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EVALUATION OF NUCLEAR METHODS FOR MEASURING ASPHALT CONTENT OF BITUMINOUS MIXTURES

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

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EVALUATION OF NUCLEAR METHODS FOR MEASURING ASPHALT CONTENT OF BITUMINOUS MIXTURES

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This research project was initiated in 1968 with the following objectives:

1) Evaluation of commercial nuclear gages for measuring density of asphalt mixtures,

2) Evaluation of commercial nuclear gages for measuring asphalt content of bituminous mixtures,

3) Construction and evaluation of laboratory equipment designed specifically for measuring asphalt content of mixtures by nuclear methods.

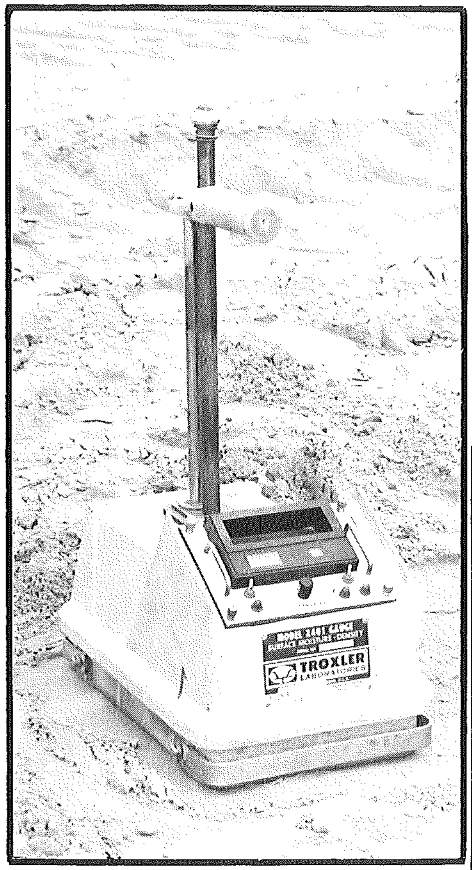
The first objective was completed and reported in Research Report No. R-745, "Evaluation of Nuclear Method for Asphalt Testing" (1). This report concerned field evaluation of the Seaman nuclear gage in both the air-gap and the surface contact modes of use. The results indicated that, with appropriate calibration, the instrument could be used to measure densities of bituminous surface courses within an accuracy of 3 to 4 lb/cu ft at the 95 percent confidence level.

Earlier work reported by DeFoe (2) indicated that the use of nuclear methods for measuring asphalt content of mixtures was feasible and recommended that further research be conducted in this area.

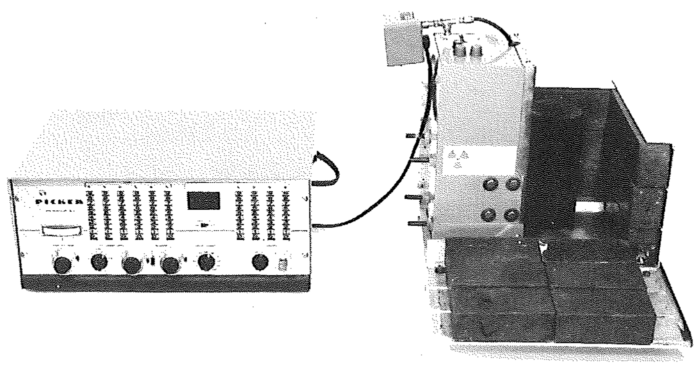
During the progress of this work a commercial gage, designed specifically for measuring the asphalt content of paving mixtures, was introduced by the Troxler Co. (Model 2226, Asphalt Content Gage). Several investigators reported favorable results using the equipment (3, 4).

On January 16, 1975, a meeting between interested parties in the Department was held to discuss the possible use of the Troxler Model 2226 Asphalt Gage for various purposes and to establish supervisory responsibilities for the work. As a result, it was decided that all evaluation testing of the new Troxler Asphalt Gage would be done by the Testing Laboratory with advice from the Research Laboratory; and the Research Laboratory would continue, and possibly expand, their project for evaluation of the soil moisture gages (as normally used for density control) to determine their suitability for measuring asphalt content of mixtures (original objective 2 of the project).

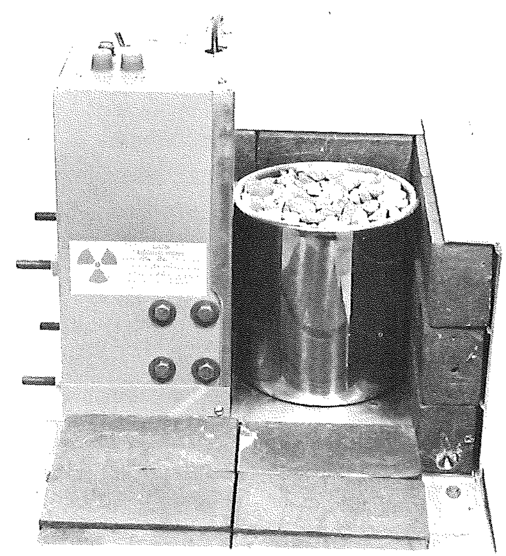
This report describes the Research Laboratory's attempts to use the soil moisture gage for measuring asphalt content supplemented, for comparison purposes, with data obtained using a mock-up system for testing small laboratory samples in both a loose and a compacted state.



