Determination of Asphalt Content of Bituminous Mixtures by Means of Radioactive Isotopes

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With a proper combination of radioactive isotopes and electronic equipment, it is possible to determine the relative concentration of hydrogen ions in a bituminous mixture. The only source of hydrogen ions in a dry bituminous material is the bitumen itself. Thus, it is possible to determine the percent of bitumen in a mix from curves which are based on tests of standard samples. From data accumulated by means of a 25-millicurie source of radium-D beryllium and an enriched boron-fluorid 10 counting tube, a curve of counts of slow neutrons vs. asphalt content, in pounds per cubic inch, is presented for the samples tested. Also shown is a family of curves relating counts of slow neutrons to percent of asphalt by weight for various total unit weights of samples. A table is presented which gives mix data and test results for all samples tested. It is concluded that a quick and reasonably accurate technique for determining asphalt content by means of radioactive isotopes has been found.

● AS the world fast approaches the full realization of the blessings or chaos of the Atomic Age, it seems fitting that every opportunity for the peaceful application of atomic energy should be explored. This paper presents a brief discussion of the principles involved and the test procedure developed by the authors to determine the asphalt content of bituminous mixtures by means of radioactive isotopes. The study reported was jointly sponsored by the National Science Foundation and the University of Wyoming and carried out in the research laboratories of the Civil Engineering Department.

THEORETICAL PRINCIPLES

Petroleum asphalts are relatively pure hydrocarbons. The amount of hydrogen in a given quantity of asphalt is dependent upon the characteristics of the parent crude and the process and temperature of manufacture, but is relatively constant for similar products of fixed origin from a given refinery. No other constituent of a dry bituminous pavement mixture contains an appreciable amount of hydrogen. Since hydrogen ions are capable of reducing to measurable values the energy level of certain emanations from radioactive material, it has been possible to correlate within a reasonable variation the percentage of asphalt in a given mix against counts of radiation particles altered by the hydrogen in the asphalt.

In their decay processes, radioactive isotopes produce a series of radiations including alpha, beta, gamma, and neutron emissions. Fast neutrons, or neutron emanations of a high energy level, lose a portion of their energy when they come in contact with hydrogen ions and become slow or thermal neutrons. Slow neutrons are detectable by the counting tube described below while fast neutrons are not. Thus, for a given geometry of instrumentation, the count of slow neutrons by the tube is directly proportional to the number of hydrogen ions, or percent of asphalt, in the sample.

For this research, the fast neutrons were produced in a capsule containing a powdered mixture of radium-D and beryllium. The decay of radium-D produces a gamma emission and the bombarding of beryllium by the gamma particles results in the liberation of fast neutrons from the beryllium. The fast neutron emission of the above source is not constant with time but is subject to an uncontrolled variation. According to the specifications of "Atomic Energy of Canada" who supplied the source, the neutron output of the 25-millicuric source is "9.0 × 10^4 n/sec. ± 15% Standard Deviation." This variation is undoubtedly an important source of scatter in test results; however, its effect was minimized by using a relatively long time interval for each count and taking a relatively large number of counts for each sample. Neutron sources of 10 and 25-millicuric strength with a half life of 22 years were first used in the experiments but the use of the 10-millicuric source was later discounted. There is some evidence that a source of greater strength than 25 millicuries might produce more uniform results.

EQUIPMENT

Figures 1 and 2 show the counter tube which registered the impulses from slow neutrons. The tube shown is a type containing enriched boron-fluoride 10 and was manufactured by N. Wood Counter Laboratory. Previous counter tubes, reported by Belcher *et al.* (*1*), used silver foil which emitted gamma particles when it was bombarded by slow neutrons. Because of the gamma emission of the Ra-D-Be source, it was difficult to determine how much of the count was caused by slow neutron bombardment and how much was caused by source radiation. Thus, the new tube which counts slow neutrons directly was preferable for the test reported herein. The electrical impulse in the tube resulting from the passage of a slow neutron was amplified and recorded on the scaler shown in Figure 1. This instrument, a Model 162 Decade Scaler, was produced by the Nuclear Instrument and Chemical Corporation.

