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SURVEY ON STRAIGHT ASPHALT PROPERTIES IN JAPAN

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Survey on Straight Asphalt Properties in Japan

by

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Synopsis:

The data presented here are the compiled achievements of tests and studies on the properties of present straight asphalt in Japan, and which were conducted from September 1985 to March 1986 for clarifying the quality of straight asphalt for road pavements as well as the problems related to its test method.

The contents can be roughly divided into

- (1) the survey of quality and properties prescribed in JIS (Japanese Industrial Standards)
- (2) the survey of quality and properties not prescribed in JIS, and
- (3) the analysis of the correlations between properties.

Asphalt used in the tests were all straight asphalt for road pavement currently being produced in Japan. The data will provide the useful information necessary for knowing the quality and properties of present straight asphalt and for reviewing the desirable way of preparing quality standards in the future.

Key Words: Pavement, Straight Asphalt, Quality Standards, Physical Properties and Chemical Analysis

Abstract

Road pavements in Japan are now mostly of asphalt pavement, and straight asphalt is being mainly used for road pavement. In Japan, the quality standard of straight asphalt for road pavement is prescribed in JIS K 2207 (Japanese Industrial Standards). However, these standards were prepared by making a partial revision (a revision was made to 100/120 grades) to the quality standards of the Asphalt Pavement Manual of 1978 edition, and the quality standards for straight asphalt (40/60 to 80/100) for road pavement have not changed since 1978. During the period from 1978 to today, the kinds of crude oil for asphalt have increased as a result of diversified overseas suppliers of crude oil, and also, petroleum refining technology such as heavy oil cracking has advanced considerably. Under such a background, it is now often said that the property of asphalt seems to have changed recently. On the other hand, previously unseen failure patterns now occur and road traffic has become much heavier recently and thus the requirements for the quality of paving asphalt have been diversified.

However, a national survey across the country on the quality and properties of straight asphalt has not been made in last ten years, and the quality test method for asphalt has not been actively reviewed. It has therefore been difficult to perform specific discussion on the quality and standards of asphalt. Because of this, the Pavement Division and Chemistry Division of the Public Works Research Institute have carried out a survey on the quality of straight asphalt. In this research, the present situation of the quality are clarified and various property evaluation tests are reviewed with respect to all the straight asphalt and the results compiled in this paper offers the precious information necessary for reviewing the quality and test methods of straight asphalt in the future.

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1. Outline of the Study

1.1 Purpose

The quality of petroleum asphalt is required to fully maintain the functions necessary for asphalt pavements and must satisfy the standards of JIS K 2207 (hereinafter called the JIS Standards: Table 1.1). However, discussions on the quality of asphalt are being more actively conducted in recent years under the background of changes in asphalt production methods resulting from more diversified crude oil supply and the development of petroleum refining technology.

Under the circumstances stated above, it was decided to clarify the present quality of asphalt and to study the future direction of property tests by performing various property tests on all straight asphalts currently produced for roads in Japan.

Table 1.1 Requirements for Petroleum Asphalt (JIS K 2207)

	Penetration Grade							
	40-60		60-80		80-100		100-120	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Penetration at 25°C, 100g, 5sec, 1/10mm	40	60	60	80	80	100	100	120
Softening point, °C	47.0	55.0	44.0	52.0	42.0	50.0	40.0	50.0
Ductility at 15°C min., cm	10		100		100		100	
Solubility in trichloroethane, min., %	99.0		99.0		99.0		99.0	
Flash point, Cleveland Open Cup, min., °C	260		260		260		260	
Specific gravity at 25°C, min.	1.000		1.000		1.000		1.000	
Thin-film oven test:								
Mass change, max., %		0.6		0.6		0.6		
Penetration of residue, % of original, min.	58		55		50		-	
Loss-on-heating test:								
Volatilization loss, max., %		-		-		-		
Penetration ratio after testing*		110		110		110		0.5

* Penetration ratio after testing = $\frac{\text{Penetration of residue after heating without agitation}}{\text{Penetration of residue after heating with agitation}}$

1.2 Asphalts and Another Materials

The asphalts tested in this study were collected from various refineries across Japan. The details are shown in Table 1.2 and the list of refineries in Table 1.3. The principal properties of aggregates for stripping tests are shown in Table 1.4. For the preliminary tests and other confirmation tests, 60/80 straight asphalt (oil can Nos. B-1 to B-3) was used differently from the main tests, and the properties of this asphalt are shown in Table 1.5 (from test certificate).

Table 1.2 Classification of Samples

Grades	Number	Identification no.
40/60	5	40/60 - 1 to 40/60 - 5
60/80	23	60/80 - 1 to 60/80 - 23
80/100	11	80/100 - 1 to 80/100 - 11

Table 1.3 List of Refineries

No.	Company name	Refinery	40/60	60/80	80/100
1	ASIA KYOSEKI CO., LTD.	Sakaide Ref.		o	
2	IDEMITSU KOSAN CO., LTD.	Chiba Ref.	o	o	o
3	"	Tokuyama Ref.		o	
4	KASHIMA OIL CO., LTD.	Kashima Ref.		o	
5	KYOKUTO PETROLEUM INDUSTRIES LTD.	Chiba Ref.		o	
6	KOA OIL CO., LTD.	Marifu Ref.		o	
7	COSMO OIL CO., LTD.	Chiba Ref.		o	o
8	"	Yokkaichi Ref.		o	o
9	SANKYO YUKA KOGYO K.K.	Ichikawa Ref.	o	o	
10	SHOWA SHELL SEKIYU CO., LTD.	Kawasaki Ref.	o	o	o
11	SEIBU SEKIYU CO., LTD.	Yamaguchi Ref.		o	
12	SHOWA YOKKAICHI SEKIYU CO., LTD.	Yokkaichi Ref.		o	o
13	TOA NENRYO KOGYO K.K.	Kawasaki Ref.		o	
14	"	Wakayama Ref.		o	
15	TOHOKU OIL CO., LTD.	Sendai Ref.		o	o
16	NIPPON MINING CO., LTD.	Mizushima oil Ref.		o	
17	"	Chita oil Reef.		o	
18	NIPPON OIL CO., LTD.	Niigata Ref.		o	
19	NIPPON PETROLEUM REEFINING CO., LTD.	Negishi Ref.	o	o	o
20	"	Muroran Ref.			o
21	FUJI OIL CO., LTD.	Sodegaura Ref.		o	o
22	KAINAN PETROLEUM REFINING CO., LTD.	Kainan Ref.		o	o
23	MITSUBISHI OIL CO., LTD.	Kawasaki Ref.	o	o	
24	"	Mizushima Ref.		o	

Table 1.4 Property of Aggregate for Stripping Test

Origin		Ishioka Shi, Ibaraki Pref.
Rock		Hard sandstone
Specific gravity	Surface dry	2.644
	Bulk	2.627
	Apparent	2.673
Water absorption		0.66%

Table 1.5 Property of Asphalt of Preliminary Test

Item	Values on test certificate
Penetration (25°C) (1/10 mm)	77
Softening point (°C)	44.7
Ductility (15°C) (cm)	100+
Flash point (°C)	356
Solubility in trichloroethane (%)	99.7
Specific gravity (25/25°C)	1.035
Penetration ratio after loss-on-heating test (%)	101
Loss on thin film oven test (%)	+0.10
Penetration of residue on thin-film oven test (%)	69
High temperature kinematic viscosity cSt 120°C	834
140°C	297
160°C	132
180°C	67

2. Contents and Items of Study

2.1 Test Items

Test items are those prescribed in JIS standards plus the several tests which are not prescribed in JIS Standards. Shown in Table 2.1 is the list of the test items. Tests were conducted twice for each item, and the mean values determined. The tests were conducted from September 1985 to March 1986 in accordance with the time schedule as shown in Table 2.2. The tests were conducted directly by 8 testers in the Public Works Research Institute. Also, preliminary tests were conducted prior to the main tests. The preliminary tests were performed on one kind of asphalt with the test items prescribed in JIS, and the rolling thin-film oven test in order to confirm testing skill and the range of precision.

Table 2.1 Table of Test Items

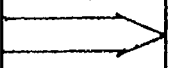
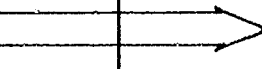
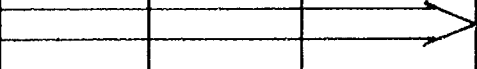
Test items	Class 1	Class 2	Class 3	Testing Methods
Penetration	25°C/5s	5°C/5s		JIS K2207
Softening point	Ring & ball (automatic)			JIS K2207
Ductility	15°C	10°C, 7°C		JIS K2207
Flash point	C. O. C.			JIS K2207
Specific gravity	25°C/25°C			JIS K2249
Solubility in trichloroethane	Trichloroethane			JIS K2207
Stripping	Stripping			Asphalt pavement manual
Viscosity at 60°C 1)	Viscosity at 60°C			Standards of PWRI
High temperature viscosity 2)	120, 140, 160 180°C			Standards of PWRI
Loss-on-heating test	Volatilization loss Penetration ratio			JIS K2207

Table 2.1 (cont'd)

Test items	Class 1	Class 2	Class 3	Testing Methods
Thin-film oven test		Mass change Penetration Softening point Ductility at 15°C Viscosity at 60°C	Separation into 4 fractions spot test	JIS K2207
Rolling thin-film oven test		Mass change Penetration Softening point Ductility at 15°C Viscosity at 60°C		ASTM D2872
Separation into 4 fractions			4 fractions	Japan Petroleum Institute Method
Spot test			Spot test	AASHTO T102
Paraffin content			Paraffin content	Japan Petroleum Institute Method

- Notes: 1. For determination of the viscosity at 60°C of original asphalt, Viscosity Tube No. 100 was used, and after heating, Viscosity Tube No. 2 was used.
2. For determination of the high temperature viscosity, Canon-Fenske viscometers were used, viz. Viscometer Nos. 450, 400, 350 and 300 for temperatures 120°, 140°, 160° and 180°C respectively.

Table 2.2 Test Schedule

Months	85'/9	10	11	12	86'/1	2	3
Preliminary test							
Class 1							
Class 2							
Class 3							
Analysis							

2.2 Preparations of Specimens

The asphalts were collected in 18-kg oil cans or pail cans and the asphalt was divided into 1-kg cans after melting and then tested. The original asphalt was only melted twice at the time of pouring into the smaller cans and at the time of preparing test specimens. Melting was performed by heating for 2 to 3 hours in a thermostatic oven at 135°C. The same procedure was also used for the preliminary test.

2.3 Other Tests

2.3.1 Wearing of Penetration Needle

Six new penetration needles No.1 to No. 6 were used in the test. Among these 6 needles, 2 needles (Nos. 1 and 2) were used in the first half of test period, other 2 needles (Nos. 4 and 6) in the last half, and the remaining 2 needles (Nos. 3 and 5) were reserved as spares and used only to confirm the change of test results stated below.

Since many specimens had to be measured in the tests, it was necessary to check the errors due to the wearing on the

penetration needles, and thus the needles were checked at certain time intervals. This checking was performed by measuring the penetration of the preliminary asphalt using all the needles. Observation by microscope and photography were also performed to check the shape change of needle.

2.3.2 Changes in Properties of Asphalt due to Repeated Heating
Melting of asphalt specimens was made twice as previously described, and the degree of change in asphalt properties due to repeated heating was confirmed. In this confirmation test, about 3 kg of preliminary asphalt was placed in a sample can and heated for about 3 hours in a thermostatic oven at 135°C, the asphalt fully agitated, samples taken, and the penetration and softening point measured. After taking the samples, the sample can was covered with a lid and left at room temperature, and the procedure was repeated the next day.

2.3.3 Comparison of the Results between Manual and Automatic Measurement of Softening Point

In Japan, automatic softening point testers are widely being used recently, and these testers were also used in this study. Therefore, the difference from the results of manual softening point test prescribed in JIS was reviewed. Preliminary asphalt was used as a specimens, and the softening point was measured twice by 8 persons by the automatic measuring method and manual measuring method. Then both precision by the same operators (note 1) and by different operators (note 2) were confirmed.

Note 1: Dispersion of the results in the case when the same persons conducted the tests using the same testing apparatus.

Note 2: Dispersion of the results in the case where the different persons conducted the tests using same testing apparatuses.

3. Results of Preliminary Tests

3.1 Results of Preliminary Tests

The results of preliminary tests conducted by 8 persons are shown in Table 3.1. From these results, it was found that the precision by each testing person and the precision between testing persons have fully satisfied the standards, except for the paraffin content test. The result of the paraffin content test are explained in "4.11 Paraffin Content."

3.2 Results of Other Tests

3.2.1 Wearing of Penetration Needle

Checking of the penetration needles was conducted 5 times, and the results are shown in Table 3.2. Needle Nos. 1 and 2 were used from September to December and needle Nos. 4 and 6 from December to February, and each needle was used about 400 times. As shown in Table 3.2, the measured values were hardly affected by the previous use of needles. Also, the difference in measured values due to different needles is within ranges 1 to 2, and this means that sufficient precision can be obtained regardless of the needle used. Needle No. 2 was mistakenly dropped during use and its tip was deformed as shown in Photo 3.1, so that its use was discontinued. This needle was used only for checking the penetration needles but, as can be seen from Table 3.2, the deformation of the degree as shown in Photo 3.1 does not greatly affect the test values. Photo 3.2 indicates the tip of a normal needle.

Table 3.1 Preliminary Test Results

Item	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation %	JIS tolerance			Remarks
						Single operator	Multilaboratory		
Penetration (25°C) 1/10mm	68	69	68	0.5	0.7	0.02A+2	0.04A+4	A; Mean value	
Softening point °C	47.0	47.5	46.5	0.3	0.7	1.0	4.0	Softening point ; 80°C	
Ductility (15°C) cm	140+	140+	140+	-	-	-	-		
Flash point °C	350	357	346	4.1	1.2	8	16		
Specific gravity (25/25°C)	1.030	1.031	1.029	0.001	0.1	0.0006	0.0010		
Solubility in trichloroethane %	99.93	100.0	99.82	0.07	0.1	0.10	0.50		
Viscosity at 60°C poise	1810	1900	1720	57.8	3.2	0.07A	0.10A	A; Mean value PWRI method	
Stripping	Less than 5%	Less than 5%	Less than 5%	-	-	-	-		
High temperature kinematic viscosity (120°C) cst	944	1087	854	81.3	8.6	1.8A	8.8A	A; Mean value	
(140°C)	317	337	304	12.1	3.8				
(160°C)	138	146	132	5.4	3.9				
(180°C)	69.4	73.3	66.5	2.4	3.8				
Volatilization loss in loss-on-heating test %	+0.01	+0.02	0	0.01	57	1) 0.10 2) 0.20 3) 0.3 or 0.1A	1) 0.20 2) 0.40 3) 0.6 or 0.2A	1) A ≤ 0.50 2) 0.5 < A ≤ 1.0 3) A > 1.0	A; Mean value
Penetration ratio after loss-on-heating test %	95	101	89	3.6	3.4	-	-		

Table 3.1 (cont'd)

Item	Mean value	Maximum value	Minimum value	On-1	Coefficient of variation %	JIS tolerance			Remarks
						Single operator	Multilaboratory		
Mass change in thin-film oven test %	+0.10	+0.10	+0.10	0	0	1) 0.04 2) 0.08A	1) 0.16 2) 0.4A	1) A < 0.4 2) A ≥ 0.4	A; Mean value
Penetration of residue in thin-film oven test %	67.7	69.7	63.4	2.2	3.2	4.0	12.0		
Mass change in rolling thin-film oven test %	+0.11	+0.20	+0.10	0.04	31	-	-		ASTM specifies only the viscosity at 60°C after testing
Penetration of residue in rolling thin-film oven test %	61.1	65.0	57.0	3.1	5.1	-	-		
Asphalt %	11.5	12.5	10.7	0.5	4.5	-	-		Japan Petroleum Institute Method contains no specification of tolerance
Resin %	22.1	23.0	20.9	0.7	3.2	-	-		
Asphalt separation %	49.9	50.7	48.3	0.9	1.7	-	-		
Saturates %	15.9	17.6	15.0	0.8	5.1	-	-		
Recovery %	99.4	100.0	99.8	0.4	0.4	-	-		
Paraffin content %	2.28	2.81	2.05	0.2	10.0	1) 0.1 2) 0.3	1) 0.3 2) 1.0	1) 0 - A - 1.0 2) 1.0 - A - 3.0,	A: Mean Value

Table 3.2 Results of Inspection of Penetration Needles

Test dates	1	2	3	4	5	6	Mean	Maximum	Minimum
Nov. 6	67	66	67	-	-	-	67	67	66
Nov. 25	66	67	66	-	-	-	66	67	66
Dec. 10	72	74*	72	73	73	73	73	73	72
Jan. 9	72	74*	73	72	72	71	72	73	71
Jan. 23	72	72*	72	70	72	71	71	72	70

* Needle deformed, and not used in main test.

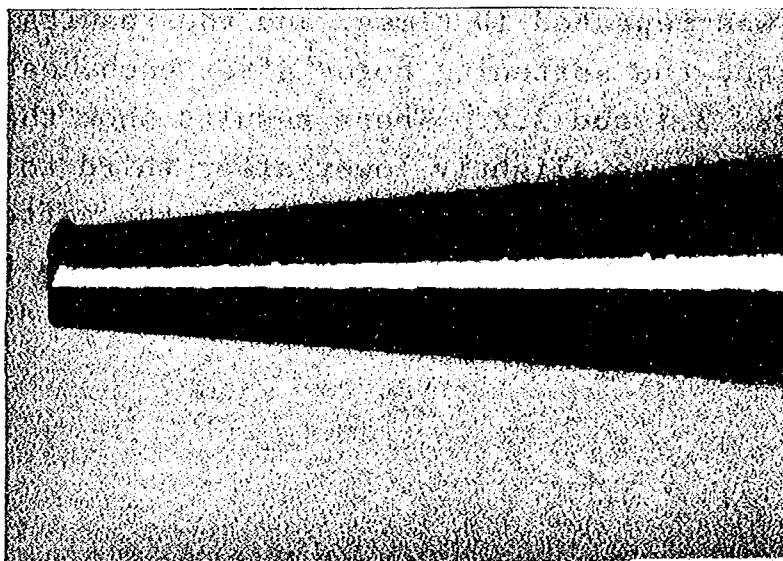


photo 3.1 Shape of Deformed Penetration Needle

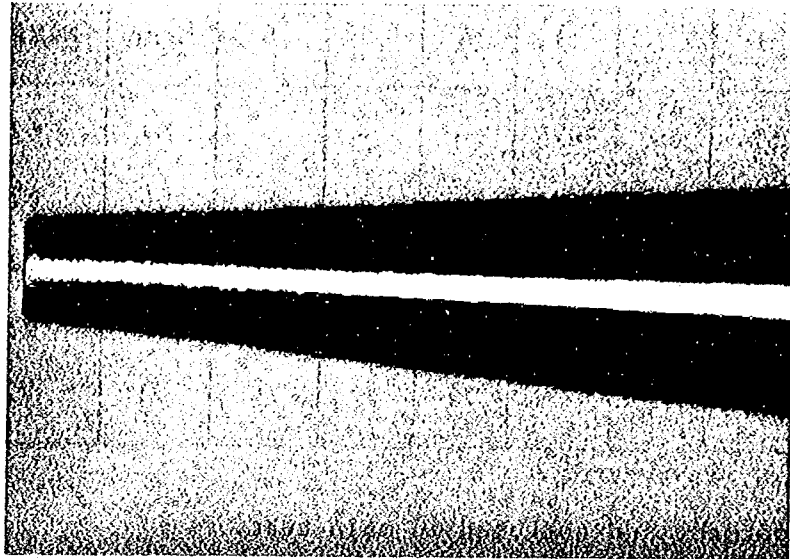


photo 3.2 Shape of Normal Penetration Needle

3.2.2 Property changes due to Repetitive Heating

The heating was repeated 10 times, and the results of the penetration and the softening point after each heating are shown in Figs. 3.1 and 3.2. These results show that the penetration tends to slightly lower after third to fourth heating. On the other hand, the value of the softening point hardly changes. From the above, melting twice in the main tests will not cause any change in properties of asphalt.