Nuclear density-moisture gage normally used for soil compaction testing.



Complete gage with bituminous sample in test chamber. Electronic controls and readout are in the scaler unit at left.



Nuclear gaging probe containing radioactive source and neutron tubes, with aggregate sample in test chamber.

Figure 1. Experimental laboratory gage and standard nuclear density-moisture gage used in the asphalt content determination project.

Description of Equipment

The nuclear gage for measuring soil moisture in the field and the laboratory gage designed specifically for asphalt content measurement, although similar in concept, differ in certain respects which could influence accuracy of results and methods of operation. Soil moisture-density gages are of interest because this type of gage is widely used for highway soil compaction inspection throughout Michigan and, if found suitable, their use could be readily expanded to include asphalt content measurement in bituminous paving projects. Their use for measuring compaction of such paving mixtures has already been evaluated.

A laboratory instrument designed specifically for measuring the asphalt content of paving mixtures was fabricated in the Research Laboratory (Fig. 1). This gage, like the soil moisture gage, operates on the principle of neutron moderation by hydrogen atoms. Fast neutrons from a radioactive source are moderated or slowed by hydrogen atoms contained in the material being tested. Detector tubes, sensitive to only slow neutrons, provide a counting rate that is directly related to the number of hydrogen atoms in the material being tested. In soils, nearly all hydrogen occurs in the form of water and, similarly, in asphalt paving mixtures the asphalt cement is the predominant source of hydrogen. Schematically, a neutron gage designed for measuring hydrogenous materials is shown in Figure 2. Gages of this configuration are normally used for measuring soil moisture in-place but were evaluated in this study for their ability to measure the asphalt content of paving mixtures.

Evaluation of the Laboratory Gage

During this laboratory study, the influence of different aggregates and asphalt cements was measured in addition to evaluating the soil gages as a means of measuring asphalt content.

Table 1 lists the different asphalts and aggregates used in this study. Except for the sands and the dense graded aggregate, all aggregates were graded to meet Departmental specifications for bituminous paving mixtures.

The effect of various asphalts and aggregates, as well as different degrees of compaction, were measured using the laboratory gage (Fig. 1). The first step in this study consisted of calibrating the instrument in order to check its sensitivity for measuring asphalt content and to provide a basis for judging the influence of the several factors to be evaluated later. Cylindrical specimens (4-in. diameter, 8-in. high) were prepared by mixing various percentages of asphalt cement with a typical aggregate. Each