CONSTRUCTION OF SAMPLES

Samples were made to cover the ranges in asphalt content normally encountered in bituminous pavement construction. It was essential that the samples be made durable enough to permit handling during testing, so an asphalt cement of 50–60 penetration was used initially. In later samples, an asphalt cement of 80–100 penetration was used. Separate tests with pure asphalt cements of all penetration ranges and with Mc-2 indicated that the grade of asphalt was not a variable in the test. Subsequent investigations have indicated that a high asphaltene content, in the magnitude of 50 percent by weight of asphalt, will produce a count variation. However, none of the as-

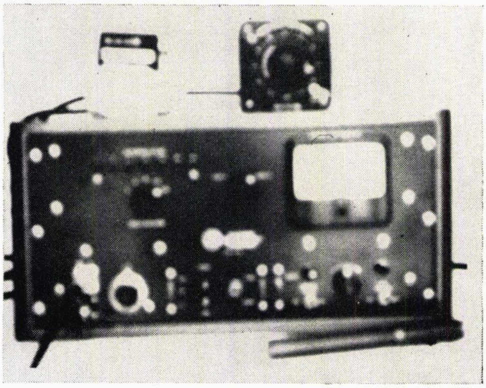

Figure 1. View of scaler, counting tube, timer, and recorder.

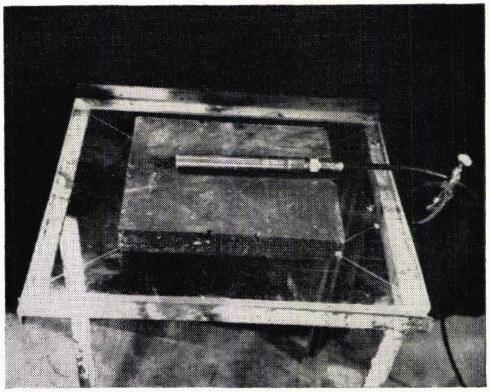

Figure 2. The bituminous sample in position for testing.

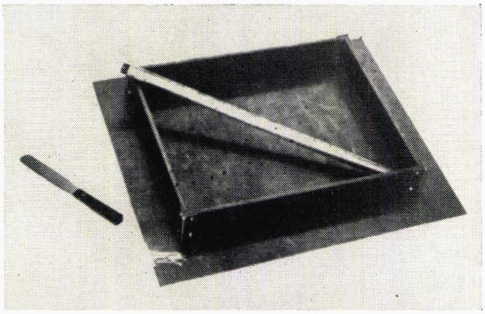

Figure 3. The steel mold in which samples were cast.

TABLE 1
MIX DATA AND TEST RESULTS

Sample No.	Mix Limestone: Sand: Cement: Bitumen	Asphalt		Unit Weight #/in³	Count	Standard Deviation
		Percent	#/in³ × 10⁻³			
	lbs.					
B-1	0:17.65:0:1.70	8.79	6.19	0.0694	228	6.5
					244	8.3
B-2	0:16.15:0.45:2.25	11.90	8.18	0.0685	305	9.8
B-3	4.0:15.5:0:1.50	7.15	5.46	0.0764	211	14.4
					190	20.6
C-1	0:20.35:0:0.545	2.61	1.77	0.0679	107	8.9
					104	8.5
					108	5.7
C-2	0:19.40:1.69:0.794	3.62	2.58	0.0710	118	9.4
					123	12.1
C-3	0:19.11:1.66:1.09	4.98	3.54	0.0710	148	15.7
					156	11.9
C-4	0:20.16:1.75:1.45	6.22	4.71	0.0759	176	5.1
					176	13.2
					181	14.1
C-5	0:20.91:2.85:1.87	7.30	6.07	0.0833	235	20.8
					231	9.0
					227	15.8
					233	13.2
					230	12.1
C-6	3.62:16.30:2.72:2.23	8.97	7.24	0.0808	285	18.2
					298	18.4
					279	16.0
C-7	2.54:16.90:2.54:2.44	10.00	7.92	0.0794	288	29.3
					273	11.8
					307	12.4
					287	10.0
C-8	2.13:16.18:3.40:2.85	11.61	9.25	0.0796	343	9.3
					351	17.8
					349	7.8
C-9	8.89:8.08:3.23:3.70	15.48	12.00	0.0776	558	25.0
C-9R	8.82:8.02:3.21:3.67	15.48	11.90	0.0770	502	12.8
					551	15.7
L-2	Field sample—U.S. 30	4.10	3.14	0.0766	134	7.4

phalt cements used contained an appreciable quantity of asphaltenes.

Samples were composed of varying amounts of washed Laramie River sand, crushed Casper limestone, and Portland cement filler in addition to the asphalt. In general, greater proportions of limestone and cement were used in the samples containing the higher asphalt contents. No discernable effect of variation of the mineral portion of the samples was noted. Samples were molded in the steel mold shown in Figure 3 to a final size of 2 by 11 by 14 inches. The mix was compacted to produce a durable sample, however, no specific degree of compaction was required since the count was influenced only by the mass of asphalt per unit volume and was independent of the material filling the voids in the asphalt matrix.