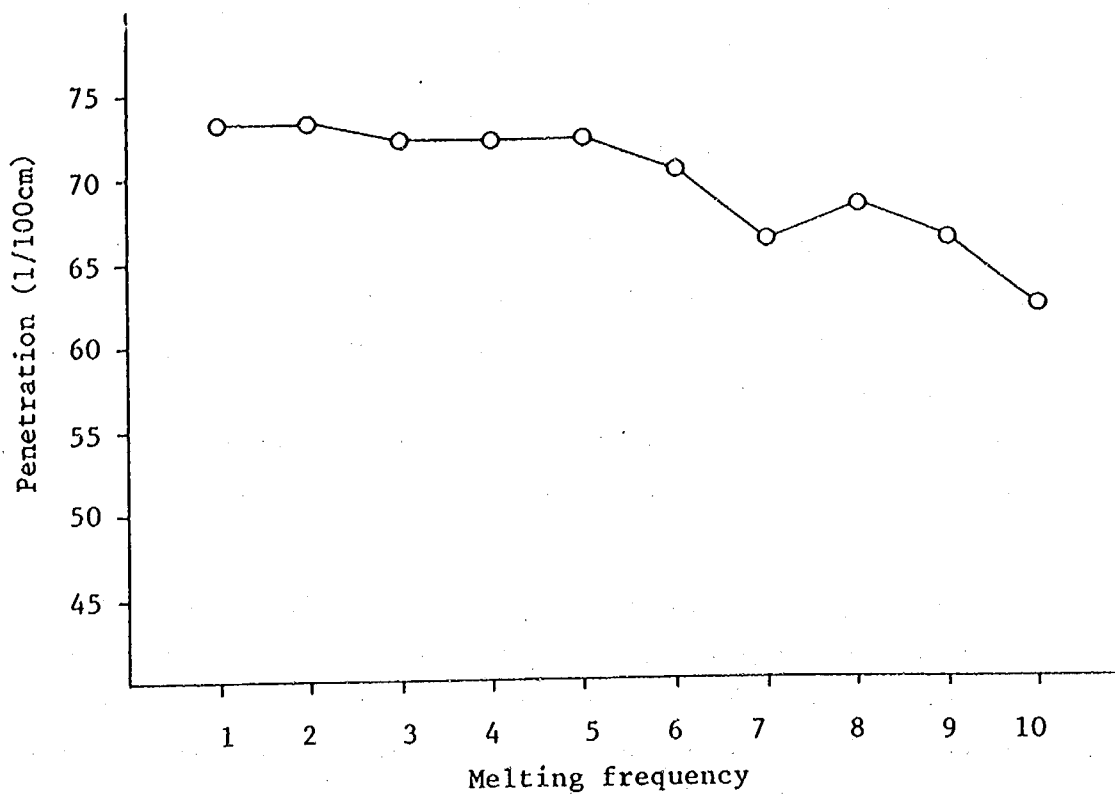


Fig. 3.1 Change of Penetration with Repetitive Heating

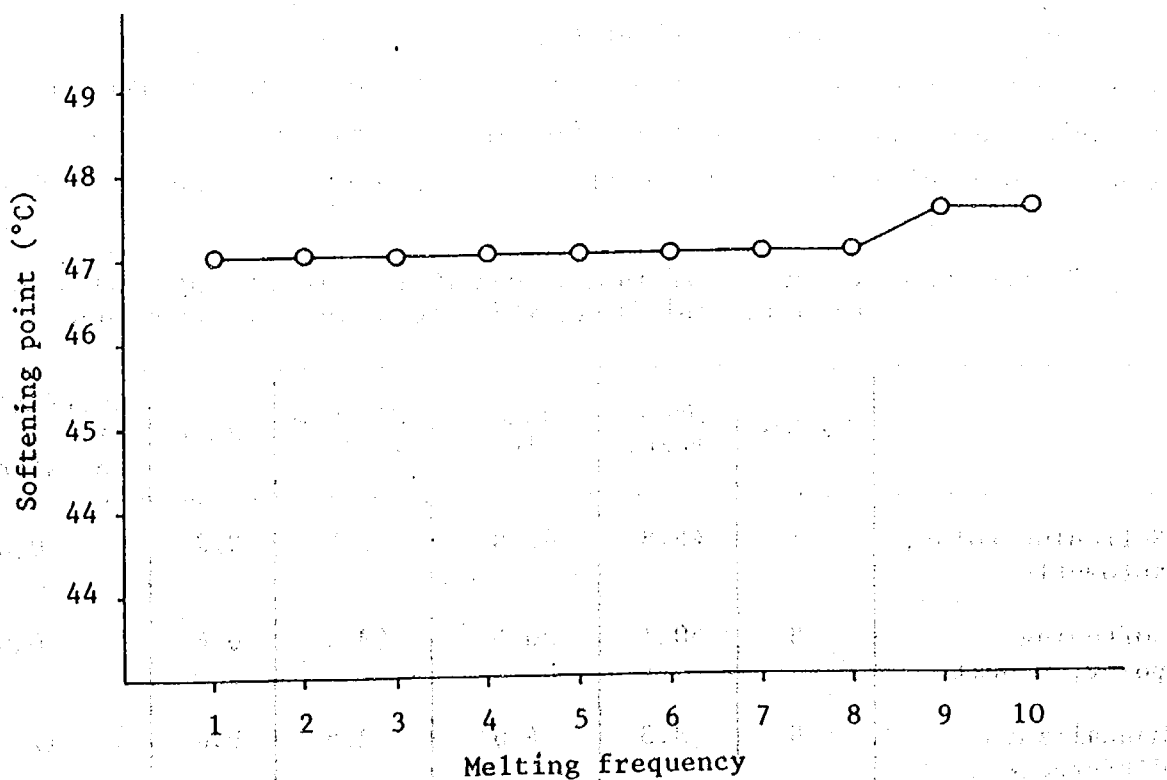


Fig. 3.2 Change of Softening Point with Repetitive Heating

3.2.3 Comparison of the Results between Manual and Automatic Measurements of Softening Point

The results of the softening point by 8 persons by using both the manual heating tester and automatic heating tester are shown in Table 3.3. Average values by manual tester are 2.5 to 4.0°C higher than values by automatic tester. The difference in mean value is 3.3°C and cannot be ignored, while the precision by the same testing person is less than 1.0°C in both the case of automatic and manual. Also, precision by different testing persons is satisfactory for both automatic and manual method, and thus the dispersion in the temperature rise for each method is not great.

In the case of automatic measurement, water is agitated by stirrer. Also, the degree of temperature rise varies between the manual and automatic. That is, the temperature rises accurately to within the range of $\pm 0.1^\circ\text{C}$ for automatic testing but the temperature rise in the manual is dispersed depending on testing person. Shown in Fig. 3.3 are the results of the temperature rise by manual heating. Higher measured values are obtained in the manual method than automatic method because the degree of temperature rise is different and, in the manual method, there is no agitation in the container and water temperature rise is ununiformly transferred into the specimens.

Table 3.3 Results of Measurement of Softening Point by Manual and Automatic Testing Instruments

	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
Softening point, automatic	8	46.8	47.0	46.5	0.3	0.6
Softening point, manual	8	50.1	50.5	49.5	0.4	0.9
Manual/auto difference	8	3.3	4.0	2.5	0.6	17.9

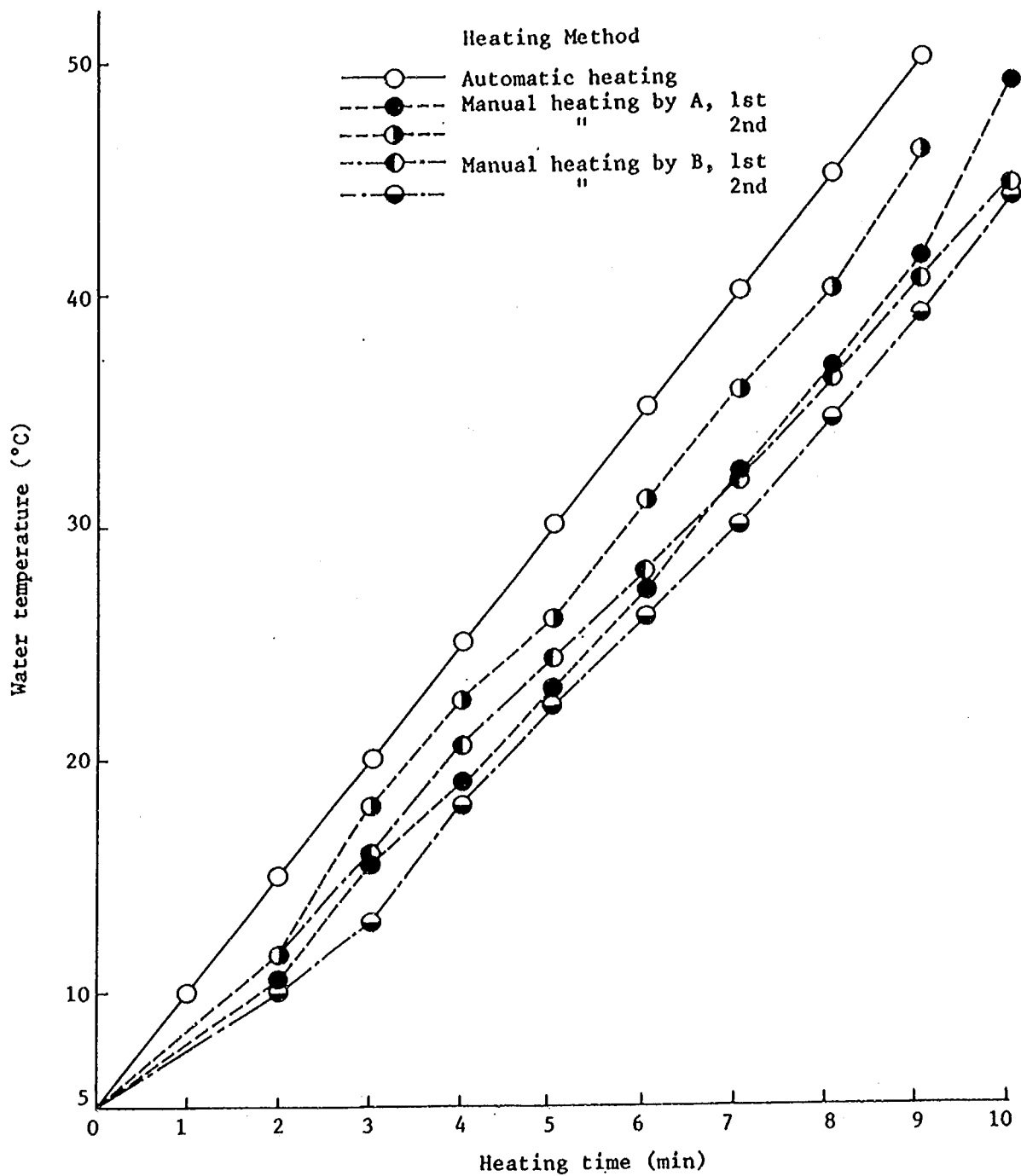


Fig. 3.3 Temperature Measurements of Softening Point Test

3.3 Conclusion

The following has been made clear from the results of the preliminary tests and other confirmation tests:

- 1) Precision by each testing person and precision between testing persons can fully satisfy the provisions of the standards, except those for the paraffin content test.
- 2) Even after the repeated use of penetration needles up to 400 times (2 to 3 months in the present tests), the shape of the needles hardly either changes or affects the value.
- 3) The condition of melting of asphalt (twice, and 2 to 3 hours at 135°C) hardly affects the properties of asphalt.
- 4) The softening points by manual measurement are higher than those by automatic measurement, and the difference cannot be ignored.

4. Results of Main Tests

The results of the main tests are explained below. Also, where it is necessary to calculate the test result from multiple measured values, the dispersion of test values by the same testing person is explained. Where the same test was conducted separately by two testing persons, the dispersion of test values is also explained.

4.1 Penetration Tests

4.1.1 Penetration at 25°C

Results of the penetration tests at 25°C are shown in Table 4.1 and Fig. 4.1. The penetrations of 40/60 asphalt are 47 to 52, which is almost at the center of standard value range. About 60% of the penetrations of 60/80 asphalt are the lower limit value range (60 to 70) below the center of standard value range. The penetrations of 80/100 asphalt are in the range of 83 to 94, and about 50% asphalt have values between 90 and 94. However, the mean value of each grade is almost at the center of the standard value range. Dispersion of the test values (mean of measured values at 3 points) for each specimen by two testing persons is shown in Fig. 4.2. The dispersion is in the range of 0 to 1 for 40/60, of 0 to 2 for 60/80 and of 0 to 4 for 80/100. The dispersion increases as the grade becomes larger.

Also, the dispersion of penetration at 3 measuring points in the one test (by one testing person) is in the range of 0 to 1 for 40/60, of 0 to 2 for 60/80 and of 0 to 3 for 80/100.

Therefore, the dispersion of penetration at 3 measuring points also increases as the grade becomes larger.

Table 4.1 Penetration at 25°C

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	49.8	52	47	1.9	3.9
60/80	23	67.8	76	61	3.5	5.2
80/100	11	88.6	94	83	3.4	3.8

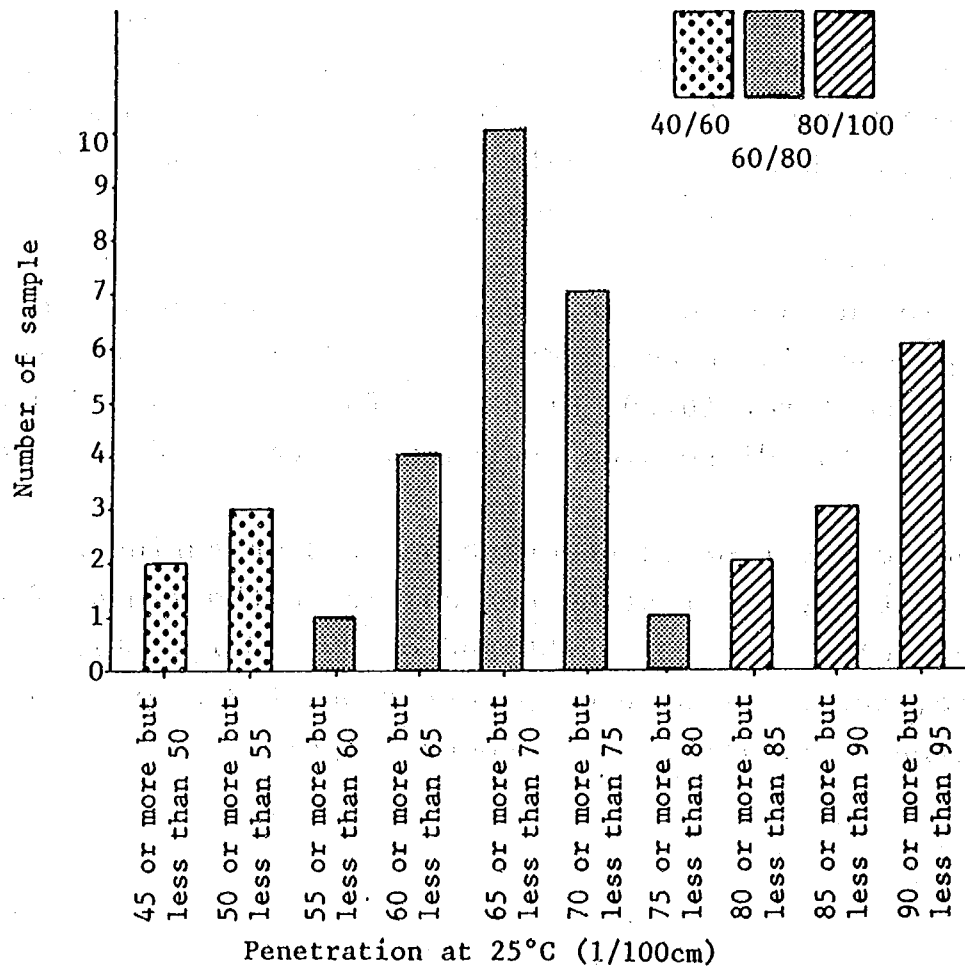


Fig. 4.1 Penetration at 25°C

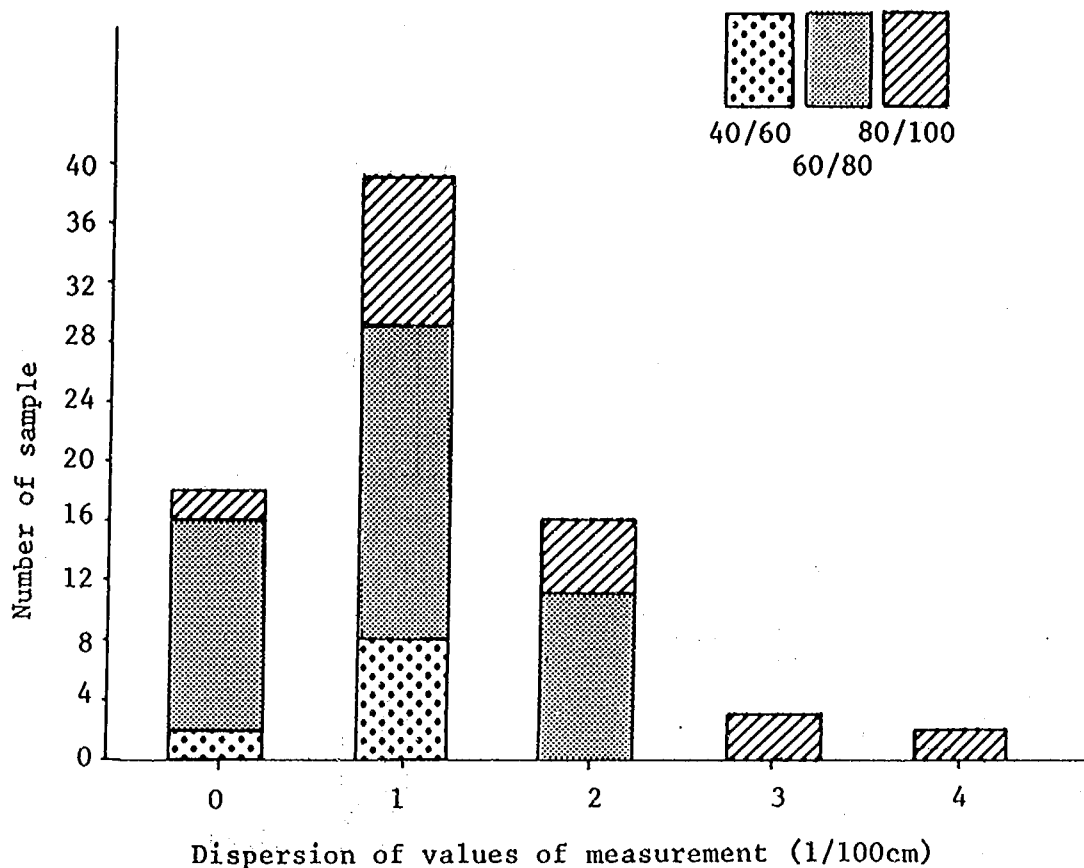


Fig. 4.2 Dispersion of 25°C Penetration between Two Persons

4.1.2 Penetration at 5°C

Results of penetration under the loading conditions of 5°C, 100 g and 5 seconds are shown in Table 4.2 and Fig. 4.3. Since penetration at 5°C was measured under the same load and loading time as 25°C penetration, the test values are almost equal to the compressed results of penetration at 25°C. The results of all asphalt are in the range of 5 to 11, therefore, no great difference in value is recognized between each asphalt.

Table 4.2 Penetration at 5°C

(1/100 cm)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	6	7	5	0.7	11.8
60/80	23	9	11	6	1.4	15.7
80/100	11	10	11	9	0.8	8.4

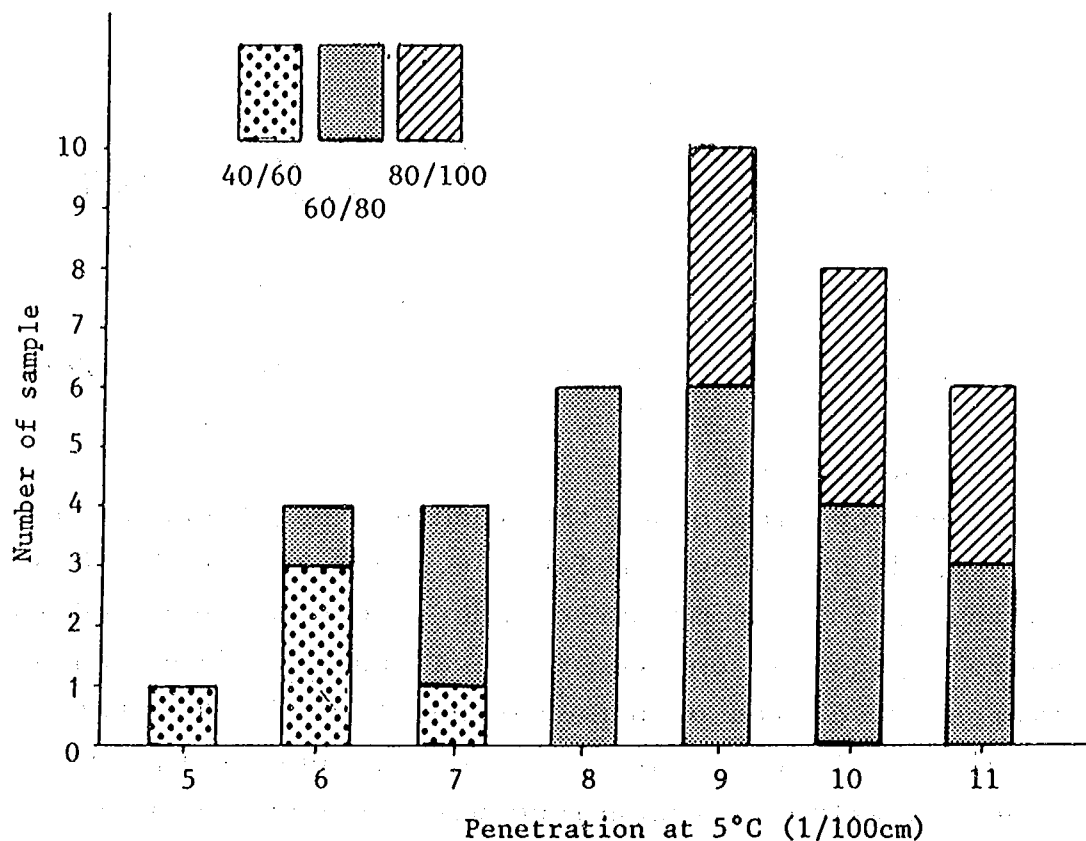


Fig. 4.3 Penetration at 5°C

Since it was not possible to change the load for the penetration measuring instrument used in this test, the loading time was set to 60 seconds, and the penetration was measured for 6 specimens. The relation between the results and 25°C penetration are shown in Fig. 4.4. However, the penetration by 60-second loading was about 16 to 18 for 60/80 and 19 to 21 for

80/100, and the range of the test values was compressed to the same as the case of 5-second loading, so that no clear tendency was recognized.

The relation between the loading time and the penetration value in the penetration test at 5°C is shown in Fig. 4.5. However, the range of test values of each loading time is small and thus no clear tendency is recognized. For the penetration at 5°C, it will be necessary to review the loading conditions by which the mean values at 5°C of all specimens can become almost equal to the mean values of all specimens obtained by standard test under the conditions of 25°C, 100 g and 5 seconds.