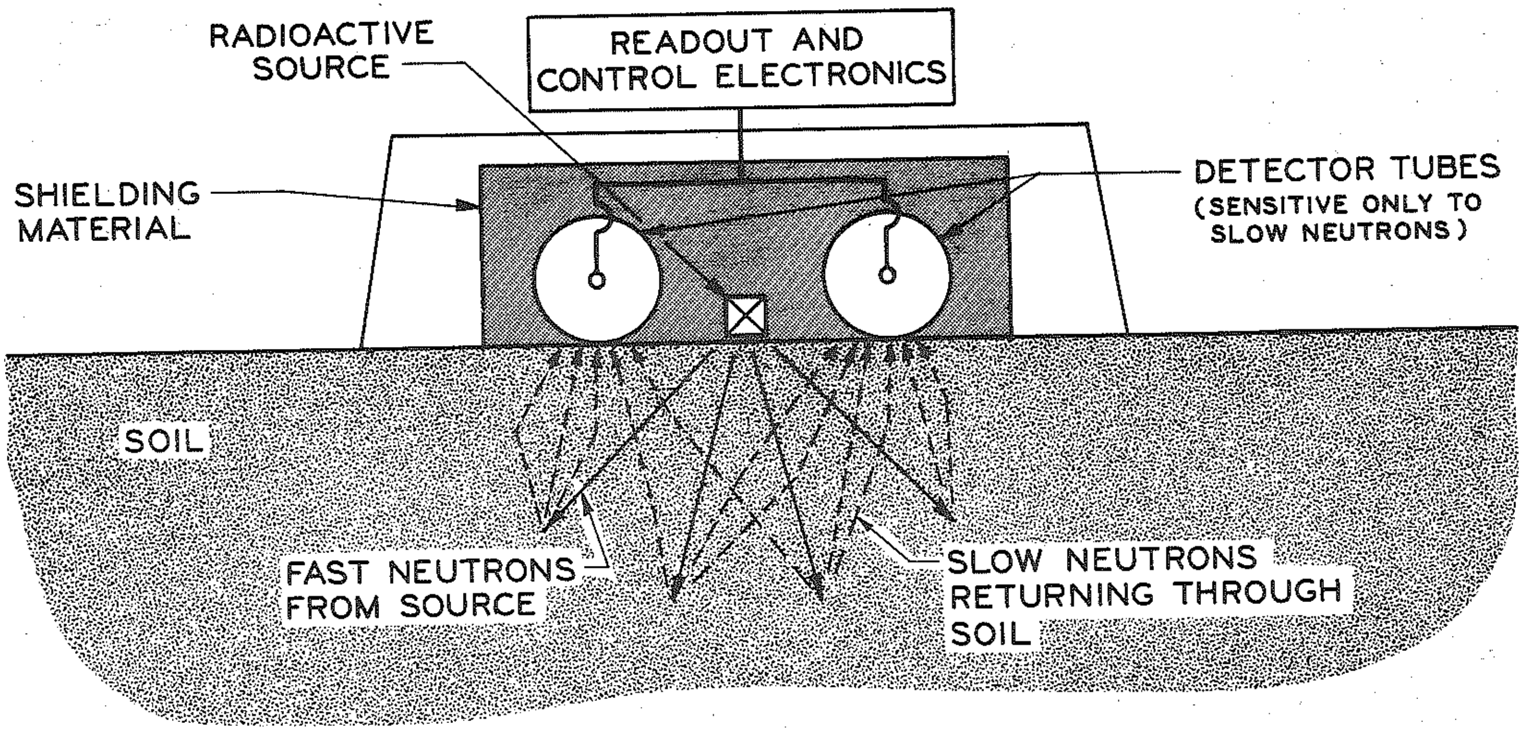


Figure 2. Schematic representation of moisture portion of a typical soil density-moisture gage.

TABLE 1
ASPHALT AND AGGREGATES USED IN EVALUATING
NUCLEAR METHODS FOR MEASURING ASPHALT CONTENT

	Sample Number	Material Description
Asphalt Cement	A-1	Leonard Refineries 85/100 penetration grade
	A-2	Leonard Refineries 200/250 penetration grade
	B-1	Marathon Oil Co. 85/100 penetration grade
	B-2	Marathon Oil Co. 200/250 penetration grade
Aggregate	1	Grand Rapids Gravel Co. 25A
	2	American Aggregates, Oxford 25A
	3	E.C. Levy Co., Dix Plant (blast furnace slag) 25A
	4	New Hudson Sand and Gravel 20A
	5	American Aggregates, Green Oaks 25A
	6	Drummond Dolomite
	7	Limestone (laboratory material, source unknown)
	8	Bayport Limestone
	9	Sand Subbase Material
	10	Sand Subbase Material
	11	Dense Graded Aggregate 23A
	12	Sand Subbase Material

specimen was placed in the gage and a one-minute reading obtained in each of three positions, obtained by rotating the sample approximately 120° between each reading. The resulting calibration, Figure 3, shows the general relationship between asphalt content and nuclear gage readings and indicates a standard error of estimate of about $\pm$ 0.2 percent in the 4 to 6 percent asphalt content range commonly used in Michigan paving mixtures. An additional set of calibration samples was prepared, using a different penetration grade of asphalt, and resulted in a similar relationship. Results of the two calibrations are also shown in Figure 3, where the average nuclear reading for each of three specimens is shown. These results show little, if any, influence due to the different penetration grades.

A second experiment was conducted designed to detect the effects of three variables; asphalt source, aggregate type, and penetration grade. Following the same procedures used in the first experiment, cylindrical specimens were formed and placed in the gage for testing. Asphalt cements of 85/100 and 200/250 penetration grades, obtained from three different suppliers, were used and mixed with two aggregates, one a natural aggre-

