an investigation was undertaken based on examination of the shale surfaced roads in existence at that time

This work resulted in the design of a shale base from which the water could drain readily and the development of a test which gives results comparable to the effects of weather and abrasion on the roads

Bases built in accordance with these findings are in good condition after 4 to 6 years of service

An investigation of the shale roads in existence in Pennsylvania in 1932 was undertaken to determine the desirability and suitability of shale for use in the construction of bases on the secondary and tertiary highway system

The roads inspected were on the township system—in other words they might be termed "shale surfaced roads" There was no attempt at shoulder construction, the shale was usually placed on the roadway in a layer 4 to 6 in thick and traffic allowed to smooth the edge of the shale layer and form a normal shoulder line Naturally both good and poor jobs were encountered In each case, however, an effort was made to ascertain the source of the material, an inspection made at the respective pit or bank, and a representative sample of the material obtained for laboratory use. The problem then was to establish a laboratory method for differentiating between the various qualities of shale as determined by field investigation on the roads surveyed The following method was developed

A TEST FOR QUALITY DETERMINATION

The important effects were those due to weathering and abrasion, which meant that forces of a similar nature would have to be introduced into the laboratory test To simulate weathering the shale sample was subjected to the sodium sulfate test in a manner comparable to that performed on rock In this test a 50 gram sample of air dried shale was used, the pieces were approximately cubical in shape and of sizes that would pass a $\frac{5}{8}$ in screen and be retained on the $\frac{1}{2}$ in screen This sample after being subjected to the usual five cycles of sodium sulfate was used for abrasion test In the abrasion test the sample was placed in a small earthen bowl approximately 4 in in diameter and 2 in deep, with six $\frac{3}{4}$ in and six $\frac{1}{2}$ in steel ball bearings The bowl was covered and then clamped on the platform of a Per Se sand shaker The toggle action produced impact of the steel ball bearings on the shale sample After 3000 revolutions the sample was removed and sieved over the $\frac{1}{2}$ in, $\frac{1}{4}$ in and $\frac{1}{8}$ in screens, and Nos 10, 100 and 200 sieves

The tests were then correlated with the observations made on these various materials under field conditions, and as a result it was decided that a shale after being subjected to the tests would be accepted if not more than 10 per cent passed the 200 mesh sieve

DESIGN OF BASE SECTION

The preliminary investigation of these township roads indicated that in the design of the base section, sumping the base thru the placing of impervious shoulder material adjacent thereto should be avoided as shale is a lower grade material than that encountered in the usual rock formation, which cannot withstand the weathering and abrasive action as successfully as rock, especially when subjected to traffic, water and frost actions. For this reason we advocated what is called a feathered edge design (Figure 1). In this design the water is allowed free drainage to the ditch line over a curved subgrade, and is not impounded in the base material. A 6 to 8 in. compacted depth of shale is laid on the roadway section. The shoulders are also of shale, and they are feathered

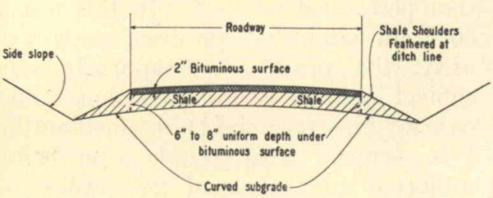

Figure 1

at the ditch line. A 2 in. bituminous penetration surface covering the width of the roadway is laid on these bases.

INSPECTION OF SHALE BASE CONSTRUCTION AFTER FOUR TO SIX YEARS OF USE

Approximately 65 miles of shale base—bituminous surface type were constructed. After 4 to 6 years of use this mileage was surveyed and its condition determined and rated. An analysis of the condition of this mileage is given in Table 1.

The poor mileage in both "trenched" and "feathered" type was tied down definitely to shale of poor quality or to shale of erratic or irregular formation, obtained from banks in which the quality or formation changed as the work progressed. These banks were abandoned when this condition became apparent. A desirable bank is shown in Figure 2, and undesirable one in Figure 3.