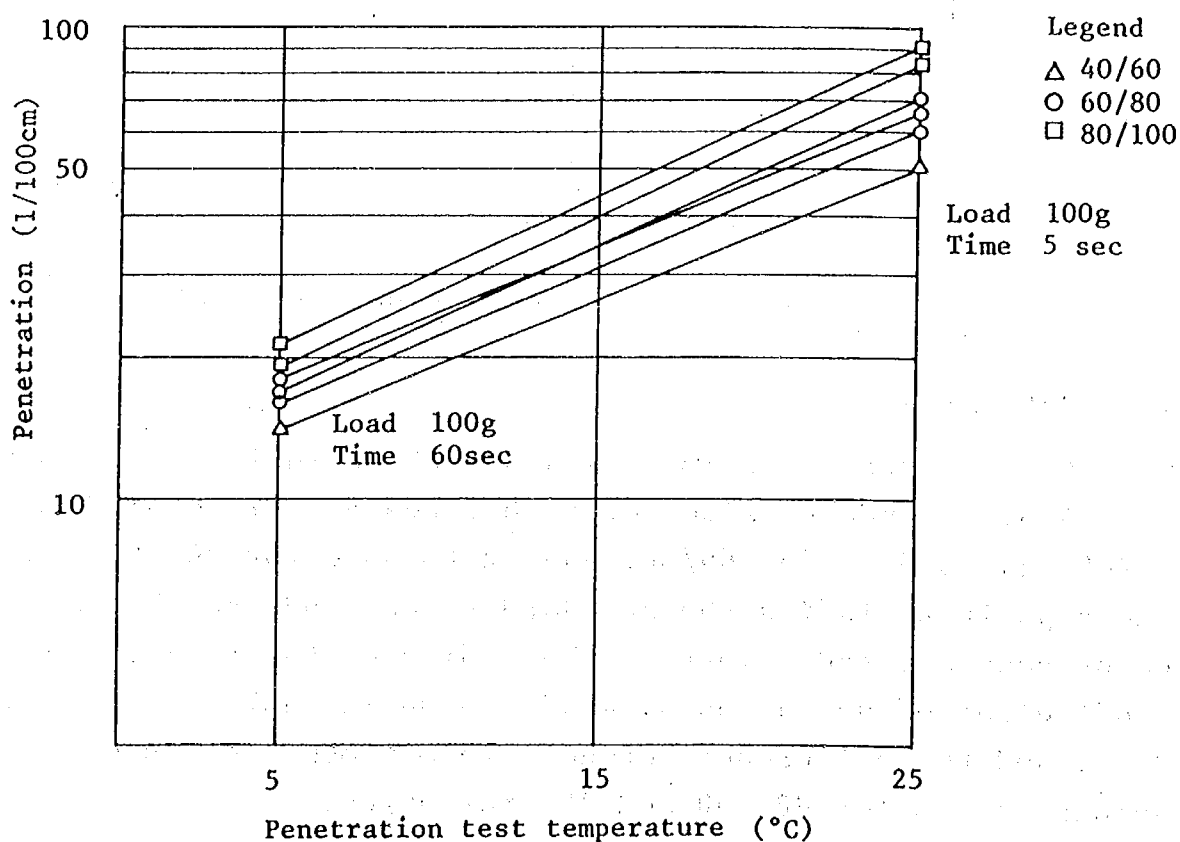


Fig 4.4 Penetration at 25°C Versus Penetration at 5°C

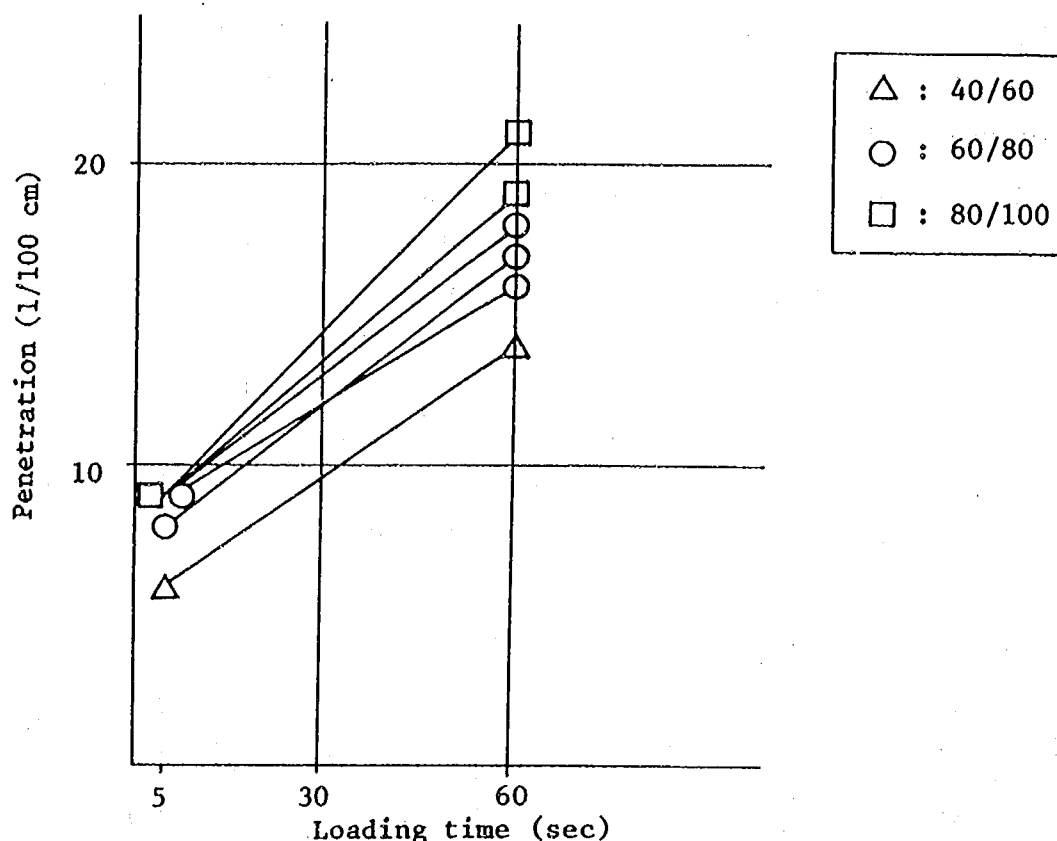


Fig. 4.5 Loading Time Versus Penetration at 5°C

4.2 Softening Point

Results of softening point tests are shown in Table 4.3 and Fig. 4.6. Standard value for each grade are 47 to 55°C for 40/60, 44 to 52°C for 60/80, and 42 to 50°C for 80/100. All the asphalt satisfies the standard values and had the softening point concentrated almost in the median of the range. The coefficient of variation by grade shown in Table 4.3 is 1.3 to 2.2%, and the difference between the maximum and minimum values is 2°C for 80/100 and 3°C for 60/80.

Table 4.3 Softening Point

°C

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	51.1	52.5	49.5	1.1	2.2
60/80	23	47.8	49.0	46.0	1.0	2.1
80/100	11	45.8	47.0	45.0	0.6	1.3

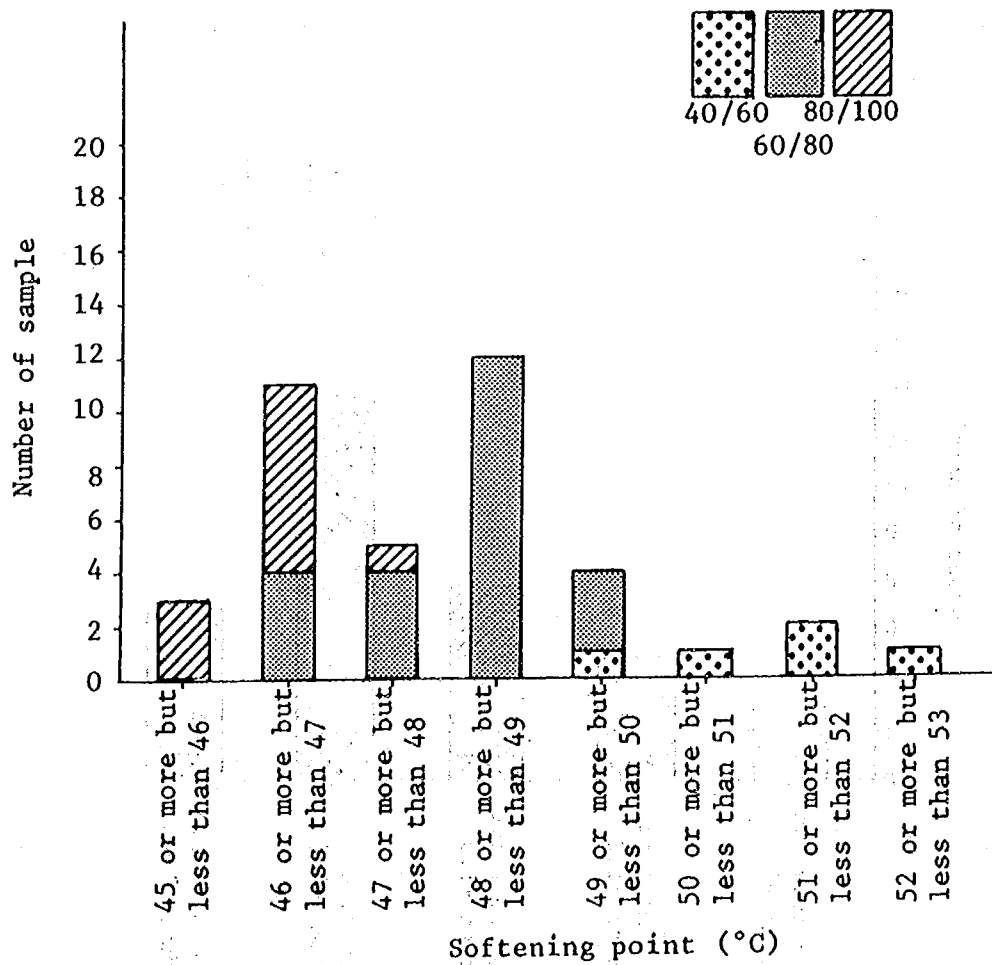


Fig. 4.6 Softening Point

4.3 Penetration Index (PI)

The results of PI calculated from the penetration and the softening point are shown in Table 4.4 and Fig. 4.7. Fig. 4.8 shows the relationship between the penetration, the softening point and the PI. The maximum value of PI for 40/60, 60/80 and 80/100 is near -0.7, and the minimum value is -1.23 for 40/60, -1.47 for 60/80 and -1.10 for 80/100. The mean value of each grade is -0.94 for 40/60, -1.03 for 60/80 and -0.90 for 80/100, and there is no significant difference by grade and each grade seems to have almost the same temperature susceptibility. It has been said that asphalt produced from the same crude oil normally has almost the same PI value even if the penetration grade is different. Thus the PI of each grade by refinery is shown in Table 4.5, but no obvious relationship can be recognized between them.

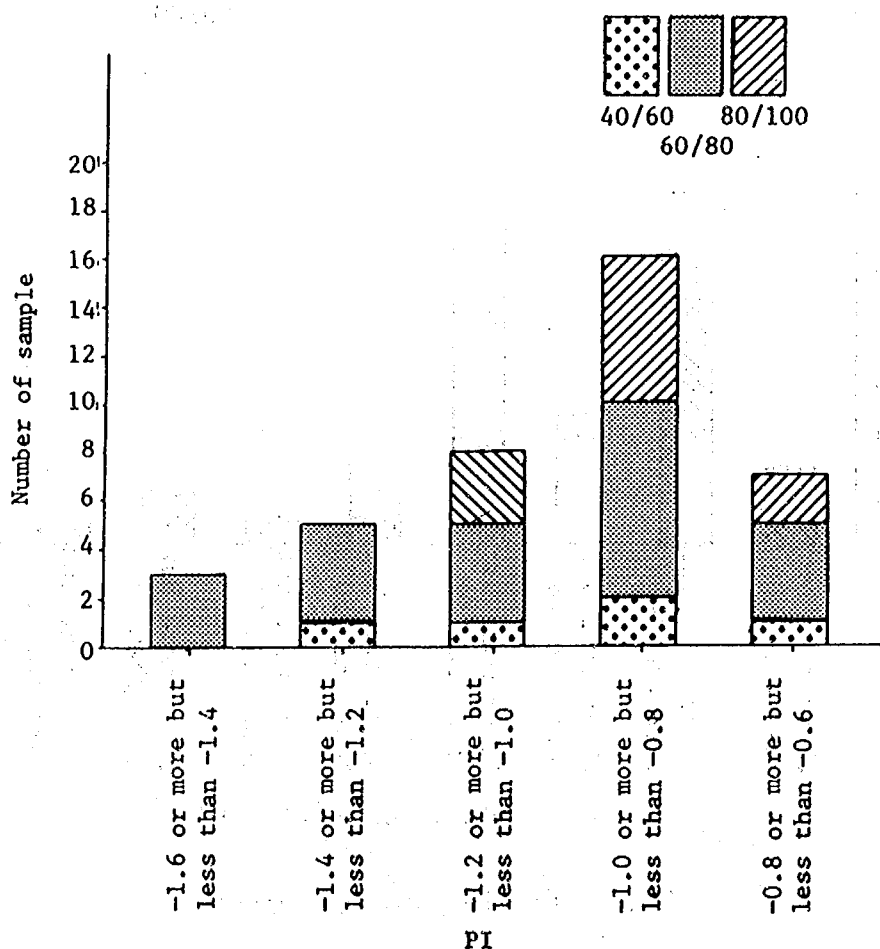


Fig. 4.7 Penetration Index (PI)

Table 4.4 Penetration Index (PI)

Grades	Number	Mean value	Maximum value	Minimum value	$\sigma n-1$	Coefficient of variation
40/60	5	-0.94	-0.74	-1.23	0.19	20.4
60/80	23	-1.03	-0.71	-1.47	0.24	22.8
80/100	11	-0.90	-0.73	-1.10	0.13	14.3

Table 4.5 Values of Penetration Index by Refinery

Refineries	Grades	PI
A	40/60	-0.88
	60/80	-1.10
	80/100	-1.07
B	40/60	-1.23
	60/80	-1.26
	80/100	-0.89
C	40/60	-1.03
	60/80	-1.26
	80/100	-0.89
D	40/60	-0.83
	60/80	-1.19

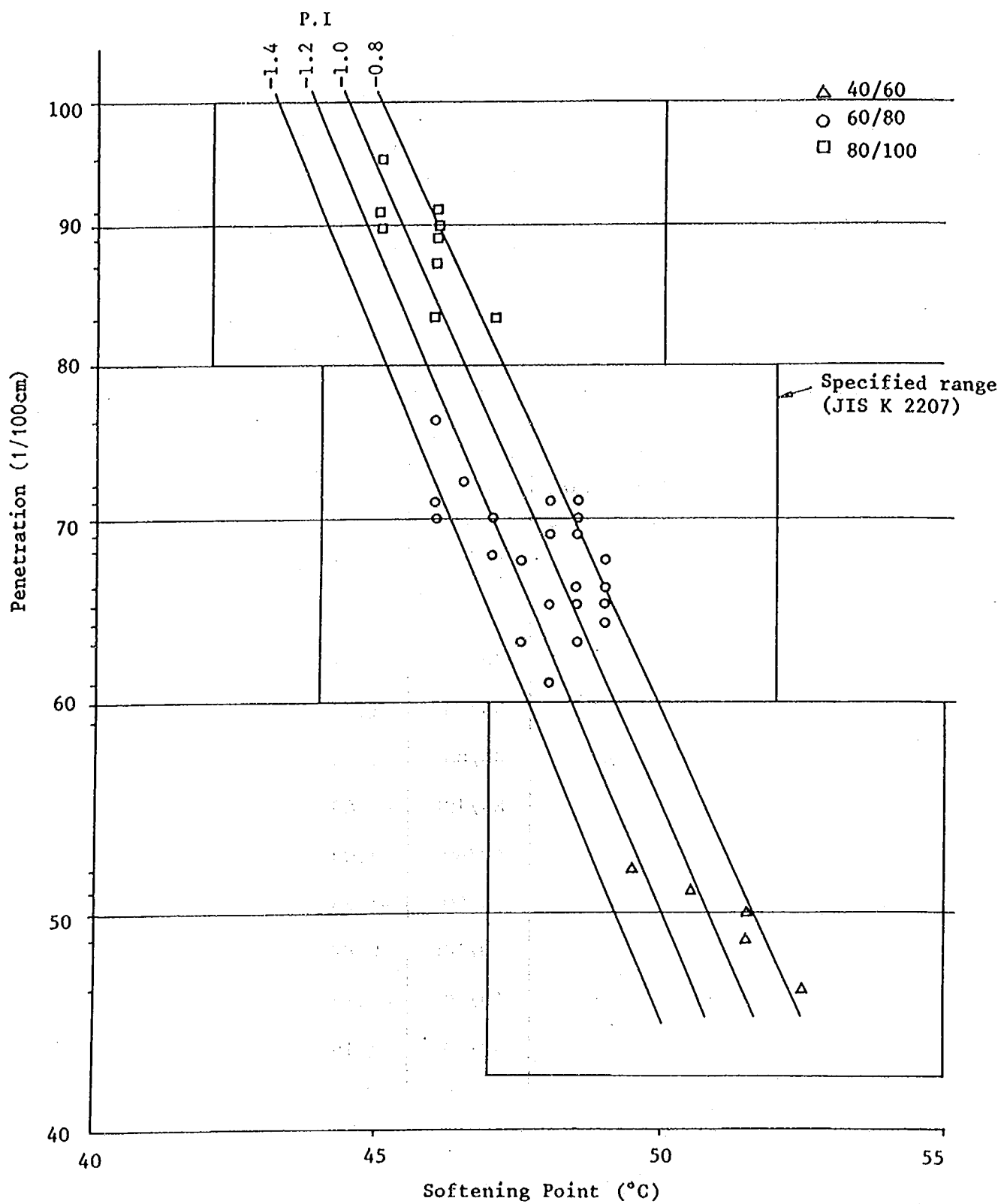


Fig. 4.8 Penetration, Softening Point and Penetration Index

4.4 Viscosity at 60°C

The results of viscosity at 60°C are shown in Table 4.6 and Fig. 4.9, and the mean values are 3980 for 40/60, 2060 for 60/80 and 1410 Poise for 80/100. The mean value differs almost according to penetration grade, however, both the 40/60 and 80/100 have a wide viscosity distribution.

JIS standards do not prescribe the viscosity at 60°C. By comparing the measured results to the classification of AASHTO's viscosity grade, the 40/60 almost corresponds to AC-40 and the 60/80 to AC-20 as shown in Fig. 4.10, but the 80/100 often has the viscosity slightly higher than the value of AC-10.

Table 4.6 Viscosity at 60°C (Poise)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	3980	4760	3060	737	18.5
60/80	23	2060	2630	1360	355	17.2
80/100	11	1410	1860	1160	204	14.5

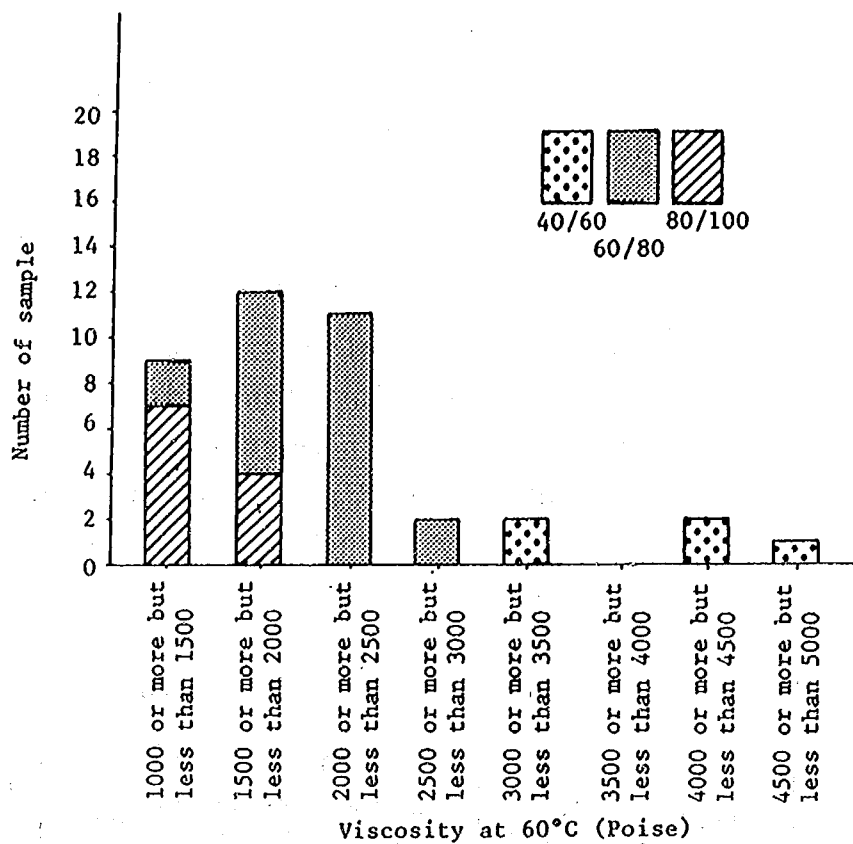


Fig. 4.9 Viscosity at 60°C

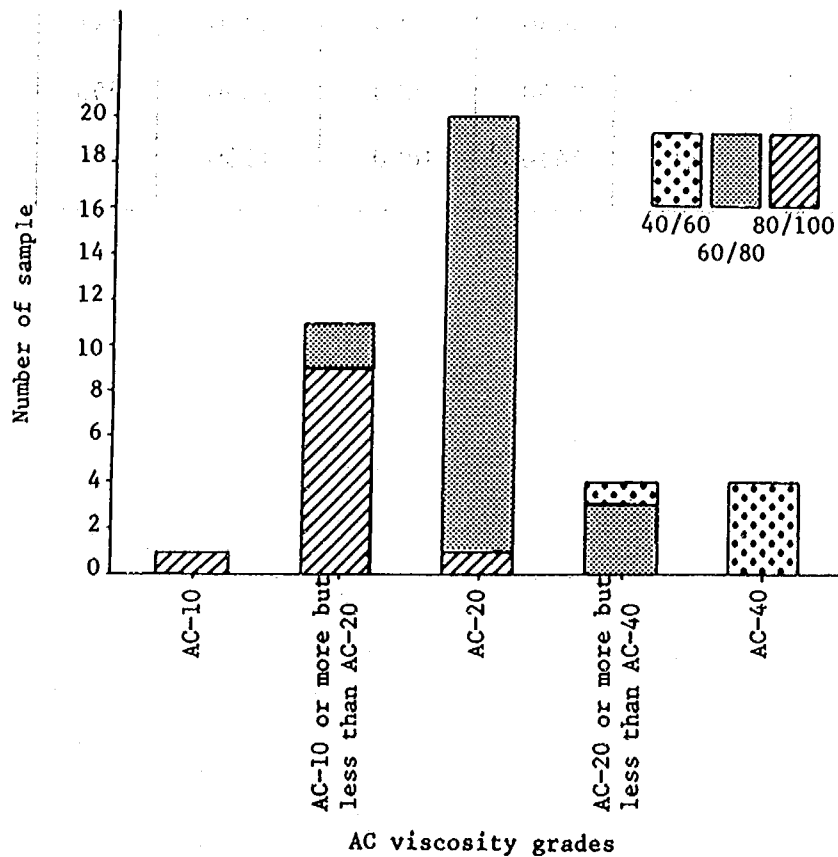


Fig. 4.10 Result of Viscosity Test at 60°C and AASHTO Viscosity Grade

4.5 High Temperature Kinematic Viscosity

The results of high temperature kinematic viscosity are shown in Table 4.7, and the correlation formulas determined from the temperature-viscosity straight lines for each asphalt are shown in Table 4.8. The viscosities at 135°C are determined by interpolation from temperature-viscosity lines and are shown in Fig. 4.11.