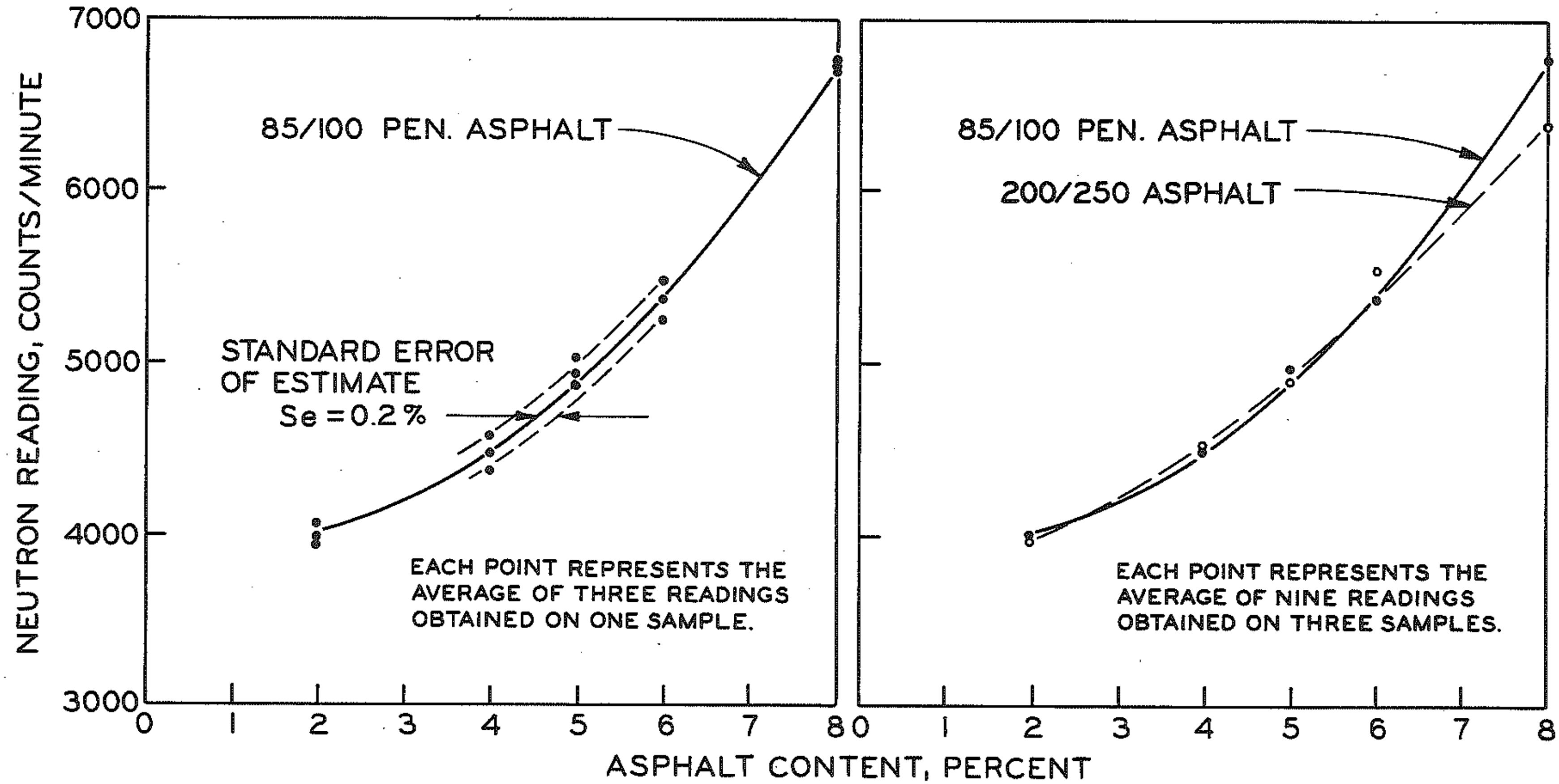


Figure 3. Calibration of laboratory asphalt content gage (left) and effect of penetration grade on gage results (right). The 85/100 curve is repeated at right for comparison purposes.

gate from the Grand Rapids area, the other a blast furnace slag from Detroit. Three replicate specimens were formed for each combination of the variables so that a total of 36 samples were involved. Three one-minute nuclear readings were obtained on each specimen. Results of this experiment, Figure 4, show a strong influence due to the different aggregates but no significant effects due to either asphalt grade or source of supply.

Because of the significant influence of different aggregate types found in the previous tests, a third experiment was performed which included a wide range of Michigan aggregates. The influence of eight different aggregates on neutron response was measured at three different density levels. Each aggregate was oven dried, compacted into the stainless steel sample container at selected density levels, and neutron readings obtained. Five replicate samples were tested for each aggregate-density combination, with three nuclear readings made on each sample. Results of this experiment, presented in Figure 5, again show the significant effect of aggregate type as well as some influence due to different density levels.

Evaluation of the Soil Moisture Gage

Nuclear gages have been used for several years to measure soil density and moisture content on Department construction projects. It was thought that the moisture function of such gages could be used to measure asphalt content of paving mixtures.

Evaluation of the soil gage for measuring asphalt content consisted of a series of experiments conducted in the Laboratory, in which sand and aggregate samples were placed in a stainless steel pan at various moisture contents. For these tests, water was used with the sand and gravel aggregates to simulate the hydrogenous effect of asphalt in order that samples could be more easily prepared and tested. Further calibration, using bituminous mixtures, was planned had acceptable levels of accuracy been obtained using water.