For all practical purposes the shales used in the "trench" construction and the "feathered" construction were on a par one with the other. In comparing

TABLE 1

CONDITION SURVEY—AGES 4 TO 6 YEARS

Type of Base	Miles Surveyed	Condition Rating[2] Per Cent of Mileage		
		Good	Fair	Poor
Trench[1]	26.50	55	36	9
Feathered	38.36	87	12	1

[1] In the trench or box type of base the shale was only placed under the roadway surface, the shoulders were of earth.

[2] Condition Ratings:

Good—Good riding, no patching to negligible patching.

Fair—Fair riding, patching more in evidence.

Poor—Rough riding, extensive patching, heaved, cracked.

Figure 2. Desirable Shale Bank. The quality is uniform. The stratification is uniform.

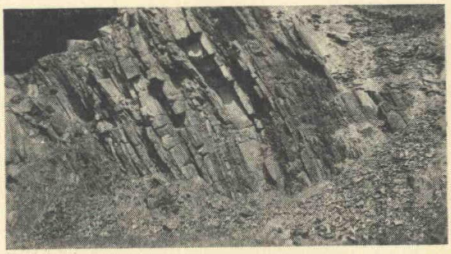

Figure 3. Undesirable Shale Bank. The quality is non-uniform. The stratification is non-uniform—shale to rock.

the two types we find that 55 per cent of the "trenched" type mileage was classed as good construction, while 85 per cent of the "feathered" type mileage was placed in this classification, a difference of 32 per cent in favor of the "feathered" design.

Figure 4 is representative of good shale base construction. Figure 5 shows the shale shoulder of the feathered edge design. Figure 6 shows a section of road in which a poor quality of shale was used in constructing the base.

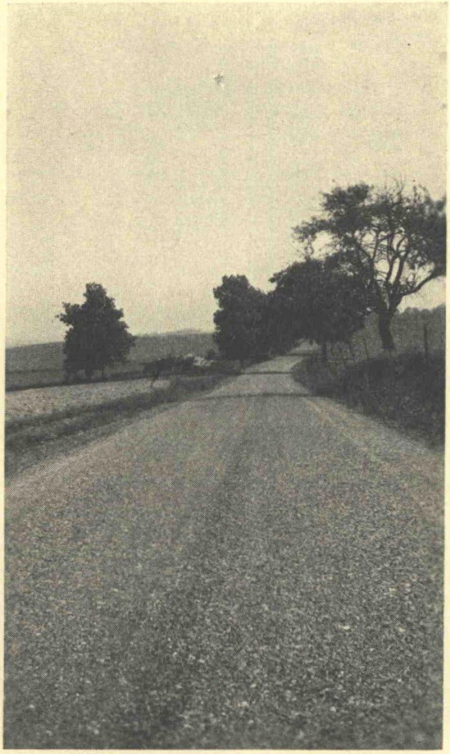

Figure 4. Shale Base. Surface in excellent condition. Good quality of shale used.

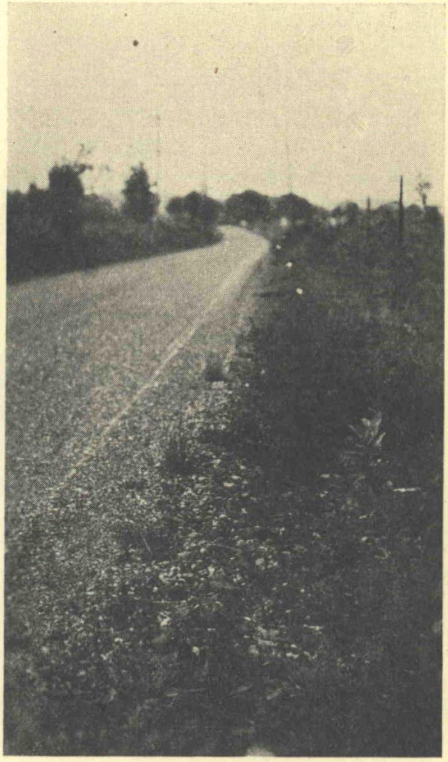

Figure 5. Shale Shoulder—Feathered Design.