Table 4.7 High Temperature Kinematic Viscosity (cSt)

Grades	°C	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	120	5	1524	1760	1300	200	13.1
	140		475	546	408	59.8	12.6
	160		192	220	171	22.2	11.6
	180		92.8	107	83.7	10.2	10.9
60/80	120	23	1007	1200	751	133	13.2
	140		353	408	267	43.4	12.3
	160		148	169	114	16.9	11.5
	180		74.7	84.8	60.9	8.1	10.9
80/100	120	11	800	908	691	16.4	9.5
	140		299	333	261	24.1	8.4
	160		131	164	112	14.6	11.1
	180		67.2	74.7	59.0	4.8	7.2

Table 4.8 Coefficients of Correlation Formula of Temperature-viscosity Line

High temperature viscosity (Regression formula)

$$\text{Log (Log } y) = A \text{ Log } x + B$$

(x: temperature, °C; y: viscosity, cSt)

Sample No.	Values of measurement			Values on test certificates		
	A	B	r	A	B	r
40/60 - 1	-1.167	2.943	0.999	-1.167	2.982	0.999
	-1.189	2.968	1.0	-1.151	2.881	0.999
	-1.188	2.967	1.0	-1.116	2.794	0.995
	-1.225	3.055	1.0	-1.170	2.931	0.999
60/80 - 5	-1.157	2.919	1.0	-1.193	2.985	0.999
	-1.182	2.942	0.999	-1.167	2.909	0.999
	-1.151	2.883	1.0	-1.139	2.849	0.999
	-1.189	2.940	1.0	-1.174	2.905	0.999
	-1.193	2.943	1.0	-1.155	2.865	0.997
	-1.208	2.983	1.0	-1.159	2.874	0.999
	-1.167	2.910	1.0	-1.135	2.839	0.999
	-1.200	2.981	0.999	-1.126	2.826	1.0
	-1.183	2.949	1.0	-1.131	2.834	0.999
	-1.176	2.916	0.999	-1.108	2.771	0.999
	-1.155	2.879	0.999	-1.151	2.872	0.999
	-1.138	2.853	0.999	-1.119	2.812	1.0
	-1.161	2.887	0.999	-1.158	2.889	1.0
	-1.200	2.957	0.999	-1.221	2.997	0.998
	-1.146	2.868	0.999	-1.100	2.768	0.999
	-1.157	2.889	0.999	-1.136	2.841	0.999
	-1.167	2.902	0.999	-1.172	2.915	0.999
	-1.146	2.868	0.999	-1.133	2.835	0.999
	-1.137	2.843	0.999	-1.456	2.856	0.999
	-1.181	2.936	0.999	-1.178	2.928	0.999
	-1.132	2.839	0.999	-1.113	2.798	0.999
	-1.141	2.859	0.999	-1.181	2.949	0.999
	-1.163	2.892	0.999	-1.129	2.823	0.999
	-1.135	2.856	0.999	-1.146	2.874	0.999
80/100 - 1	-1.149	2.860	0.999	-1.165	2.887	0.999
	-1.156	2.879	0.999	-1.101	2.756	1.0
	-1.145	2.847	0.999	-1.139	2.833	1.0
	-1.150	2.859	0.999	-1.143	2.843	1.0
	-1.128	2.816	0.999	-1.137	2.834	0.999
	-1.122	2.805	0.999	-1.117	2.799	1.0
	-1.130	2.812	0.999	-1.146	2.849	0.999
	-1.141	2.833	0.999	-1.188	2.941	0.999
	-1.144	2.838	0.999	-1.183	2.918	0.999
	-1.169	2.886	0.999	-1.156	2.857	0.999
	-1.155	2.862	0.999	-1.113	2.771	1.0

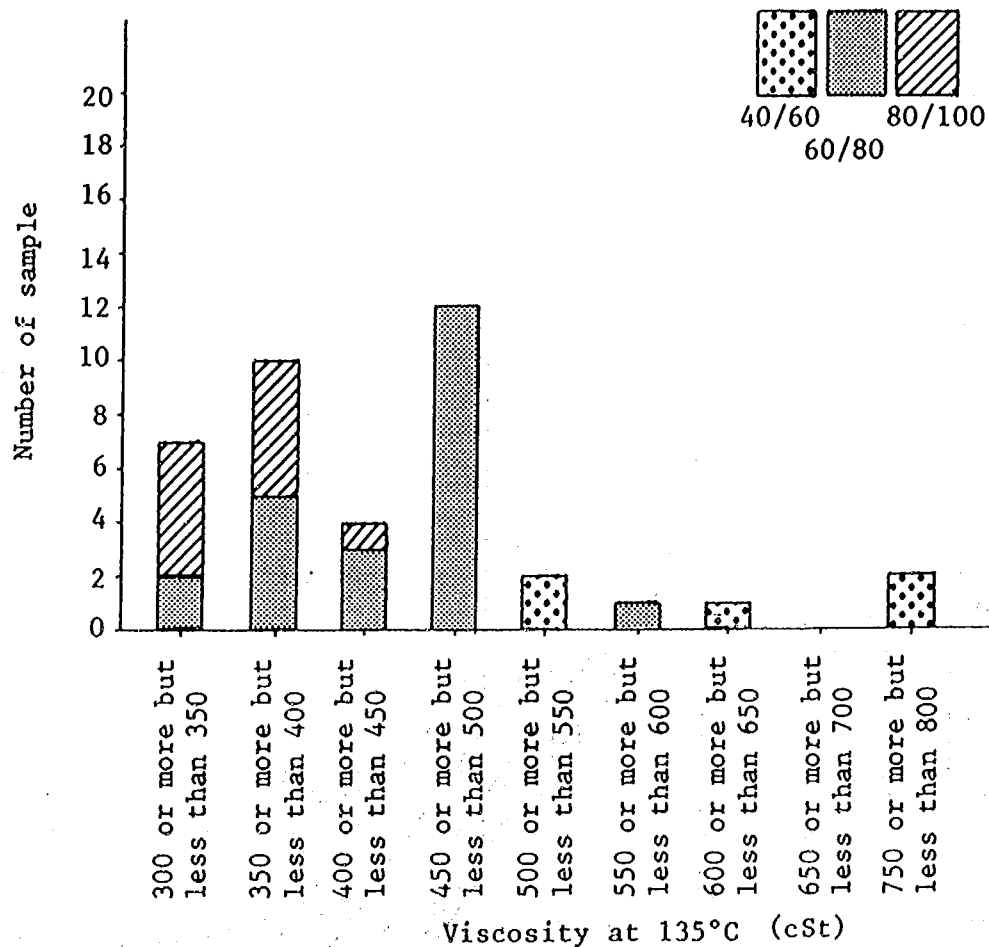


Fig. 4.11 Estimated Viscosity at 135°C

The temperature-viscosity lines are obtained by plotting the logarithm of viscosity and the temperature on the logarithmic scale. The correlation coefficients of all asphalt are higher than 0.99 and there is almost no dispersion, thereby having very good correlations. Range of temperature-viscosity lines of each asphalt grade is shown in Fig. 4.12. Ranges of lines of 60/80 and 80/100 are overlapped each other. However, the mean values of viscosity at 135°C for both grades have a significant difference with a level of significance of 5%, and the 80/100 has a slightly lower viscosity than 60/80. Also shown in Fig. 4.13 are the optimum mixing temperature and optimum compaction temperature ranges for each grade asphalt determined from the range shown in Fig. 4.12.

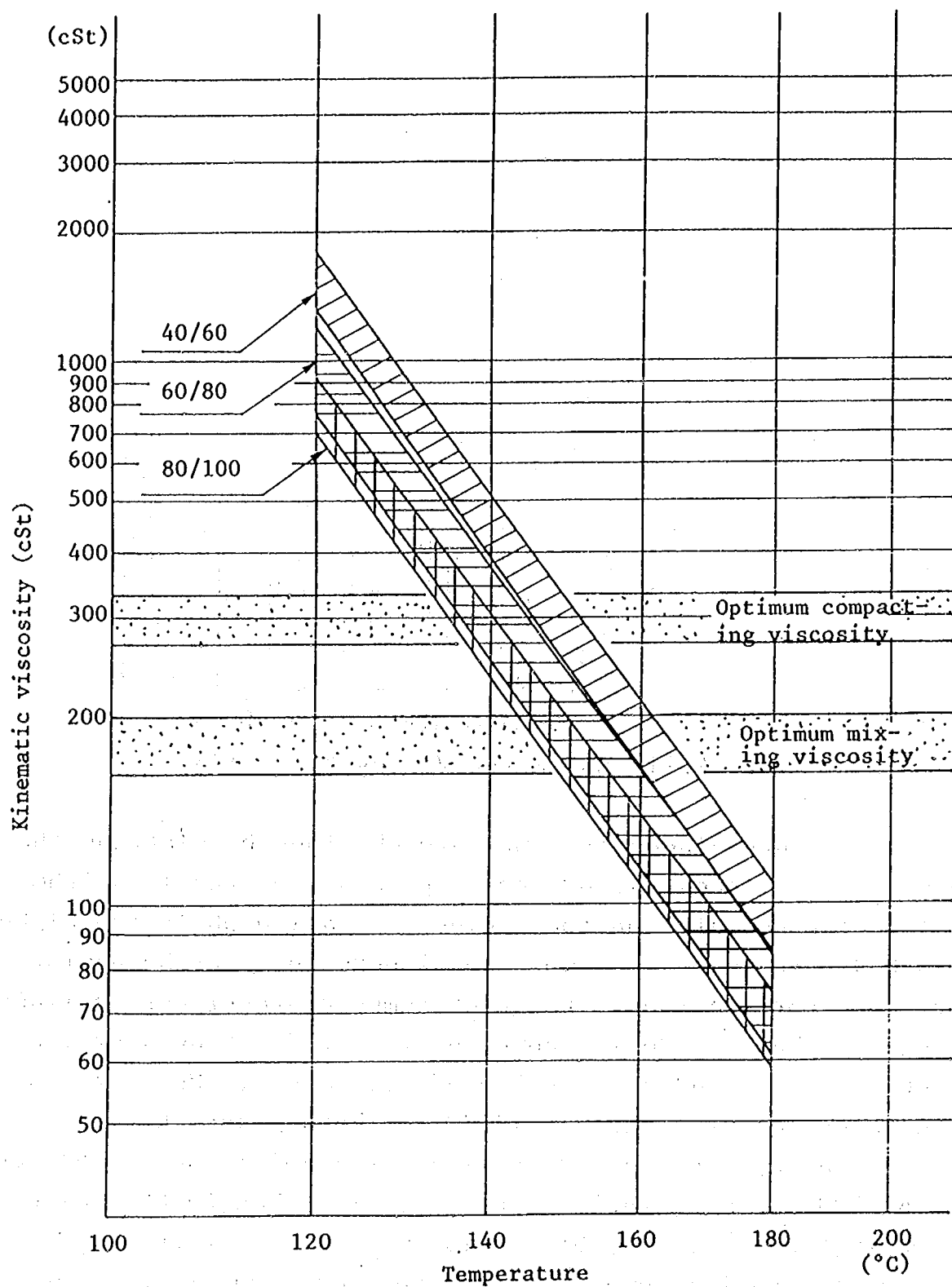


Fig. 4.12 Range of Temperature-viscosity Lines by Grade

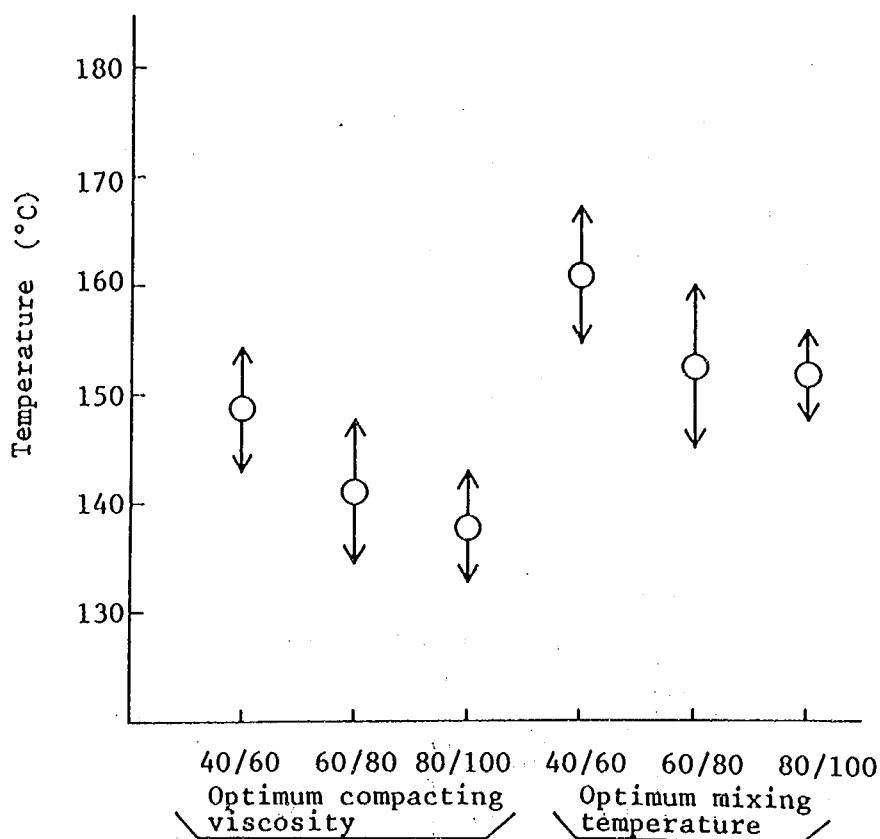


Fig. 4.13 Optimum mixing Temperature and Compacting Temperature Ranges by Grade

Fig. 4.14 shows the relationship between the PI and the gradient of temperature-viscosity for each asphalt stated above. Correlation coefficient is 0.46, and this shows that the temperature susceptibility between the softening point and 25°C does not always coincide with the temperature susceptibility in the high temperature region.

The relationship between the viscosity at 135°C and other properties are shown in Fig. 4.15 to Fig. 4.17. Respective correlation coefficient with viscosity at 135°C is 0.81 for penetration, 0.89 for softening point, and 0.94 for viscosity at 60°C. The correlation coefficient decreases as the difference between the testing temperature of each test and the testing temperature of viscosity at 135°C becomes larger.

The standard range for the viscosity at 60°C prescribed in AASHTO's viscosity standards are also shown in Fig. 4.17. As stated above, it is known that the 40/60 and 60/80 almost correspond to AC-40 value and AC-20 value respectively and that the viscosity at 60°C of 80/100 is slightly higher than AC-10 value. Also, asphalt which has viscosity at 60°C corresponding to each AC grade has viscosity at 135°C that satisfy the standard values prescribed in AASHTO'S standard.