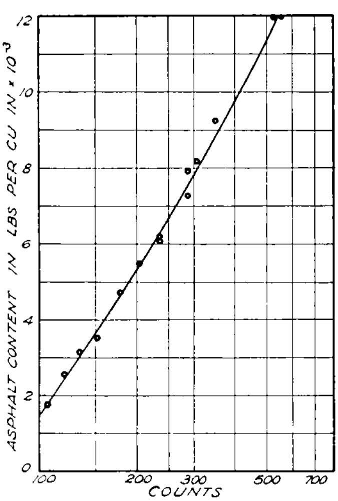

Figure 4. Relationship between counts and asphalt content in pounds per cubic inch.

The sample thickness of 2 inches was based on a series of tests in which the neutron source and the counter tube were placed on opposite sides of a hydrogenous material of adjustable thickness. It was found that the rate of counting increased as the source and tube were brought closer together until they were about 2 inches apart. Bringing the source and tube closer together than 2 inches resulted in a decrease in counts. Thus, 2 inches was selected as the "plateau" thickness for the samples;

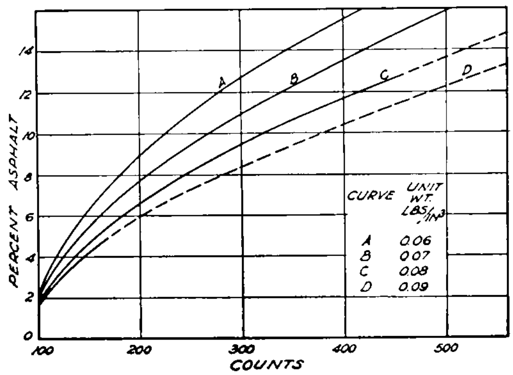

Figure 5. Chart for determining percent of asphalt from counts for various unit weights of samples.

i. e., a small variation in thickness from 2 inches produced no variation in counts.

Results obtained from two series of tests were promising but for various reasons had to be discarded. The final series of tests was performed on a total of 11 samples. Pertinent data on the composition and test results for these samples are given in Table 1. It will be noted that the asphalt content varied from 2.61 to 15.48 percent and that the asphalt density varied from 0.00177 to 0.01200 pounds per cubic inch.

During a test run, the 25-millicurie Ra-D-Be capsule was placed on the center of a lucite table with its flat side flush with the top of the table. The sample was then centered on the lucite table and the counter tube was placed on the sample directly over the source as shown in Figure 2. Counts were then determined so that the results might be analyzed statistically. The degree with which results could be duplicated may be gauged from column 6 of Table 1.

When the results of tests are plotted on semi-log paper, with logarithm of counts as abscissae and asphalt content in pounds per cubic inch as ordinates, a straight line correlation is noted as shown in Figure 4. A more useful graph of test results is shown in Figure 5. In this figure, the asphalt content in percent by weight of the total sample is plotted against counts for various unit weights of total samples.

Values for Figure 5 were computed from those plotted on Figure 4 on the assumption that the density of the asphalt matrix remained constant while a change in proportion of mineral aggregate caused a variation in both percent of asphalt and total unit weight of sample. Use of Figure 5 will enable the percentage of asphalt to be determined from the count if the density of the mix is known. For this purpose a sample 2 inches in thickness may be cut from an existing pavement and tested; or, more practically, a sample of mix may be placed in a steel mold and compacted to a reasonable density and tested. Asphalt content may then be determined directly from Figure 5.

CONCLUSIONS

The method of determining asphalt content reported herein will probably not replace the methods currently used for this purpose because of the variability of results and cost of equipment. It is of interest to note, however, that radioactive materials are suitable for the test described. With refinement, the test may warrant adoption as a quick method of checking asphalt content at fixed locations, such as stationary batch plants. It is noted that the curves presented are applicable only to the equipment and geometry used at Wyoming. Similar curves would have to be determined for other sources, geometry, and background conditions.

Further research may produce better methods of accounting for the variability of the source flux and other causes of error. Research is continuing at Wyoming to determine whether methods similar to the one described above will measure asphaltene content closely enough to detect cracked asphalts. Undoubtedly, other applications of the principles discussed above will occur to the reader.

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REFERENCE

1. BELCHER, D. J., COYKENDALL, T. R., AND SACK, H. S., "The Measurement of Soil Moisture and Density by Neutron and Gamma-Ray Scattering," Technical Development Report No. 127, Civil Aeronautics Administration Technical Development and Evaluation Center, Indianapolis, Indiana, October, 1950.