SHORTCOMINGS OF FIRST TEST METHOD USED

One undesirable feature of the first test method employed was the length of time required to obtain results. Two weeks were required from the time the material was forwarded to the laboratory until test results could be given to the men in the field.

Another undesirable feature was the temperamental nature of the tests. The results of the sodium sulfate test varied with the temperature at which the tests were conducted. This, together with the inherent rather erratic quality of the shales made the control very difficult. The development of another test procedure was found to be imperative, the main objective being the shortening of the testing time.

RECOMMENDED TEST METHOD

The principle employed in the test is that of the Los Angeles abrasion machine with the abrasion being applied in the presence of water. The apparatus (Figures 7, 8, 9) consists essentially of a piece of 6-in. pipe with two steel discs welded to the ends forming a cylindrical drum. The inside dimensions are diameter 6 in. and width 5 in., with a charging aperture 2 by 5 in. To this aperture is fitted a steel cover with a 1-in. steel angle

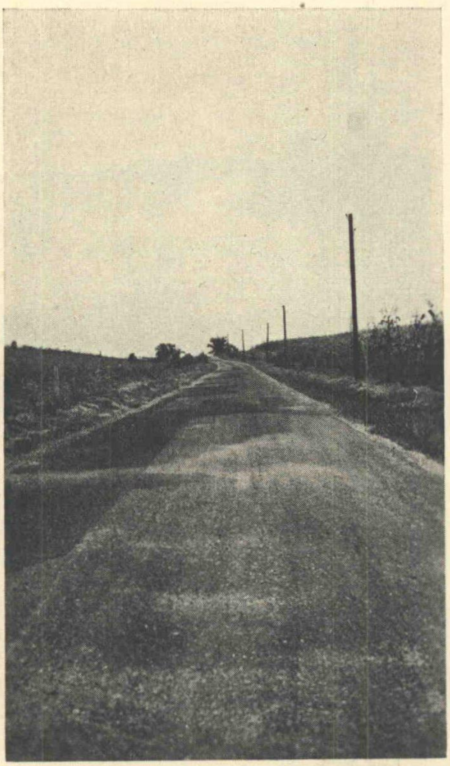

Figure 6. Shale Base. Surface in poor condition. Note patching. Poor quality of shale used in constructing this section.

trip-shelf welded to same and sealed by means of a rubber gasket, and the entire assembly, secured by wing nuts. A section of steel shaft is welded to each end, the whole suspended on shaft hangers and rotated by means of an electric motor at between 30 and 33 R.P.M.

The shale sample consists of 100 g. of air dried shale which has been cut to approximately $\frac{5}{8}$ in. cubes. In other words; pieces that will pass the $\frac{5}{8}$ in. screen and be retained on a $\frac{1}{2}$ in. screen. After the shale is placed in the drum the abrasive charge is added. This abrasive charge consists of six $\frac{3}{4}$ in. ball bearings, and six $\frac{1}{2}$ in. ball bearings. Finally 200 cc. of water are added to the drum, the