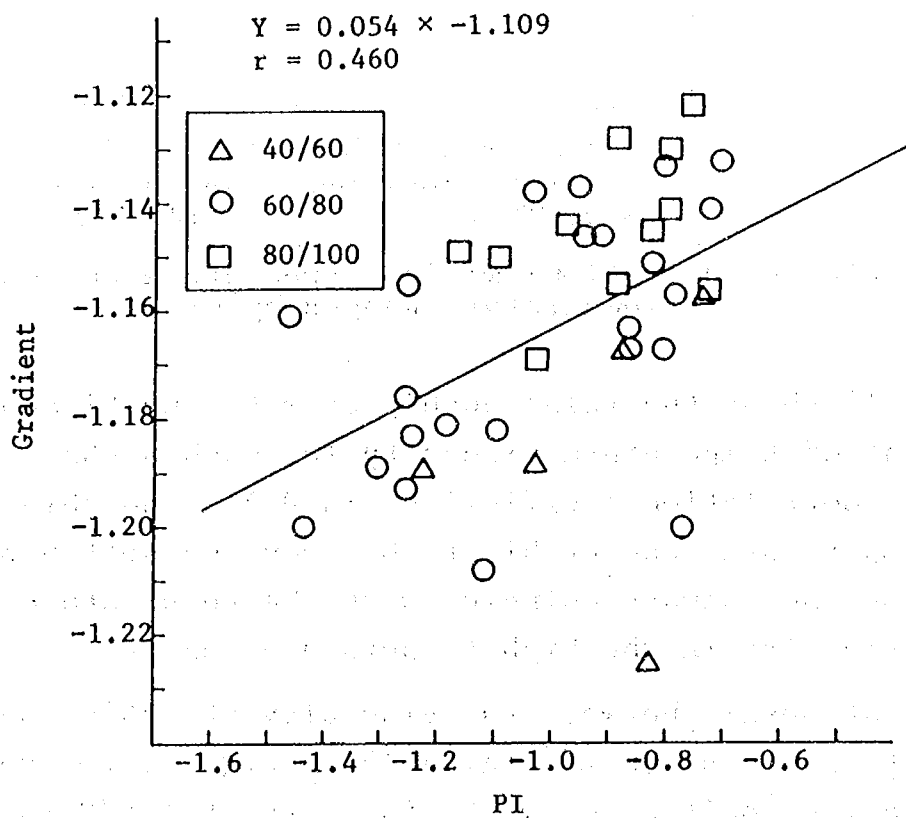


Fig. 4-14 Gradient of Temperature-viscosity Line and PI

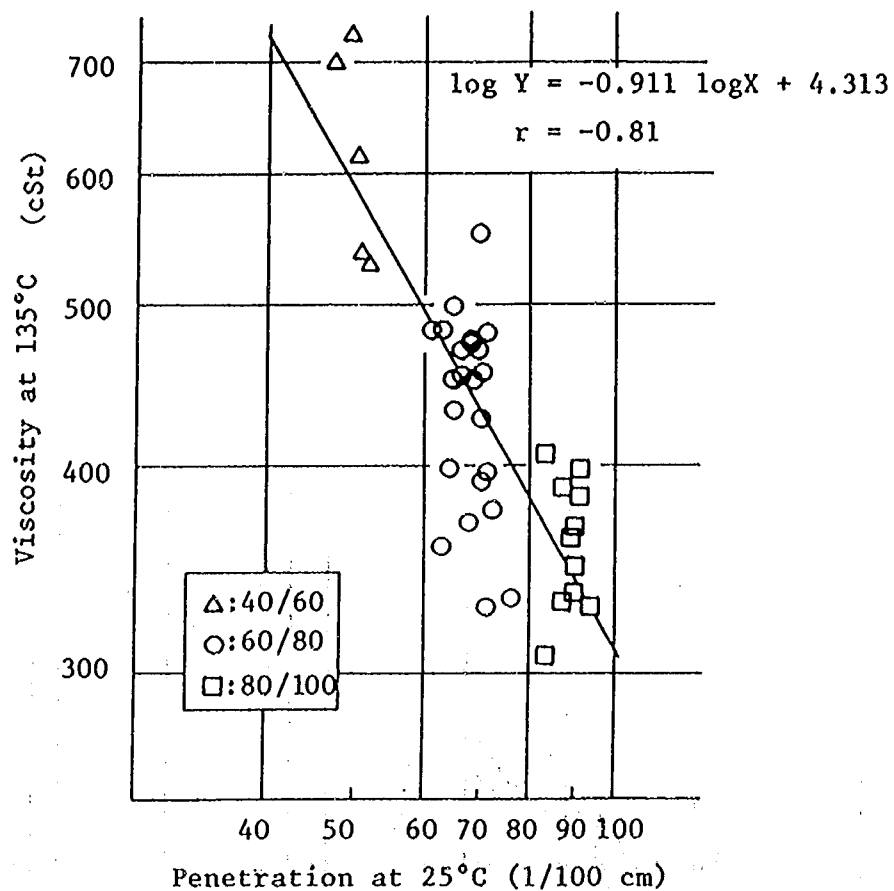


Fig. 4.15 Viscosity at 145°C Versus Penetration

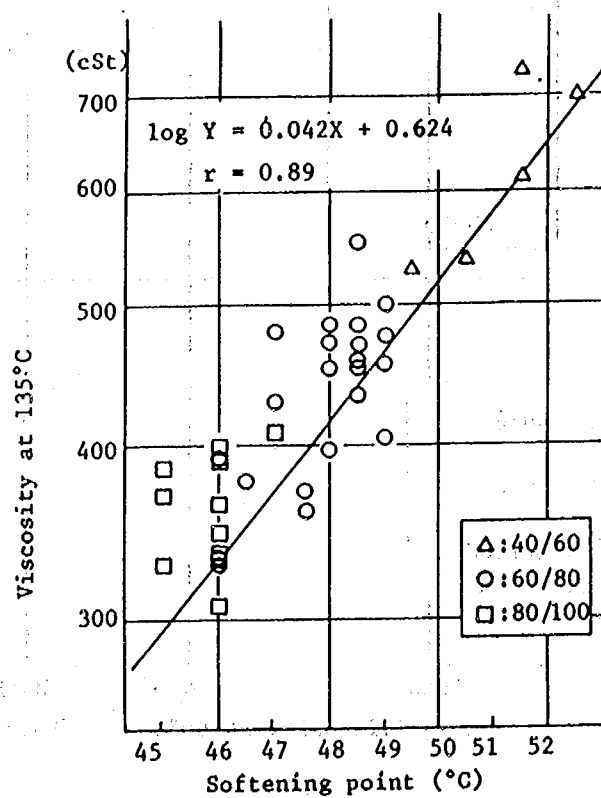


Fig. 4.16 Viscosity at 135°C Versus Softening Point

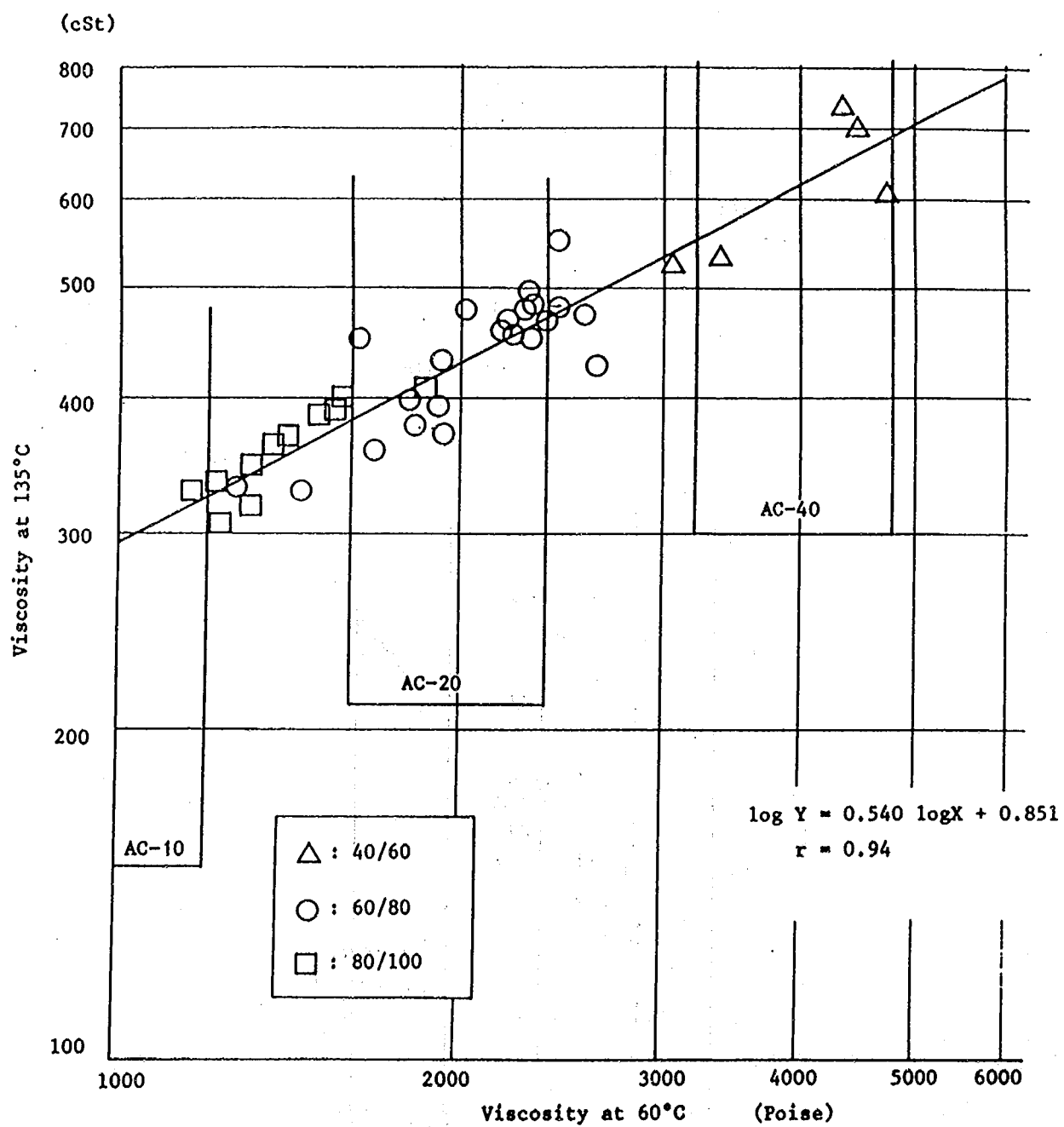


Fig. 4.17 Viscosity at 135°C Versus Viscosity at 60°C

4.6 Ductility

4.6.1 Ductility at 15°C

Ductility at 15°C is 100 or more for all the specimens and satisfies all the standard values of JIS and Asphalt Pavement Manual. There is no difference by specimen.

4.6.2 Ductility at 10°C

Since no difference was recognized in the ductility at 15°C, the ductility test was conducted at 10°C, and the results were arranged by grade and shown in Fig. 4.18.

Test values are dispersed in a wide range, and the ductility tends to increase as the grade becomes larger. The 40/60 grade is considered to be within the brittleness region at 10°C, and the difference between each specimens is small. Results of 60/80 have a wide range from the minimum of 11 to the maximum of 140 or more, and a significant difference between specimens can be seen. Results of 80/100 have values larger than 140 in 5 specimens (45%), and no significant difference is recognized.

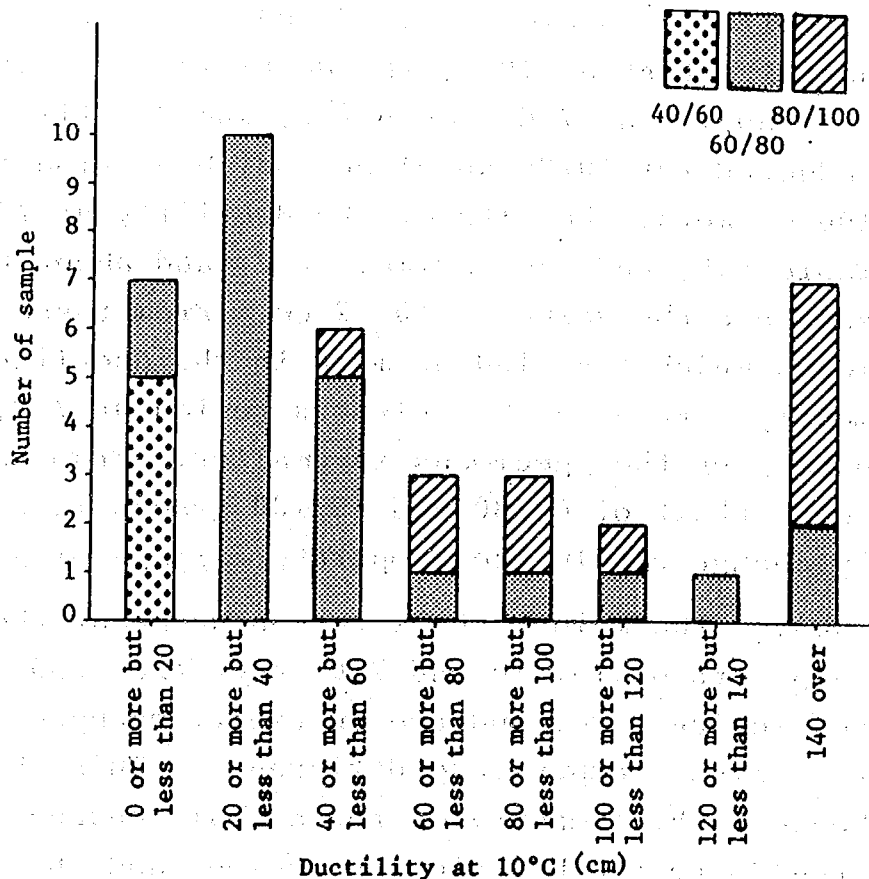


Fig. 4.18 Ductility at 10°C

Table 4.9 10°C and 7°C Ductility

Grades	No.	(cm)	
		Ductility at 7°C	Ductility at 10°C
60/80	-1	0	106
	4	5	127
	12	9	140+
	19	16	140+
80/100	-1	27	140+
	2	8	43
	3	12	140+
	4	10	140+
	5	10	88
	6	10	119
	7	10	73
	8	13	140+
	9	16	140+
	10	8	68
	11	10	92

4.6.3 Ductility at 7°C

Since about half the specimens of 80/100 have values of 140 or more in ductility test at 10°C, the ductility test was also conducted for 80/100 at 7°C. Moreover, the ductility test at 7°C was conducted for 60/80 specimens which previously have the value of 100 or more. Results of the ductility at 7°C are as shown in Table 4.9, and the maximum is 27 and about two-third of specimens have the value of 10 ± 2 cm. From these results, even specimens which have 100 or more in the ductility test at 10°C are mostly within the brittleness region at 7°C, and the difference between the specimens is smaller. From these, the ductility of asphalt of 60/80 and 80/100 grades is considered to suddenly change within the temperature range of about 10°C.

As stated above, the main tests were conducted at the 3 temperature points of 15, 10 and 7°C under the condition of constant tensioning rate, and the ductility changed abruptly even after a slight temperature difference. This change seems to occur because the property of the asphalt changes from the viscosity region to the brittleness region, and the transition temperature is considered to be located near 10 to 15°C for

40/60, around 10°C for 60/80 and near 7 to 10°C for 80/100.

4.7 Solubility in Trichloroethane

Results of test are shown in Table 4.10. The results of all the specimens satisfy more than 99.0% of the standards prescribed in JIS and the Asphalt Pavement Manual. 42% of all the specimens have values more than 99.5%. So no asphalt has abnormal inorganic matters, and the quality is sufficient. The Method of rounding the test value prescribed in JIS K 2207 is 0.01 for more than 99% and 0.1 for less than 99%. In this test, only one specimen (80/100-7) has a value less than 99%, but the test value after the rounding in accordance with JIS become equal to 99.0%, thereby barely satisfying the standards value.

Correlation between the solubility in trichloroethane and other properties is not recognized.

Table 4.10 Solubility in Trichloroethane

(%)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	99.90	99.99	99.77	0.10	0.1
60/80	23	99.85	100.0	99.39	0.18	0.2
80/100	11	99.86	99.98	99.0	0.15	0.1

4.8. Flash Point

The test results of flashpoint are shown in Table 4.11 and Fig. 4.19. The standard value of the flashpoint is higher than 260°C and all the specimens satisfied the standard value.

There is no difference in the mean value between grades with a level of significance of 5%, and about 80% of all specimens have flash point between 320 and 360°C.

At the time of measuring the flash point, film or foam was observed in several specimens and their situations were also recorded. Moreover, most specimens that produced film or foam at the first test almost produce film or foam again at the second test. So this phenomenon is considered to be a property inherent to each asphalt.

Table 4.12 shows the results arranged by each refinery. Asphalt of refinery A had the smallest value of flash point. Five specimens produced the foams of all asphalt, of which 4 specimens were from the refineries B and C. It is therefore said that the asphalt from the same refinery tends to have the same flash point value and ignition situation.

Table 4.11 Flash Point

(°C)						
Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	340	362	299	24.6	7.2
60/80	23	342	363	296	16.8	4.9
80/100	11	345	357	323	9.7	2.8

Table 4.12 Flash Point and Flashing Condition by Refinery

Refineries	Samples	Flashing point (°C)	Conditions	Samples	Flashing point (°C)	Conditions
A	40/60	299	-	60/80	296	-
B	60/80	354	Foam	80/100	343	Foam
C	60/80	346	Foam	80/100	350	Foam

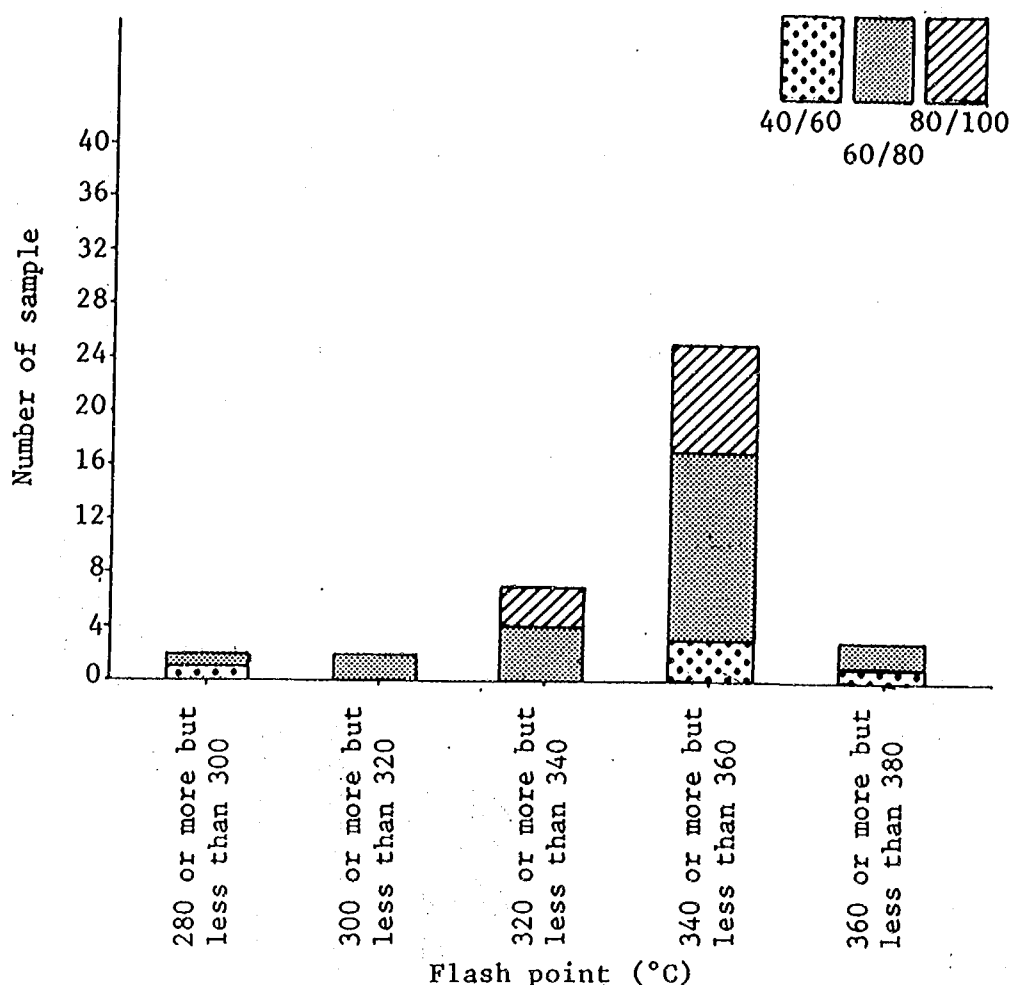


Fig. 4.19 Flash Point

4.9 Loss-on Heating Test

4.9.1 Volatilization Loss (Mass Change)

Results of volatilization loss after the loss-on heating test are shown in Table 4.13 and Fig. 4.20.

Mean value of grades 40/60, 60/80 and 80/100 are 0.006, 0.003 and -0.02 respectively. No significant difference in the mean value is seen between grades. However, 80%, 57% and 27% of specimens increased mass for 40/60, 60/80 and 80/100 respectively after the loss-on heating test, while fewer specimens increase mass as the grade becomes larger. This probably occurs because the asphalt of larger grades is more greatly affected by the decrease of mass due to volatilization rather than the increase of mass due to oxidation.

Table 4.13 Volatilization Loss in Loss-on-heating Test

(%)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	0.006	0.02	-0.01	0.01	190
60/80	23	0.003	0.03	-0.06	0.02	851
80/100	11	-0.02	0.08	-0.12	0.05	248

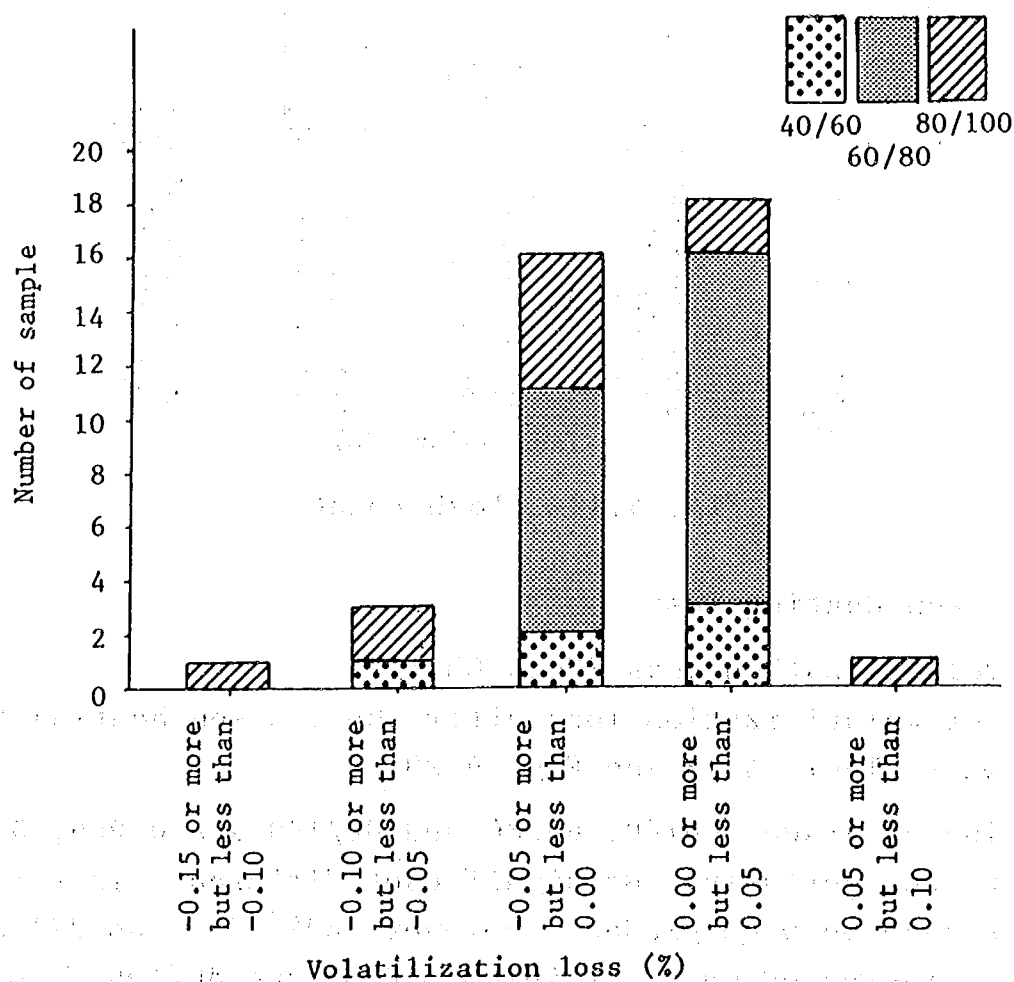


Fig. 4.20 Volatilization Loss in Loss-on-heating Test

4.9.2 Penetration Ratio

(1) Outline of Test Method

The penetration ratio after the loss-on-heating test is

prescribed in the Asphalt Pavement Manual and JIS standards for the purpose of eliminating easily segregative asphalt which has a large amount of light portion.

Outline of method of penetration ratio after loss-on-heating test are as follows;

- 1) Pour testing asphalt into two penetration cups.
- 2) Heat these specimens for 5 hours at 163°C.
- 3) After heating, stir one specimen sufficiently.
- 4) Measure the penetration of each specimen.
- 5) Penetration Ratio = (mean penetration of unstirred specimen)/(mean penetration of stirred penetration)

(2) Test Results

The results of penetration ratio after the loss-on-heating test are shown in Table 4.14 and Fig. 4.21. The standard value of the penetration ratio is less than 110, and all the specimens fully satisfy the standards.

Mean value of the penetration ratio is 99.0, 95.9 and 91.6 for the grades of 40/60, 60/80 and 80/100 respectively, and thus the penetration ratio tends to decrease as the grade increases. Though there is a significant difference between 60/80 and 80/100 at a level of significance of 5%, no significant difference is recognized between 40/60 and 60/80. Also, the dispersion of test results within the grade tends to increase as the grade becomes larger.

It is normally considered that the penetration ratio after loss-on-heating test does not measure the hardening properties due to deterioration by heating, and thus the lower limit of the penetration ratio is not prescribed. However, about 20% of unstirred specimens of 40/60 and 60/80 and almost all the unstirred specimens of 80/100 showed nonuniform surface conditions, which a light portion or hardened portion partially segregated on the surface. Also, the penetration ratio was calculated for each measuring point (penetration at

each measuring point of unstirred specimen)/(mean penetration of stirred specimen) , and one measuring point of 234 measuring points of all the specimens (39 specimens x 2 cups x 3 measuring points) had a penetration ratio of higher than 110. Moreover, as stated above, segregation of hardened portions due to deterioration is often observed, so the test value is greatly affected by the penetration measuring position. Even the values of penetration at 3 points in a cup have a maximum difference of 26. It is necessary for this test to review the testing operation itself and lower limit of standard.