The first calibration involved 11 samples of fine, uniformly graded sand prepared at moisture contents ranging from 0 to 10.1 percent. Results indicated that accuracies (as indicated by one standard error of estimate) of 0.35 percent hydrogenous material might be expected (Fig. 6). Coarser aggregates were then prepared as pan samples, and nuclear gage moisture readings obtained. Results obtained in this aggregate calibration, also shown in Figure 6, indicated a comparable level of accuracy, with a standard error of estimate of 0.36 percent moisture. These tests, however, clearly show the need for separate calibration curves for each aggregate. Eight additional samples of two different sands were prepared and tested with the results shown in Figure 7. The need for calibrating for each material is again obvious.

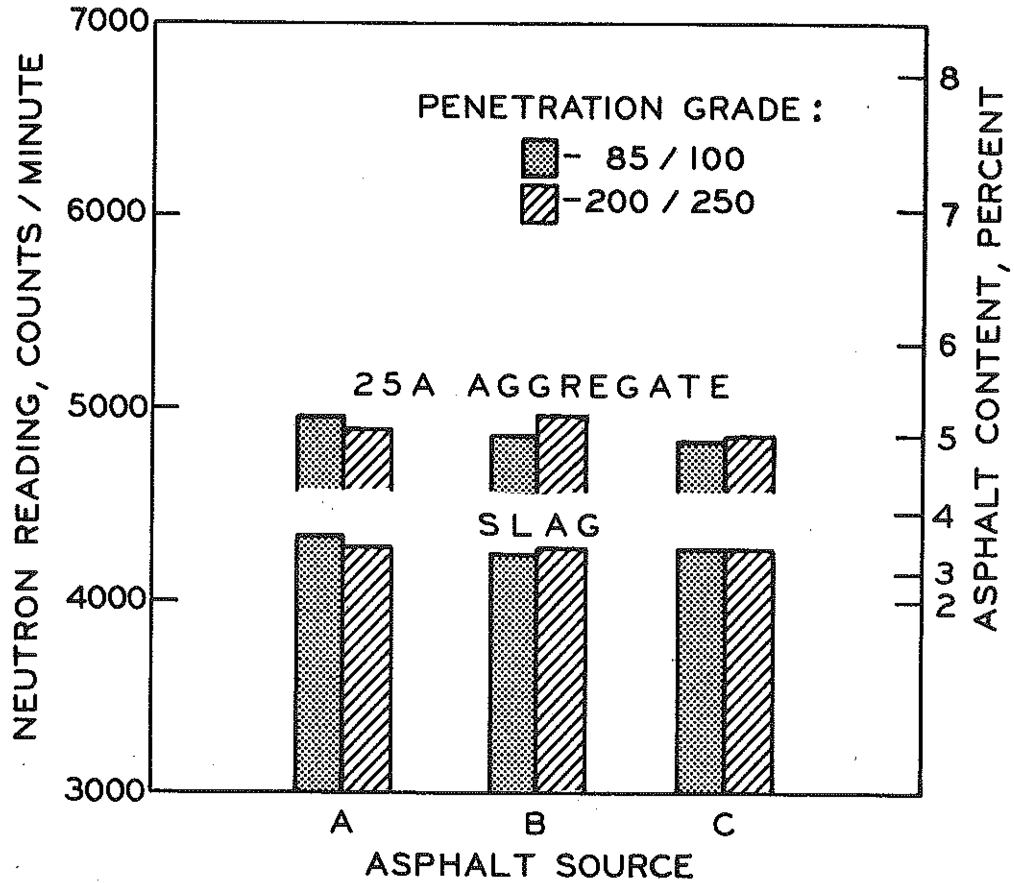


Figure 4. Influence of different asphalts and aggregate types on laboratory gage response.