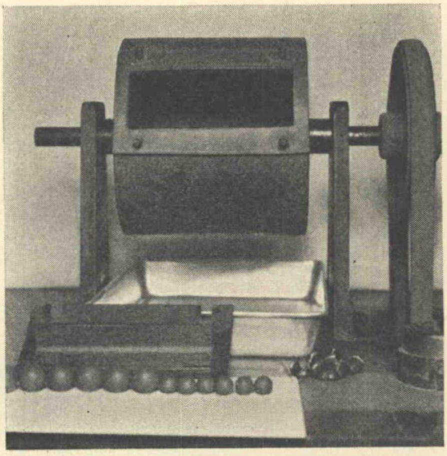

Figure 7. Shale Abrasion Machine

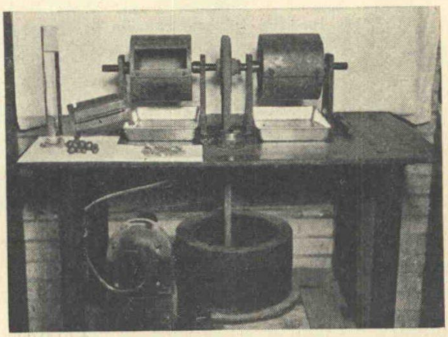

Figure 8. Shale Abrasion Machine—Assembly—Test Specimen and Charge.

cover placed securely and the entire charge subjected to 2,000 revolutions, at 30 to 33 R.P.M. The sample is then removed from the drum and washed on a 10 mesh sieve. The portion retained on the 10 mesh sieve is dried, weighed, and the loss recorded.