Table 4.14 Penetration Ratio after Loss-on-heating Test

(%)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	99.0	101.1	95.8	2.1	2.1
60/80	23	95.9	106.6	88.2	4.4	4.6
80/100	11	91.6	102.7	80.9	7.0	7.6

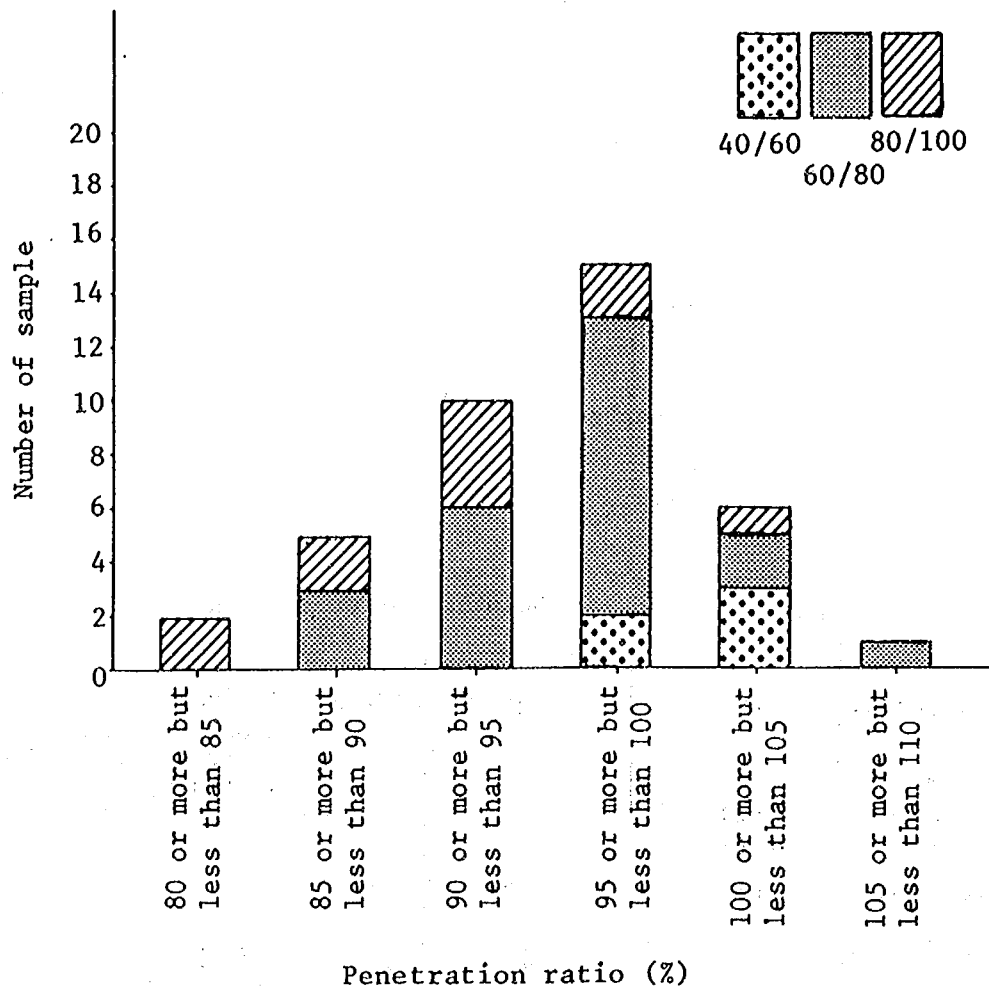


Fig. 4.21 Penetration Ratio after Loss-on-heating Test

4.10 Separation into Four Fractions

4.10.1 Outline of Test Method

Asphalt comprises various kinds of hydrocarbon and its compounds, and it is almost impossible to know the each component. Therefore, in the method whereby the compositions of asphalt are analyzed, the compositions are separated into several groups having similar properties. There are many asphalt separation methods, for example, ASTM prescribes "Separation into Four Fractions." in ASTM D 4124.

As a Japanese standardized method of asphalt separation similar to ASTM D 4124, there is a standard called "the Asphalt Composition Analysis Method by Column Chromatography (JPI-5S-22-83)" established by the Japan Petroleum Institute. This is standardized on the basis of a conventional method

called the Iijima's Method, and this JPI method was used in the present tests. According to this method, asphalt is separated into the four fractions of asphalten, resin, aromatics and saturatus as illustrated in Fig. 4.22.

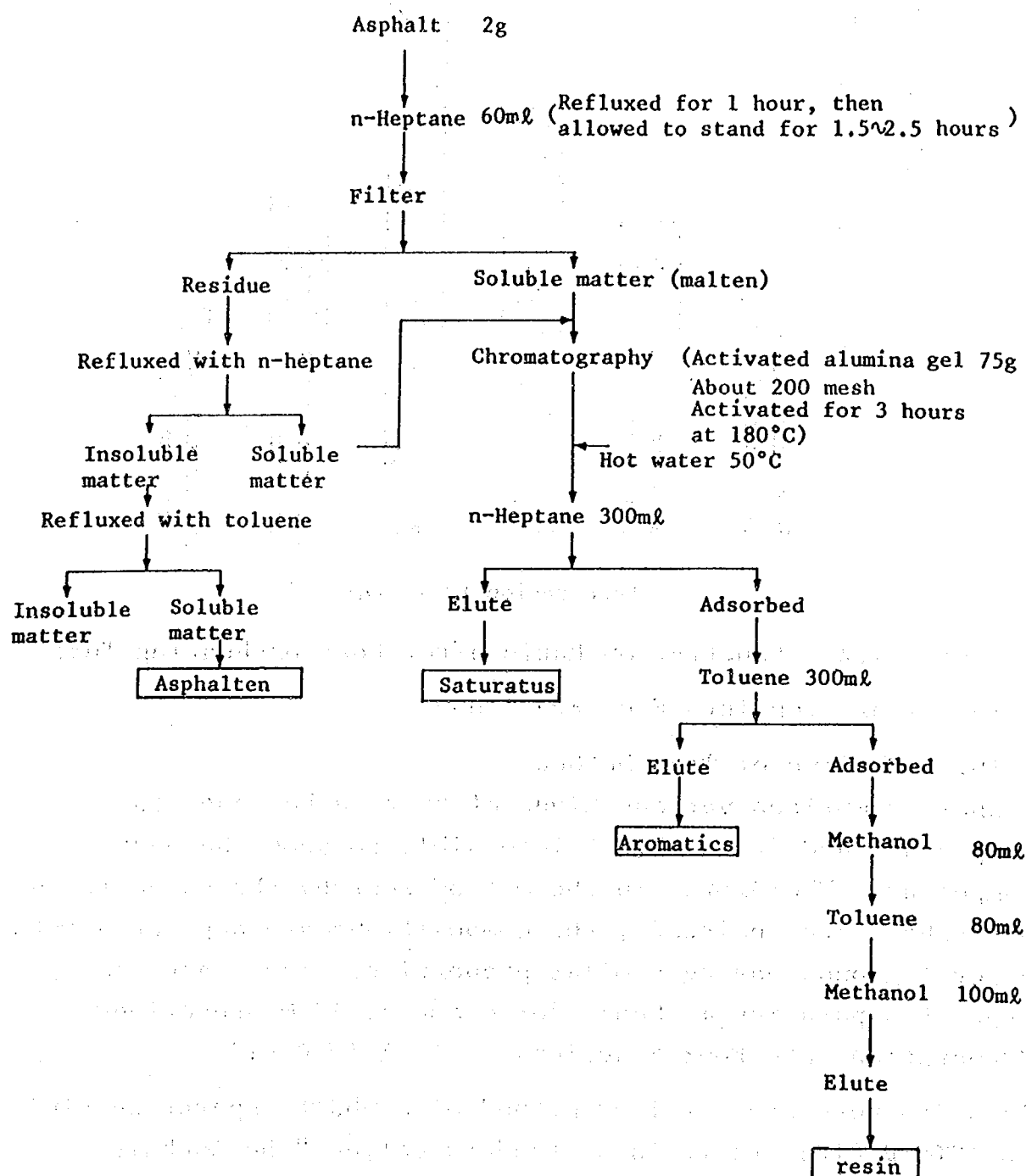


Fig. 4.22 Test Method for Separation of Asphalt into Four Fractions (Asphalt Separation Test)

4.10.2 Test Results

Results of the separation test of original asphalt are shown in Tables 4.15 to 4.18 and Figs. 4.23 to 4.26. Asphalten contents are about 12% for all grades and there is no significant difference at the level of significance of 5%. In the case of resin, there is a significant difference between 40/60 and 60/80 at the level of significance of 5%, and the content of 40/60 is smaller. In the case of aromatics and saturatus, no differences are recognized between all the grades at a level of significance of 5%.

Recovery is higher than 96% except for 2 specimens that have a recovery of 91.9% and 95.1%. This seems to occur because these specimens have components which are strongly adsorbed by almina-gel and are thus unrecoverable.

Table 4.15 Result of Asphalt Separation Test (Asphalten)
(%)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	12.5	15.8	8.5	2.8	21.9
60/80	23	12.4	16.4	9.0	1.9	15.7
80/100	11	11.3	15.8	8.8	1.9	17.3

Table 4.16 Result of Asphalt Separation Test (Resin)
(%)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	20.4	21.8	18.4	1.4	7.0
60/80	23	22.7	28.0	19.3	1.8	8.1
80/100	11	22.5	23.8	20.9	1.1	4.8

Table 4.17 Result of Asphalt Separation Test (Aromatics)
(%)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	50.8	55.6	43.6	4.5	8.9
60/80	23	49.3	53.1	43.2	2.6	5.4
80/100	11	49.9	54.2	43.4	2.8	5.7

Table 4.18 Result of Asphalt Separation Test (Saturatus)
(%)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	15.1	18.5	13.4	2.0	13.3
60/80	23	14.9	18.4	12.4	1.7	11.2
80/100	11	15.6	17.2	13.5	1.1	6.8

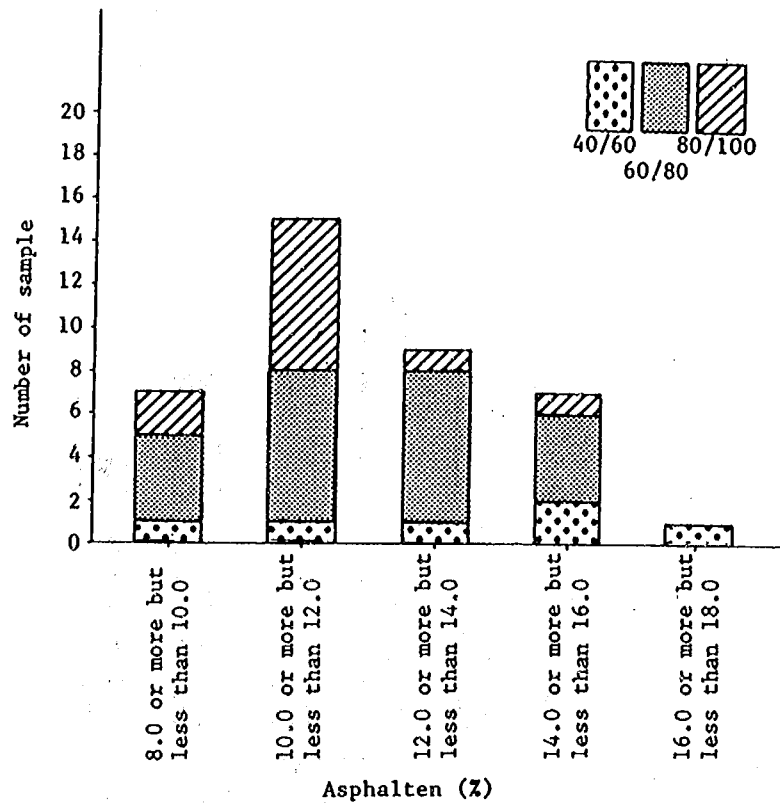


Fig. 4.23 Result of Asphalt Separation Test (Asphalt)

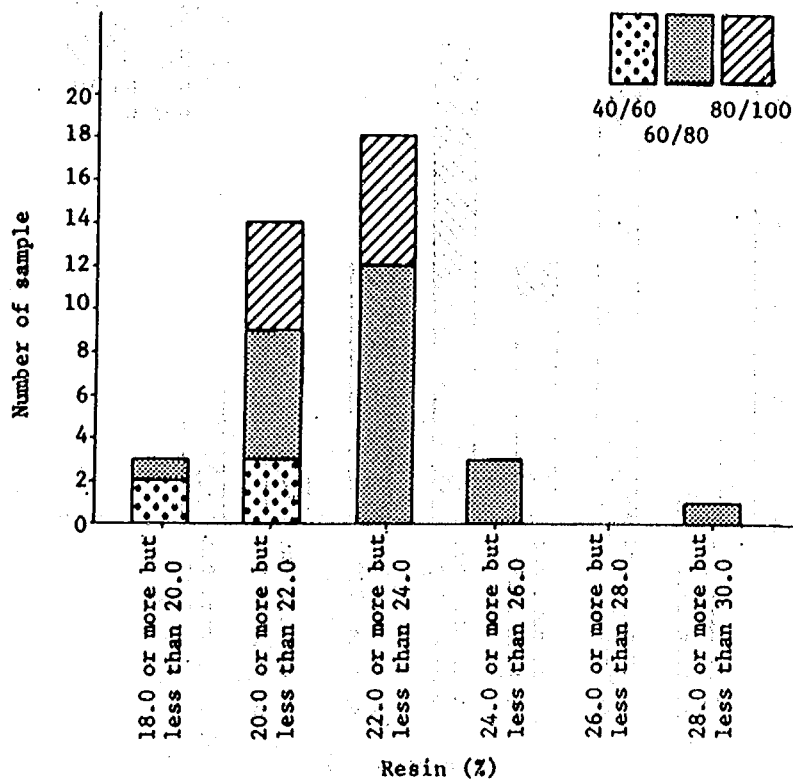


Fig. 4.24 Result of Asphalt Separation Test (Resin)

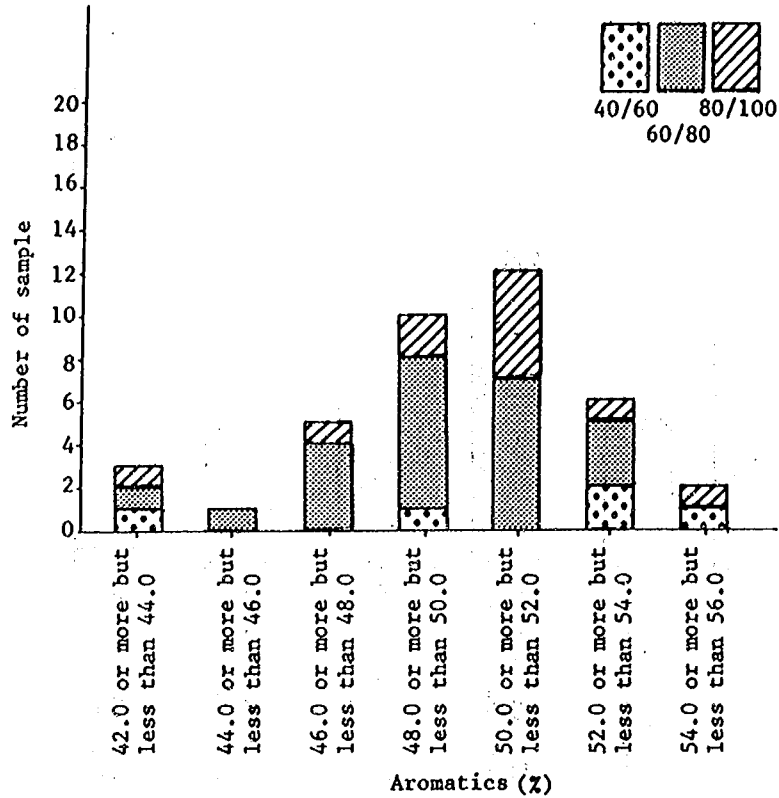


Fig. 4.25 Result of Asphalt Separation Test (Aromatics)

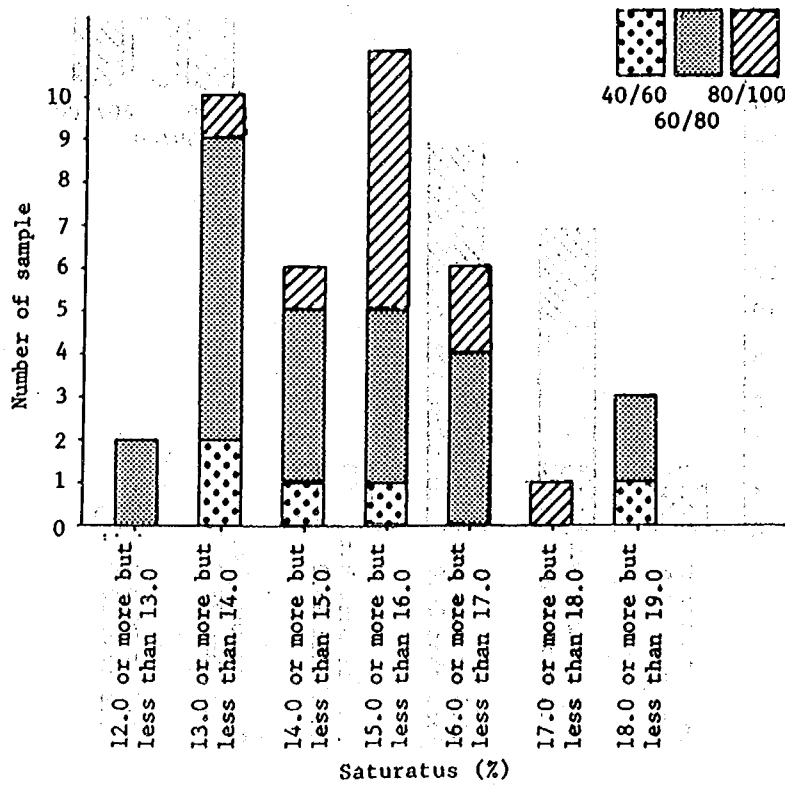


Fig. 4.26 Result of Asphalt Separation Test (Saturatus)

All the specimens have similar fraction contents so that definitive comparison is not possible. Because of this, principle ingredient analysis is conducted on the result. Fig. 4.27 shows a graph with the first main component plotted on the abscissas and the second main component on the ordinate. Table 4.19 shows the characteristic vector. From the characteristic vector, much aromatics is located toward the right side and much saturatus toward the left side along the abscissa in Fig. 4.27. Along the ordinate, much asphalten is located upward and much resin downward. Results are divided into 7 groups marked by "0", and the groups III, IV and VII are far from other large groups. Group VI contains 2 specimens with a low recovery. Group V contains specimens from the same refinery. Thus, several groups are found to be far from the majority of groups. However, the correlation of two large groups I and II with other properties is not recognized clearly.

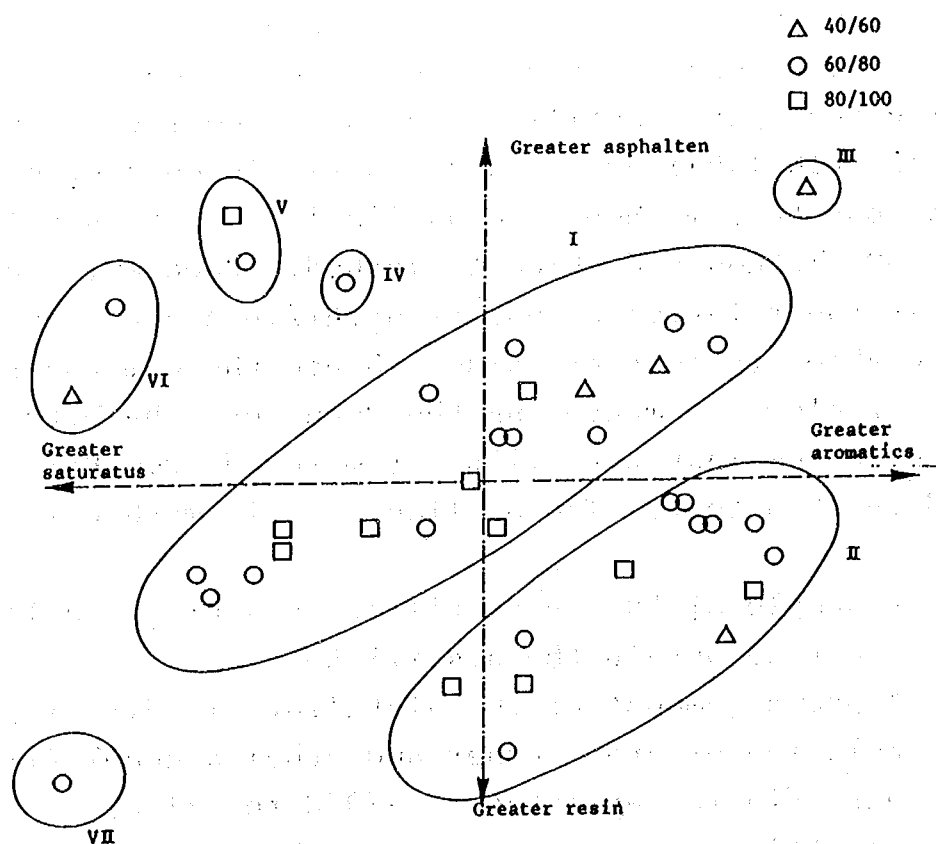


Fig. 4.27 Principle Ingredient Analysis of Asphalt Separation Test Result

Table 4.19 Characteristic Vectors by
Principal Ingredient Analysis

	First Principal ingredient characteristic vector	Second principal ingredient characteristic vector
Asphalten	0.05	0.74
Resin	-0.26	-0.62
Aromatics	0.69	-0.25
Saturates	-0.68	0.04
Cumulative contribution ratio	43.5	80.3

4.11 Paraffin Content

4.11.1 Outline of Test Method

It is said that the inclusion of a large amount of paraffin content in the asphalt results in the poor adhesion of asphalt to aggregates, poor ductility and low viscosity. The German Standards (DIN 1995) prescribes a paraffin content of less than 2%. Various test methods are available such as Holde's method, UOP method and chromatography method. However, these can show only the relative amount of paraffin content and cannot find the absolute content value. Since these methods have certain problems in measuring the accuracy, the Method of the Japan Petroleum Institute (1965) (improved from Holde's method) is used in this test. The outline of this method is explained below.

- (1) A sample of 50g is distilled in a distillation flask in order to obtain the distillate.
- (2) A proper amount of the distillate is dissolved in a solution of ethyl ether and ethyl alcohol (1:1), and paraffin is deposited at -20°C to -21°C .
- (3) Paraffin is recovered by warm benzene, and the percentage of the paraffin content is determined.
- (4) The same steps are taken for 3 amounts of the distillate, and the percentage of paraffin content that

can produce the amount of recovered paraffin content of 0.075 g is determined. This is used as the percentage of paraffin content.