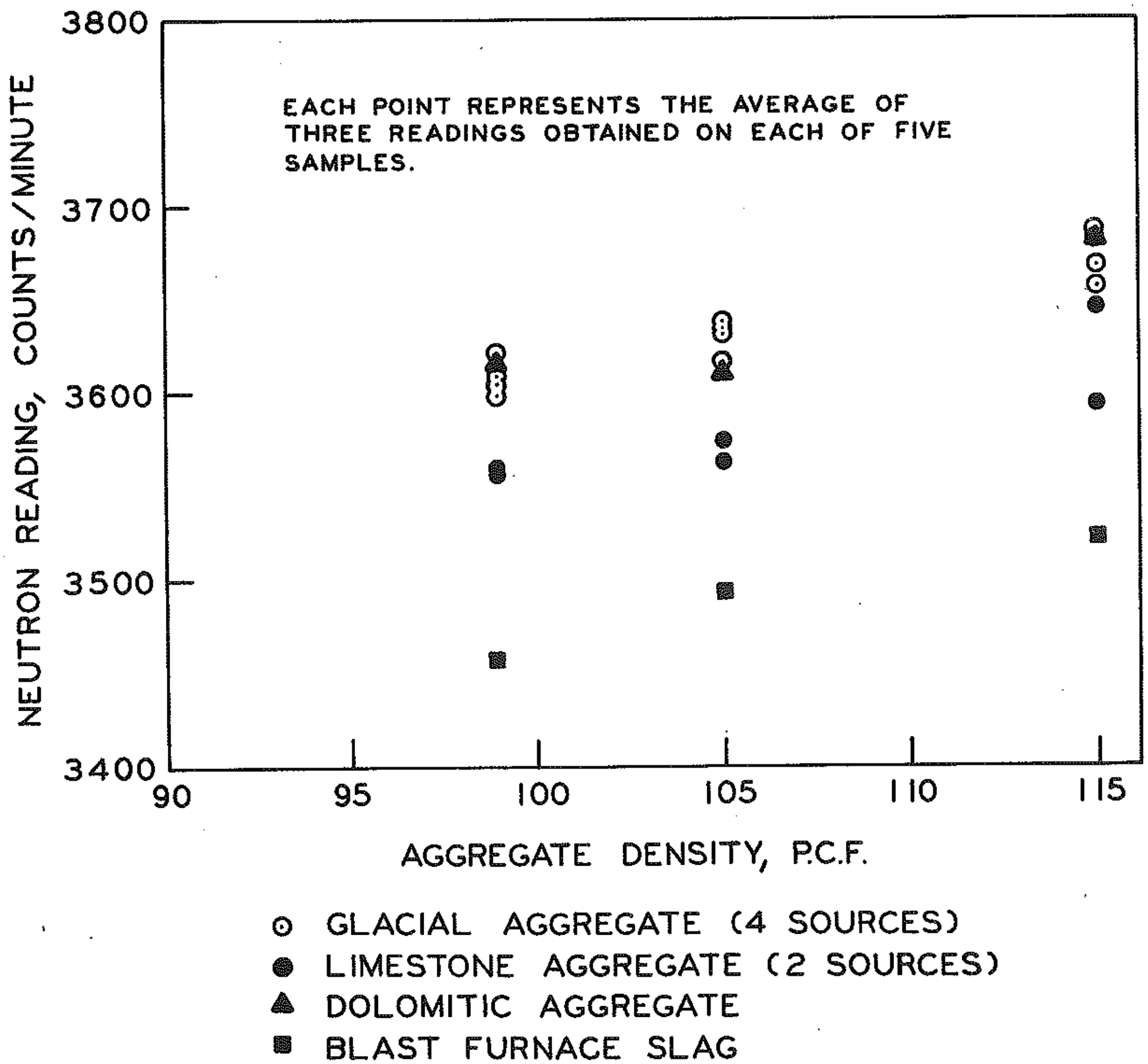


Figure 5. Effect of different aggregates and density levels on laboratory gage readings. Samples consisted of oven dry aggregate with no asphalt.