This method of test was then corre-

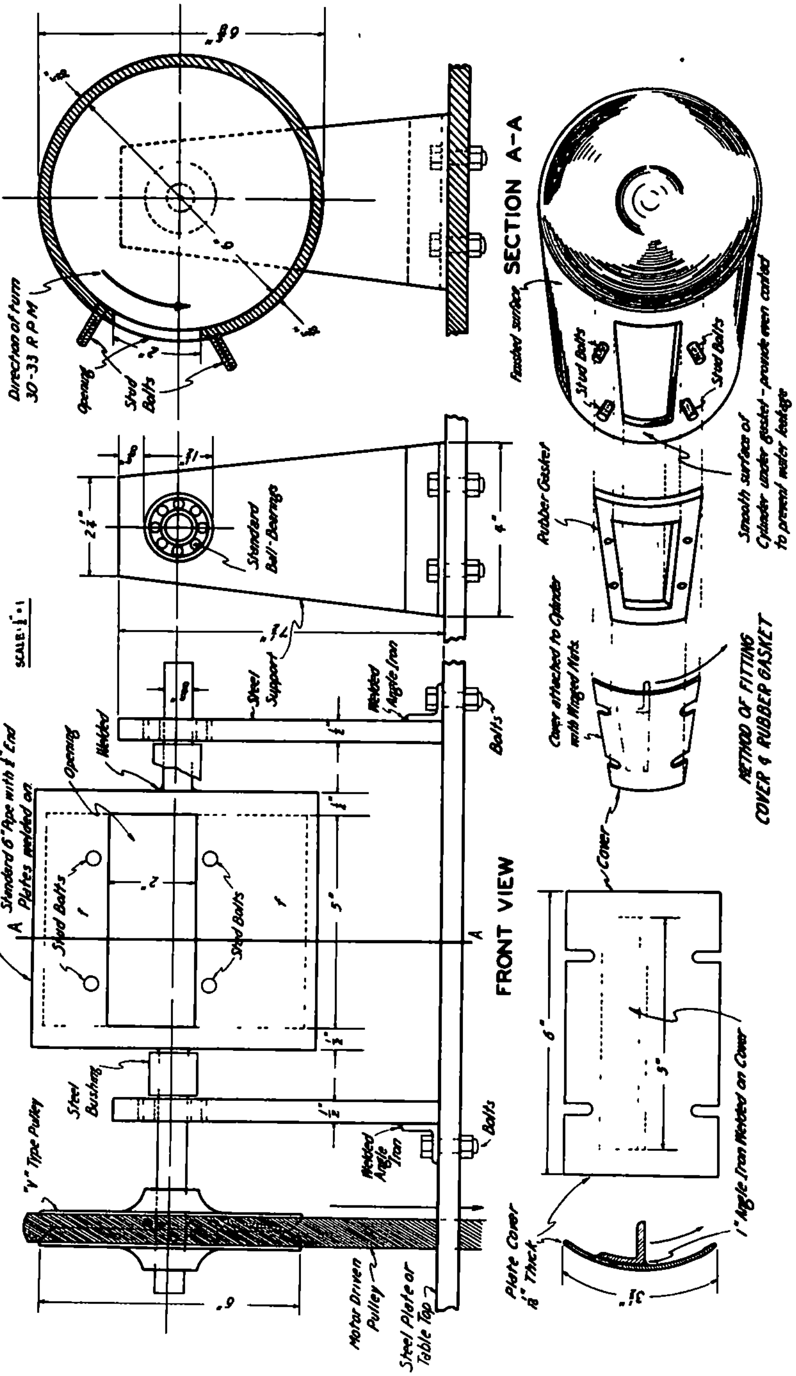

Figure 9. Shale Abrasion Machine, Pennsylvania Department of Highways

lated with the field service tests Based on the observations of the conditions of these various roads it was learned that a shale tested in this manner could have an abrasive loss up to 45 per cent and be suitable for use in shale base construction Due to the eccentric nature of the shale formations, however, it was thought best to place a safeguard on preliminary samples obtained from the shale source and a limit of 30 per cent loss by abrasion is permitted on these samples, while on the control samples, which are received from time to time during the construction, a limit of 45 per cent loss by abrasion is permitted

CONCLUSIONS

The design and test procedure have given good results in Pennsylvania and are presented for the information of those interested in the hope that investigation in other States will be stimulated We intend to work further in our efforts to extend the use and control of shale to types of construction other than that mentioned in this paper

APPENDIX

Test Methods Tried

Abrasion loss at 2,000, 4,000 and 6,000 revolutions, dry method, no water added While there is a material increase in abrasion loss as the number of revolutions is increased, the increase in the number of revolutions does not give any wider range for differentiating between shale qualities

Size of particles in shale test specimen There is no great difference in abrasion loss between $\frac{5}{8}$-in and $\frac{1}{2}$-in cubes, that is, a sample made up of $\frac{5}{8}$-in cubes and one made up of $\frac{1}{2}$-in cubes There is a material difference when the sample is made up of smaller size particles

Wet and dry abrasion methods tried The wet method is desirable from the standpoint of paralleling field conditions, it also definitely identifies poor quality

Soaking versus immediate test There is no great difference in abrasion loss between samples tested immediately (with the addition of water) and samples of the same shale soaked in water at room temperature for 24, 48 and 72 hours before testing

Possibilities for further study

1 Changing size and weight of steel charge
2 Changing quantity of water charge
3 Changing speed of drum
4 Changing number of revolutions
5 Method of preparing sample At the present time the cubes for the test specimen are prepared by means of a hammer.
6 Correlating the effect of test particle size
7 Developing test for thinly laminated shales
8 Establishing requirements dependent on type of construction

DISCUSSION ON SHALE IN CONSTRUCTION

Mr C N Conner, *Bureau of Public Roads* Mr Rahn has pointed out the desirability of carrying the shale surfacing material to the full width of the graded roadbed That important point deserves more attention than most highway designers have given it and it should be emphasized This method of construction has been in general use since before 1920 in the Southern States where sand clay and top soil surfaces of featheredge cross section extending over the full width of the roadbed have given excellent service Within the past few years engineers in the Western States and in one or two Eastern States have adopted this method, and are abandoning the old trench type section which was flanked by soil shoulders More aggregate is required for the full width section than for the narrower trench section but this can easily be justified because of lower maintenance costs resulting from better drainage and because of improved service to traffic provided by the wider surface

Mr Rahn We are very partial to that design and we hope that similar practice can be developed in the construction of waterbound macadam and gravel in Pennsylvania

Chairman Jackson There is need for information on how to develop low-cost materials The Bureau of Public Roads has received many inquiries concerning tests of shale and base materials, some of which we have referred to the Pennsylvania engineers knowing of their experience