4.11.2 Test Results

Results of the paraffin content test are shown in Table 4.20 and Fig. 4.28. Since it was not possible to make the test twice in succession for all the specimens, the results shown in Table 4.20 and Fig. 4.28 are the results of test conducted only once. However, the test was repeated for several specimens.

The results almost concentrated in the range of 2% as shown in Fig. 4.28, and there is no difference between mean value of paraffin content of each grade at the level of significance of 5%. There are two specimens with a paraffin content of less than 1%, and this is considered to be caused by differences in the crude oil.

The correlation between the paraffin content and other properties are analyzed, but the correlations are generally not so significant. Correlation with the 60°C viscosity is relatively significant as shown in Fig. 4.29. However, the correlation coefficient was 0.52 and this is not so high.

Table 4.20 Paraffin Content

(%)						
Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	1.76	2.08	0.71	0.6	34
60/80	23	2.07	2.84	0.43	0.5	23
80/100	11	2.48	3.44	1.09	0.8	32

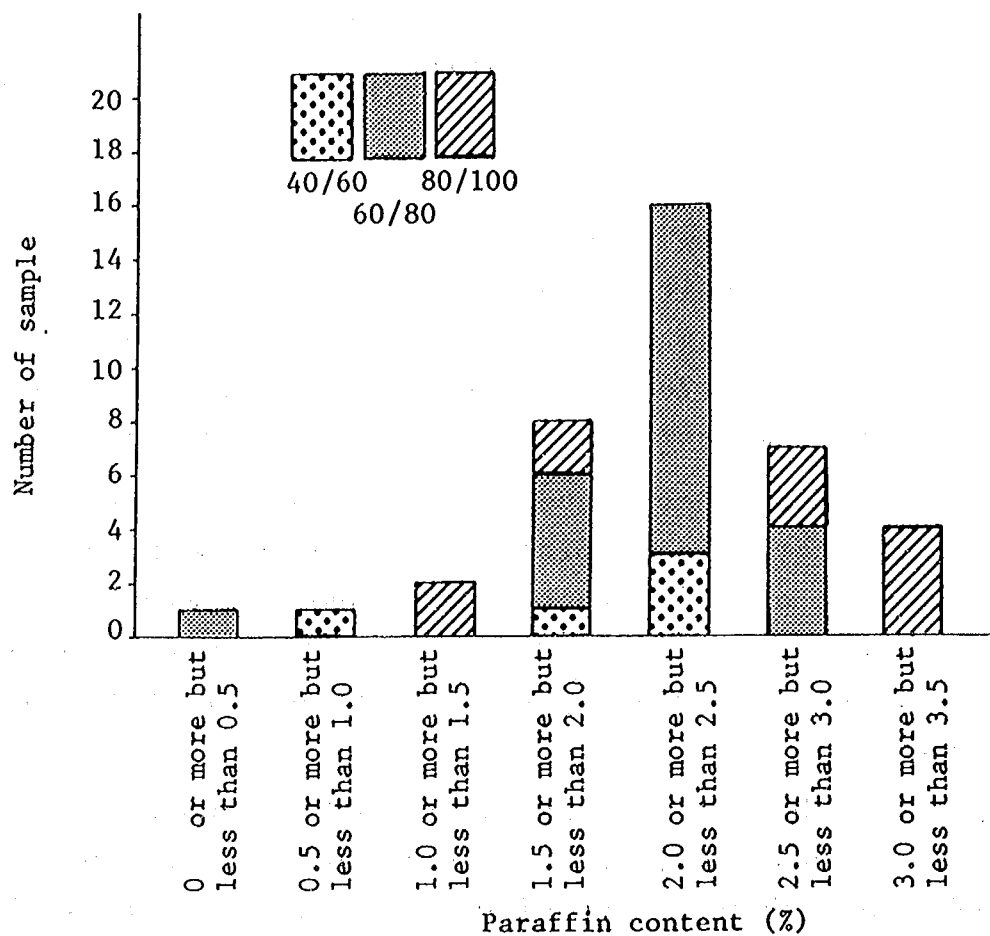


Fig. 4.28 Paraffin Content

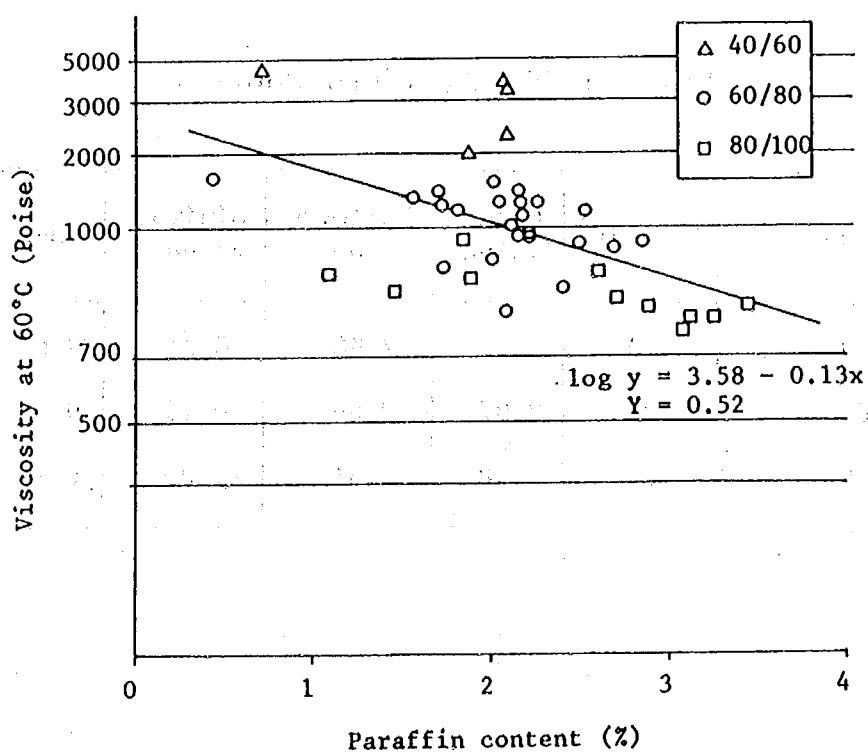


Fig. 4.29 Paraffin Content Versus Viscosity at 60°C

The Japan Petroleum Institute prescribes a single operator precision of less than 0.3% and a multilaboratory precision of less than 1%. According to the results of the preliminary tests shown in Table 4.21, the single operator precisions for the same specimen by 3 out of 8 testing persons are higher than 0.3% and thus do not satisfy the standard. With respect to the dispersion of test results by 2 testing persons, 1 specimen exceeded 1% as shown in Table 4.22.

For the paraffin content tests, main tests were conducted after making the testing persons fully skilled with the testing operation in advance. Nevertheless, the dispersion is found as stated above, and this probably means that provision for testing operation contains some problems.

Table 4.21 Result of Preliminary Test of Paraffin Content

Item	A	B	C	D	E	F	G	H
Sample No.1	2.33	2.20	2.25	2.34	2.30	2.31	2.06	2.31
No.2	2.28	2.18	2.05	1.75	2.28	3.30	2.41	2.03
Mean value	2.30	2.19	2.15	2.05	2.29	2.81	2.24	2.17
Single operator precision	0.05	0.02	0.20	0.59	0.02	0.99	0.35	0.28

Table 4.22 Precision of Paraffin Content by 8 Testers (%)

Sample	1	2	Precision
40/60 - 1	2.08	1.69	0.39
3	2.08	2.18	0.10
60/80 - 5	2.21	2.54	0.33
7	1.80	1.55	0.25
9	2.50	1.87	0.63
11	1.69	2.86	1.17
12	2.40	2.76	0.76
14	2.52	1.67	0.85

4.12 Spot Test

4.12.1 Outline of Test Method

This test is virtually intended to find the difference between ordinary straight asphalt and abnormally treated asphalt by determining the homogeneity or non-homogeneity. If a large amount of carbon or the like resulted from cracking by heating is mixed in asphalt, carbon insoluble in solvents is segregated on filter paper and this is judged to be positive in the spot test. The method of the spot test is prescribed in AASHTO T 102, and its outline is as follows:

- (1) Add standard naphtha of 10.2 ml to a sample of 2 g and stir for prescribed time, and drop the solution on prescribed filter paper at a predetermined temperature.
- (2) Observe the filter paper 5 minutes later. Judge as positive if black spots or particle-like matters are recognized, and negative if uniform brown shapes are recognized.
- (3) In the case of positive, repeat the same operation by using a solution to which xylene is added, and find the amount (%) of xylene that makes the solution negative. (Equivalent of xylene)

4.12.2 Test Results

Results of the spot test are negative for each asphalt and no differences in the results are observed.

Spot test was also conducted for several specimens after thin-film oven test, but none of them is positive.

4.13 Specific Gravity

Results of the specific gravity test are shown in Table 4.23 and Fig. 4.30.

The standard value of the specific gravity is higher than 1.000. All specimens satisfy the standard value, and 70% of specimens have the specific gravity falling into the range of 1.025 to 1.035.

Fig. 4.31 shows the relationship between the penetration and the specific gravity. It is said that the specific gravity

increases as the penetration decreases, but the results have a large dispersion, and the correlation coefficient is -0.49. There is a difference between 60/80 and 80/100 but no difference between 40/60 and 60/80 at the level of significance of 5%. So it is said that there is no obvious correlation between specific gravity and penetration.

Table 4.23 Specific Gravity

(25/25°C)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	1.032	1.037	1.027	0.0041	0.40
60/80	23	1.030	1.038	1.023	0.0038	0.36
80/100	11	1.026	1.031	1.021	0.0031	0.30

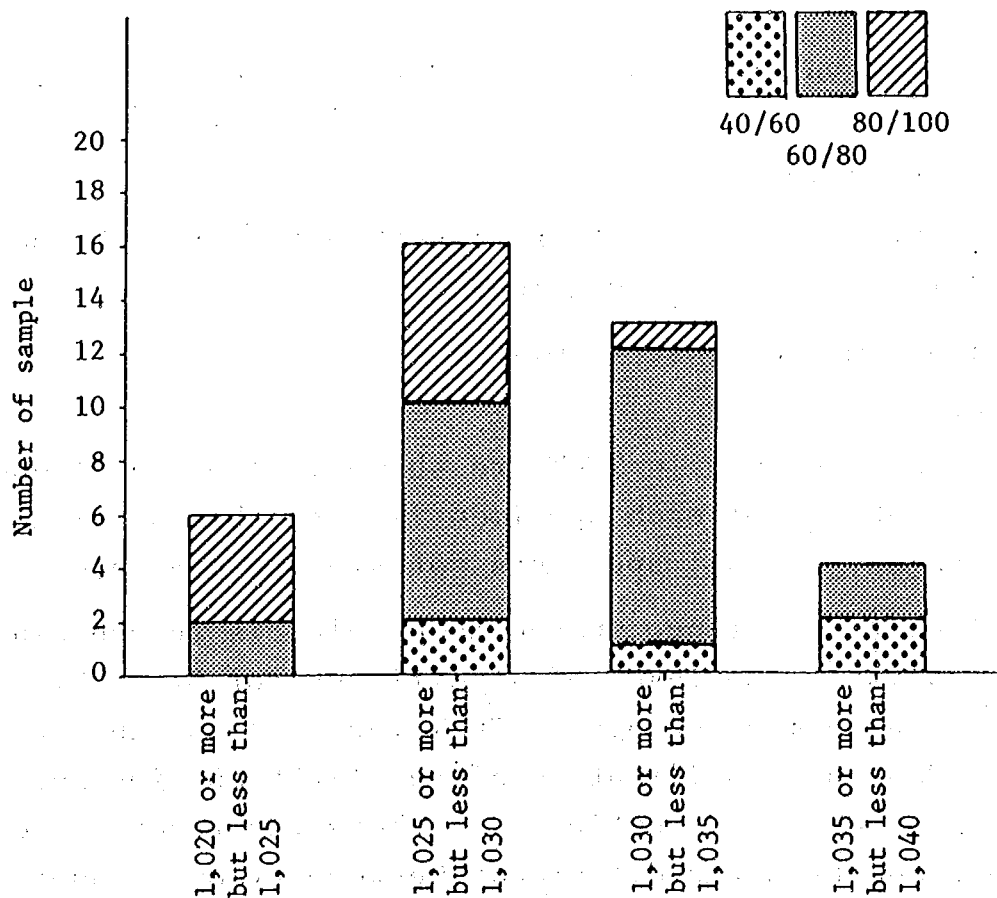


Fig. 4.30 Specific Gravity (25/25°C)

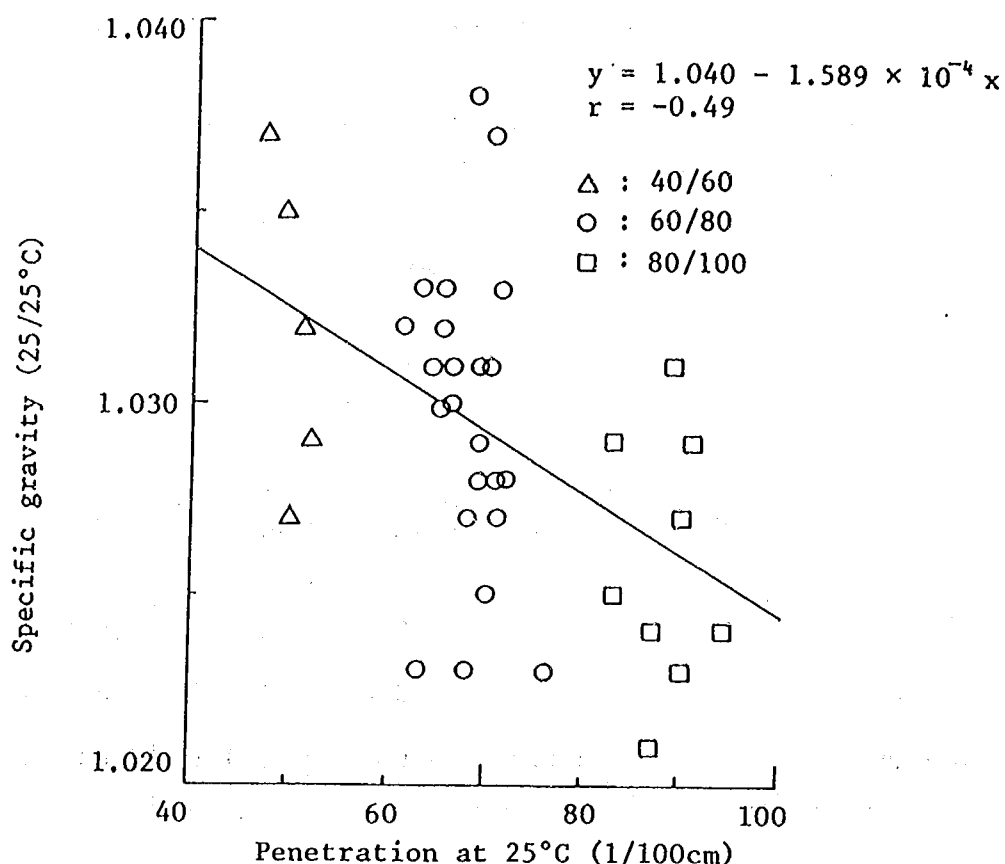


Fig. 4.31 Penetration at 25°C Versus Specific Gravity

4.14 Stripping Test

Result of the stripping test is less than 5% for each specimen, and no differences were recognized.

4.15 Thin-Film Oven Test (TFOT)

4.15.1 Mass Change

Results of mass change in TFOT are shown in Table 4.24 and Fig. 4.32. Mass change of each specimen is less than 0.14% in absolute value, and all specimens satisfy the standard value.

No significant difference in the mean value is recognized between grades at the level of significance of 5%. This seems to occur because mass change in TFOT includes not only the decrement due to volatilization of the light portion but also the increment due to oxidation. So these two reactions cancel each other and thus the difference between grades cannot appear clearly.

Table 4.24 Mass Change in TFOT

(%)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	0.06	0.09	-0.04	0.06	101
60/80	23	0.06	0.11	-0.14	0.07	117
80/100	11	0.03	0.09	-0.11	0.07	298

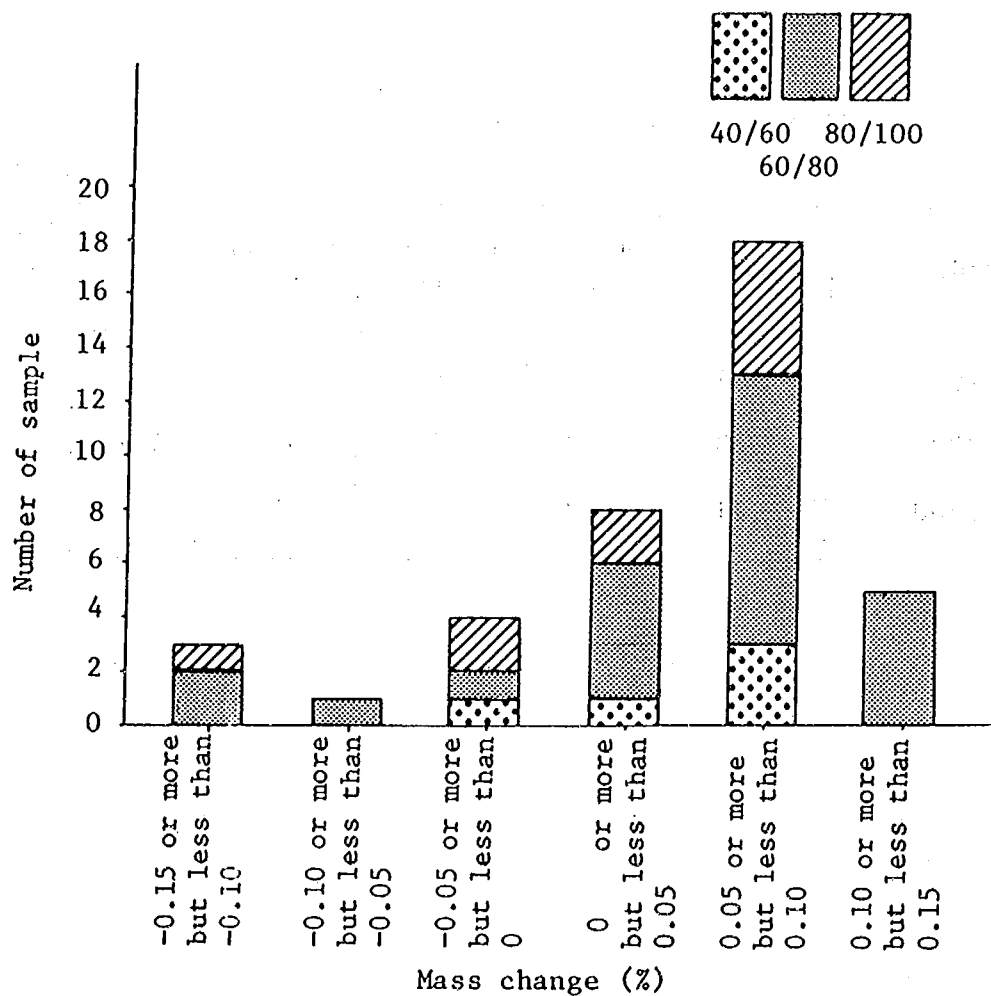


Fig. 4.32 Mass Change in TFOT

4.15.2 Penetration

Results of the penetration test after TFOT are shown in Table 4.25 and Fig. 4.33. Also, the values of penetration of residue in TFOT are shown in Table 4.26 and Fig. 4.34. JIS and the

Asphalt Pavement Manual prescribe that the values of penetration of residue are more than 58% for 40/60, 55% for 60/80 and 50% for 80/100, and all the specimens satisfy the standard value.

Relation between penetration of original asphalt and penetration of residue in TFOT is shown in Fig. 4.35. Mean value of penetration of residue has a significant difference between the grades, and the penetration of residue decreases as the asphalt grade becomes larger. This occurs probably because asphalt has a lower viscosity easily spreads or contains more components which are easily hardened by volatilization or oxidation.