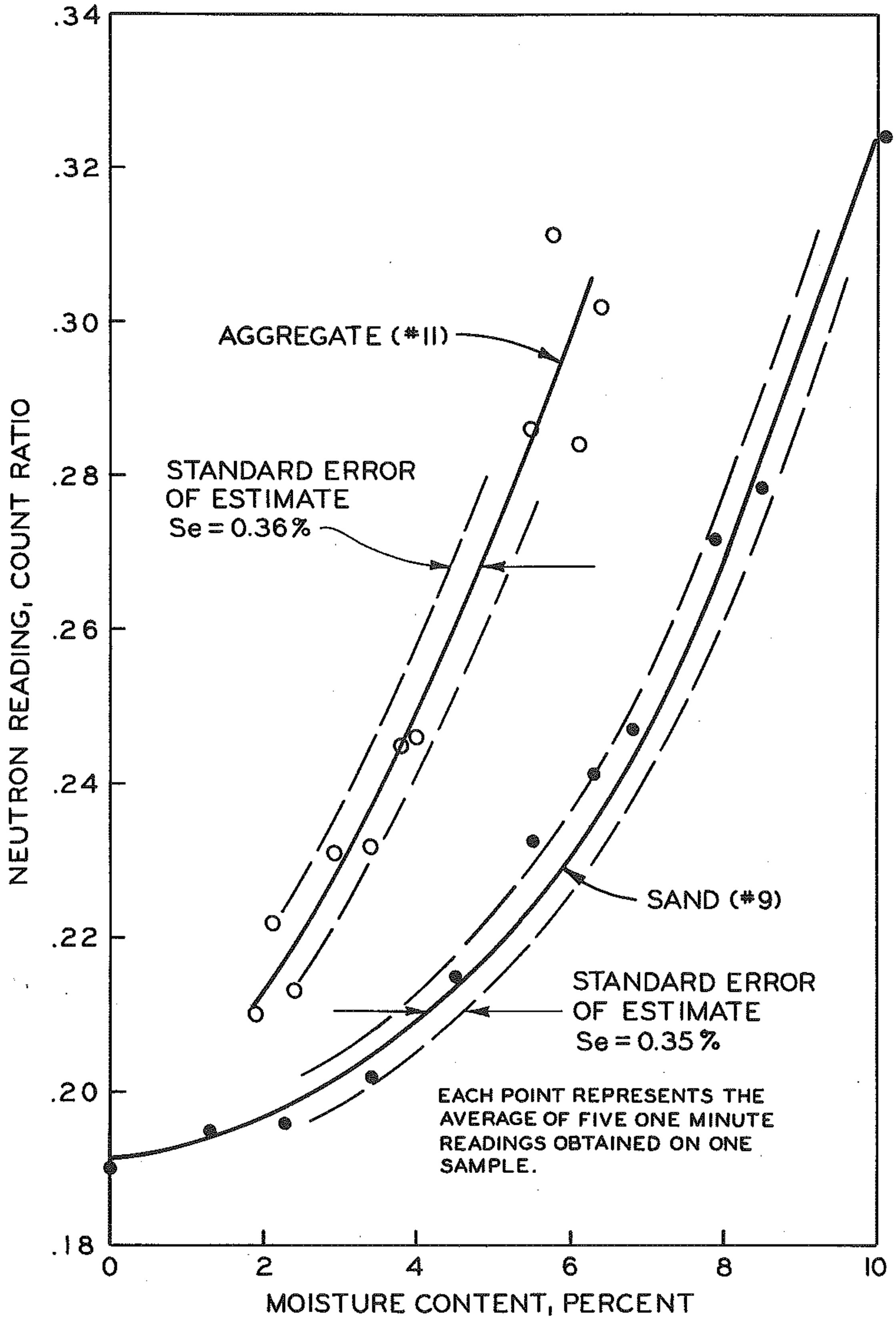


Figure 6. Calibration of Troxler soil gage involving laboratory pan samples of moist sands and aggregates.

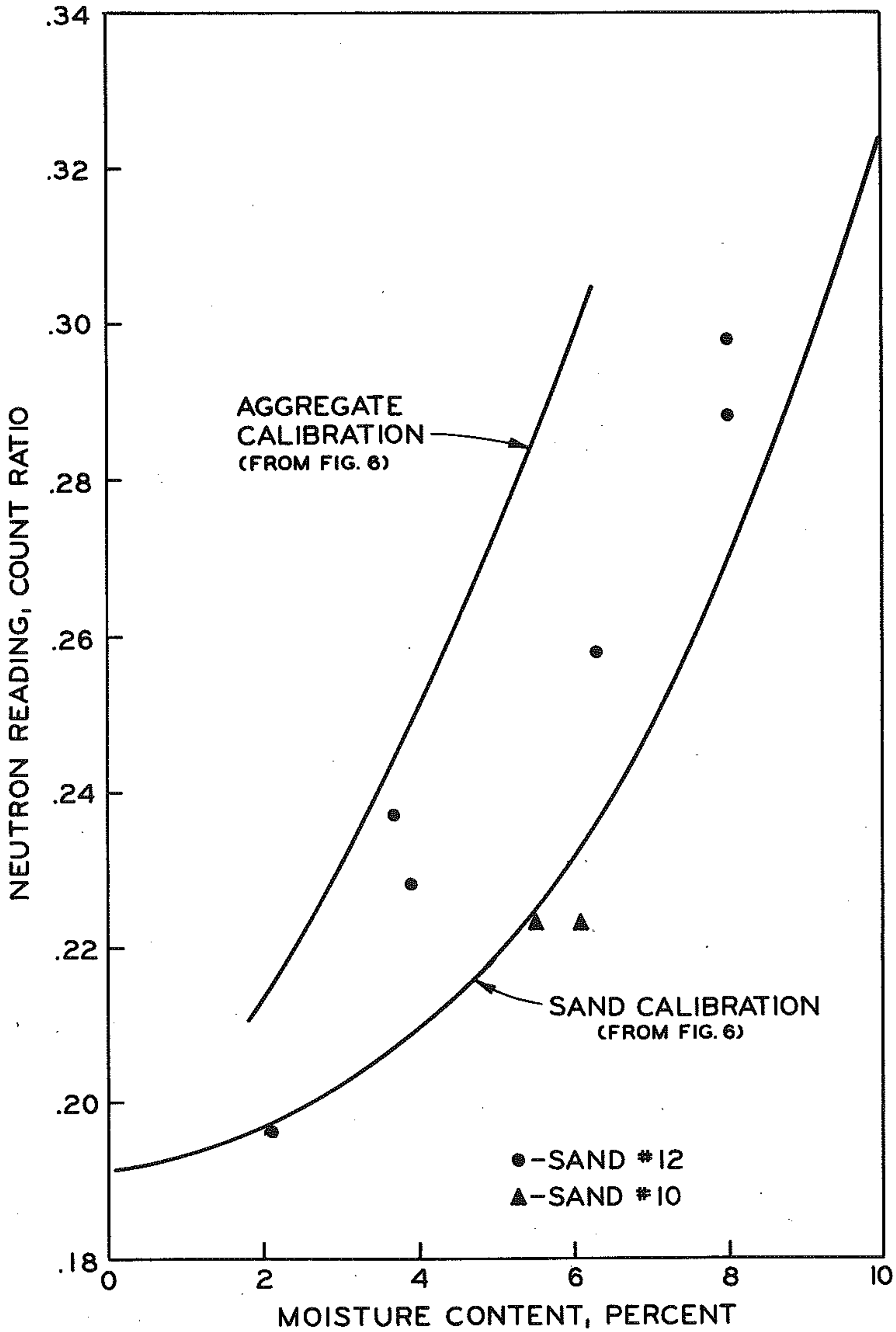


Figure 7. Comparison of test results from several sands and aggregate as measured with the Troxler soil gage using pan samples.

Discussion of Results

An experimental laboratory gage was constructed to study, more closely, the effects that different asphalts and aggregates, as used in typical bituminous mixtures, might have on nuclear gage response. Different aggregates, especially dolomites and slags, were found to have significant effects on asphalt content values as indicated by the gage. A typical soil density-moisture gage, Troxler Model 2401, was evaluated for its ability to measure asphalt content of mixtures placed in sample pans. This evaluation involved moist sands and gravels (to simulate bituminous mixtures) and indicates that individual calibration curves are required for different aggregate types used in paving mixtures.

The accuracy of nuclear gages for measuring soil moisture content has been reported to range from 0.3 to 3.0 lb/cu ft under field conditions, with some improvement when used under laboratory conditions (5). Precision of the gages, however, is in a range of 0.05 to 0.5 lb/cu ft, which reflects the theoretical limit of accuracy that might be expected. Precision is the inherent repeatability of the instrument when operated under unchanging conditions, such as on a reference standard or calibration block. Precision is controlled by the random decay of the radioactive source and by the electronic stability of the instrumentation. Accuracy, which is the difference between the indicated value and a true value, depends on proper calibration for the materials being tested, sample homogeneity and chemical composition of the sample.

AASHTO Guide Specifications (6) for Highway Construction recommend that asphalt contents of paving mixtures be measured within 0.4 percent of the design value. With an accuracy (standard error) of 0.35 percent the gage does not seem well suited for project control. Actual variability of plant mixes, tabulated from recent construction records, indicate that plants operate with standard deviations ranging from 0.04 to 0.52 percent with an overall average of 0.15 percent. Standard deviations exceeding 0.2 percent were found for only 12 of 57 projects studied.

Gages designed for the sole purpose of measuring asphalt content of paving mixtures became available soon after this project was initiated. These instruments, designed for laboratory use, have been evaluated by several highway agencies. The Pennsylvania Department of Highways (7) reported that accuracies, as defined by one standard error, of $\pm$ 0.2 percent were obtainable in mixes containing from 3 to 12 percent asphalt. Other investigators report accuracies of 0.1 to 0.3 percent at testing times of 10 to 20 minutes (8, 9). Factors reported to influence test results were aggregate types, asphalt penetration grades and types, and aggregate moisture content.

Conclusions

Two types of nuclear gages were evaluated during this study to determine their suitability for bituminous aggregate mixtures. The following specific conclusions were applicable to the different gages:

1) The laboratory asphalt gage (designed specifically for asphalt content measurement) was accurate within ± 0.2 percent, as indicated by one standard error of estimate, for a 4 to 6 percent asphalt content range. However, the results obtained were strongly influenced by the type of aggregate used in the mixtures indicating that the gage must be calibrated for each type aggregate used. Results were not influenced by different sources and grades of asphalt.

2) The Troxler moisture-density gage (when using water in place of asphalt to represent the gage-sensitive hydrogenous component of the mixture) was accurate within only ± 0.35 percent (one standard error of estimate), a value barely within the upper AASHTO specification variation limit of 0.4 percent and much higher than the ± 0.15 percent standard deviations generally obtained with conventional extraction methods.

Based on results obtained during this study, it is recommended that only a gage specifically designed for the purpose be used for measuring asphalt contents of bituminous mixtures and that individual calibration curves be developed for each basic aggregate type used.

The conventional nuclear moisture-density gages do not appear to be suitable for accurate measurement of asphalt content of bituminous paving.

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