Table 4.25 Penetration After TFOT

(1/100 cm)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	36.0	37	35	1.0	2.8
60/80	23	46.7	55	43	2.9	6.3
80/100	11	56.2	62	50	4.0	7.0

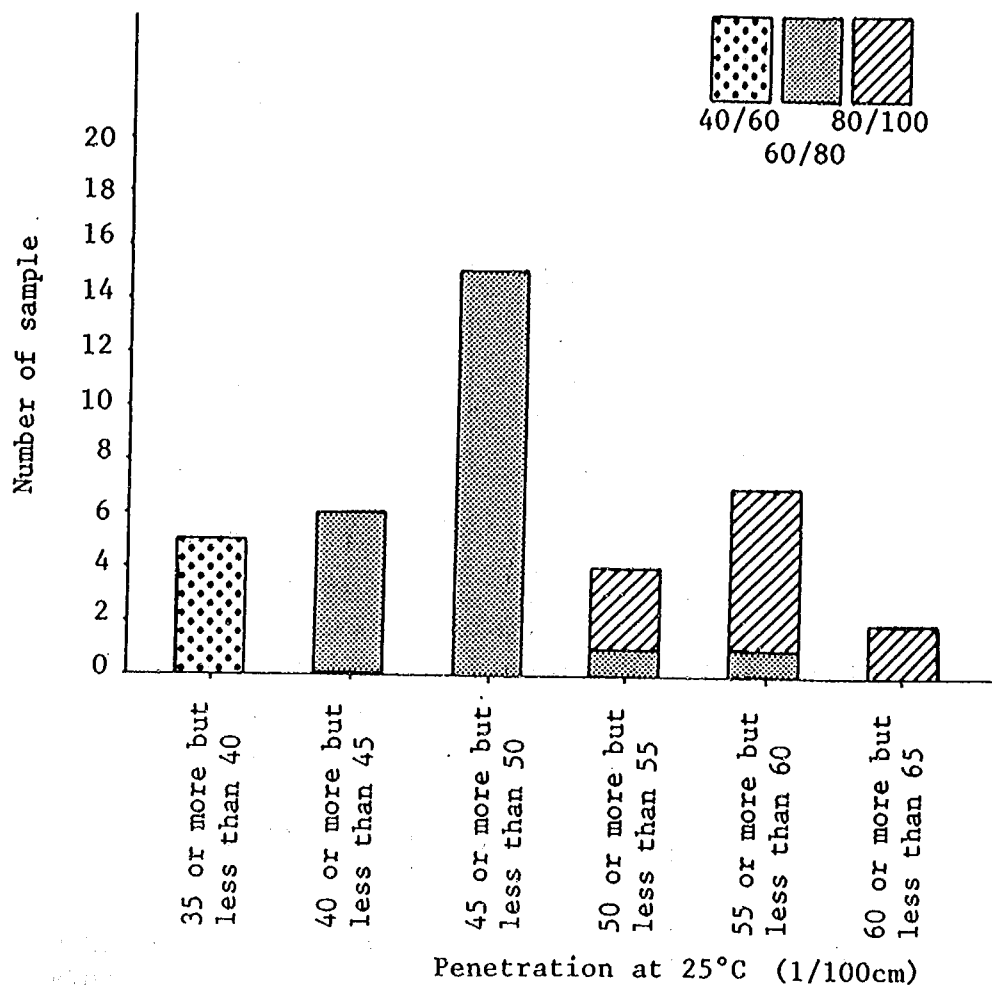


Fig. 4.33 Penetration after TFOT

Table 4.26 Penetration of Residue in TFOT

(%)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	72.4	74.5	68.6	2.5	3.3
60/80	23	68.6	75.4	59.9	4.0	5.8
80/100	11	63.2	68.9	60.2	3.0	4.8

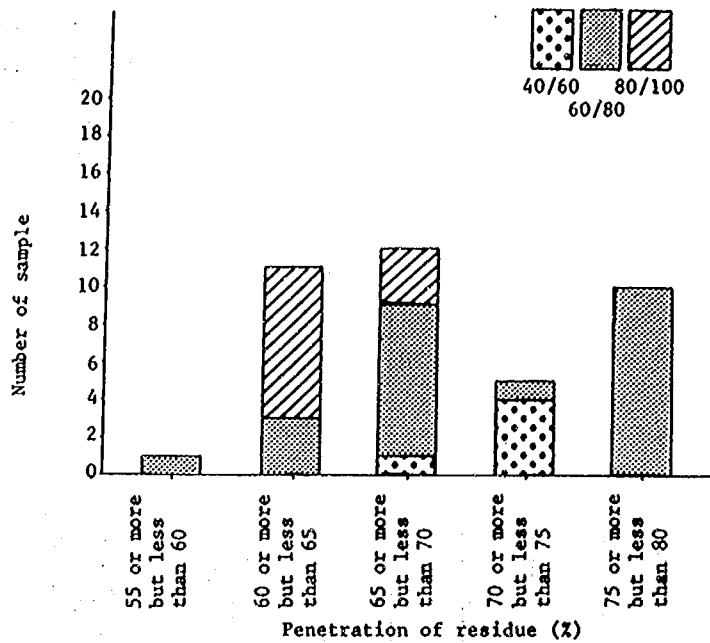


Fig. 4.34 Penetration Residue in TFOT

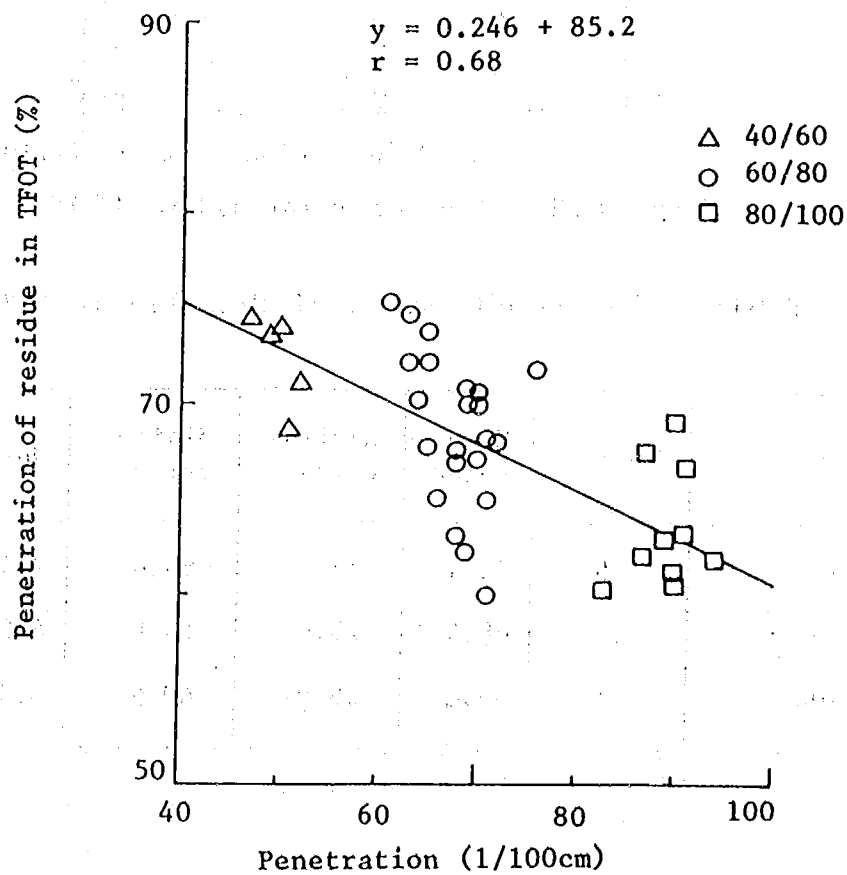


Fig. 4.35 Penetration of Original Asphalt Versus Penetration of Residue in TFOT

4.15.3 Softening Point

Results of the softening point test after the TFOT are shown in Table 4.27 and Fig. 4.36. Table 4.28 shows the change rate for the softening point $[(\text{softening point after heating})/(\text{softening point before heating}) \times 100]$. The rise in softening point is recognized in each asphalt, and the mean value of change rate seems to increase as the grade becomes larger. However, there are no difference between 40/60 and 60/80 and between 60/80 and 80/100 at the level of significance of 5%.

Table 4.27 Softening Point after TFOT

(°C)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	54.5	56.0	53.0	1.1	2.0
60/80	23	51.6	53.5	49.5	1.1	2.1
80/100	11	49.8	52.0	48.5	1.0	2.1

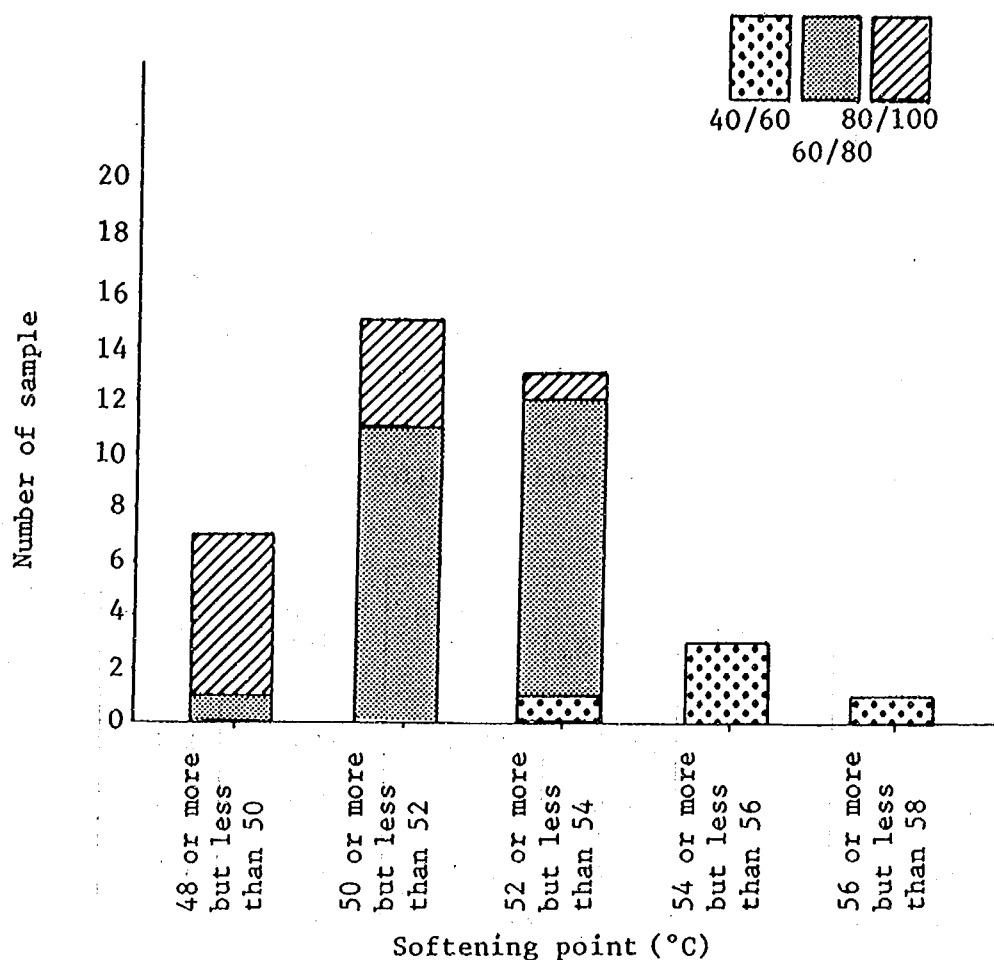


Fig. 4.36 Softening Point after TFOT

Table 4.28 Softening Point Change Rate in TFOT

(%)						
Grades	Number	Mean value	Maximum value	Minimum value	σn-1	Coefficient of variation
40/60	5	106.7	107.9	105.8	0.9	0.8
60/80	23	107.9	110.9	104.1	1.5	1.4
80/100	11	108.6	110.6	106.5	1.6	1.4

4.15.4 Penetration Index (PI)

Values of PI after TFOT are shown in Table 4.29 and Fig. 4.37. Mean values of PI for each grade before and after TFOT is shown in Table 4.30. The relationship between the penetration,

softening point and PI is shown in Fig. 4.38.

Mean value of PI changing rate of 80/100 before and after TFOT has a difference from other grades at the level of significance of 5% and the PI value tends to decrease after TFOT. This occurs probably because the rise in softening point is smaller than the drop in penetration.

Table 4.29 Penetration Index after TFOT

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	-0.86	-0.60	-1.13	0.19	22.3
60/80	23	-0.96	-0.52	-1.35	0.20	21.1
80/100	11	-0.99	-0.71	-1.23	0.17	17.3

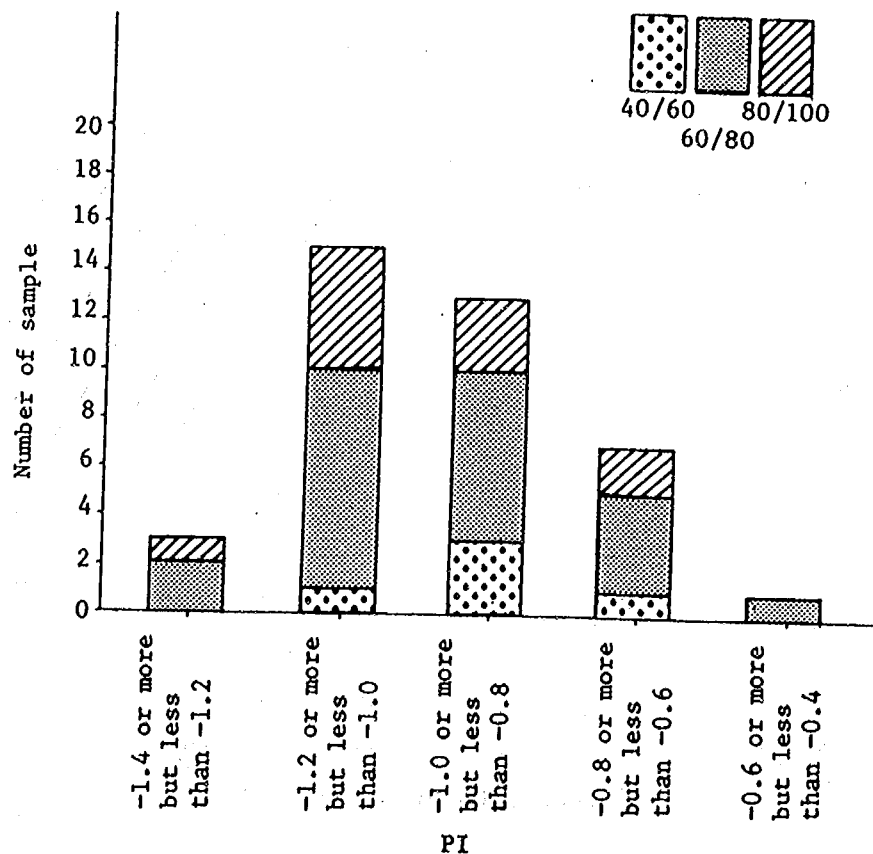


Fig. 4.37 Penetration Index (PI) after TFOT

Table 4.30 Mean Value of Penetration Index before and after TFOT

Grades	Before oven test	After oven test	Difference
40/60	-0.94	-0.86	0.08
60/80	-1.03	-0.96	0.07
80/100	-0.90	-0.99	-0.09

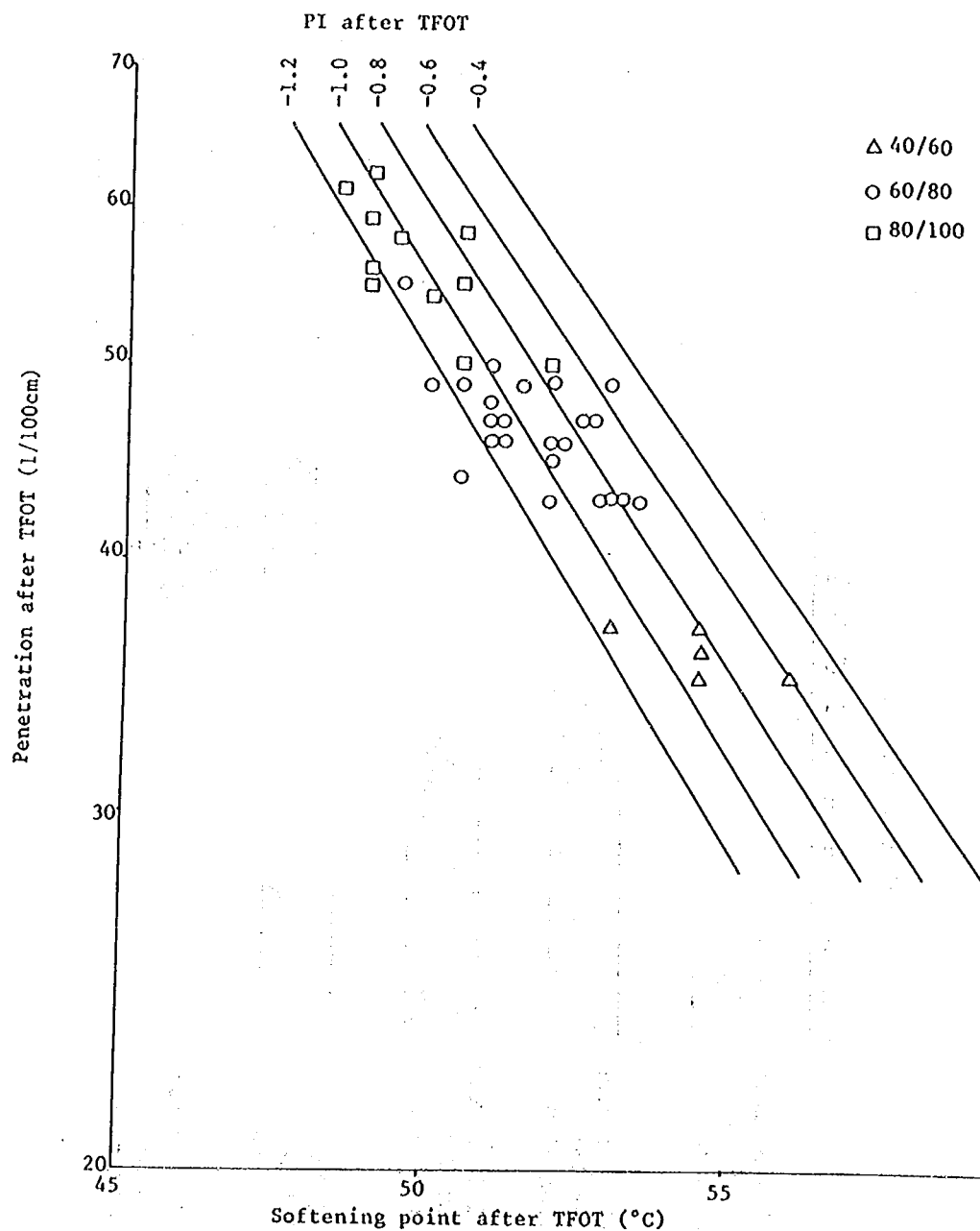


Fig. 4.38 Penetration, Softening Point and PI

4.15.5 Ductility (15°C)

Results of ductility test after TFOT are shown in Table 4.31 and Fig. 4.39. 80% of specimens have values between 0 and 60 cm and the mean is 34.4 cm (140 or more is calculated as 140) in the case of 40/60; 70% of specimens have values between 20 and 100 cm and the mean is 74.6 cm in the case of 60/80; and 80% of specimens have values between 60 and 140+ cm and the mean is 105.2 cm in the case of 80/100. As stated above, there is the difference in the mean value between the grades, and the ductility increases as the grade becomes larger. And Fig. 4.39 shows that the ductility after TFOT for each grade varies, and the difference between specimens appears even in the same grade.

Table 4.31 Ductility at 15°C after TFOT

(cm)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	34.3	88	9	33.1	96.3
60/80	23	74.6	140+	20	44.1	59.1
80/100	11	105.2	140+	32	42.2	40.1

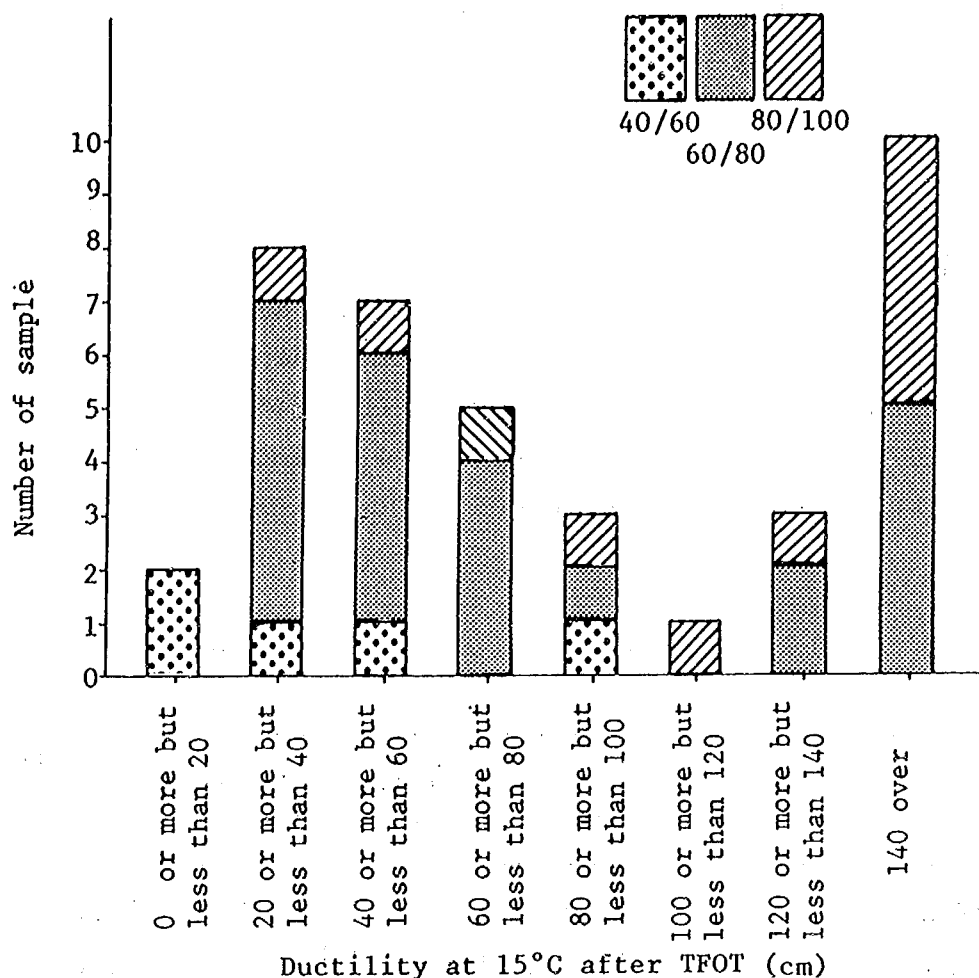


Fig. 4.39 Ductility after TFOT

A ductility test was performed for 3 test pieces for each specimen. Table 4.32 shows the mean of the coefficient of variation which calculated from values of 3 pieces. The dispersion of the ductility (15°C) after TFOT becomes smaller than the ductility (10°C) before TFOT.

Table 4.32 Coefficients of Variation of Ductility at 10°C of Original Asphalt and Ductility at 15°C after TFOT

Grades	Coefficient of variation of original asphalt (10°C)	Coefficient of variation after TFOT
40/60	49.3	11.6
60/80	20.2	9.9
80/100	21.7	10.8

4.15.6 Viscosity at 60°C

Results of viscosity at 60°C after TFOT are shown in Table 4.33 and Fig. 4.40. The mean values are 7650, 4210 and 3330 poise respectively for the grade of 40/60, 60/80 and 80/100. When comparing the viscosity at 60°C before TFOT to the AASHTO viscosity grade, the grades 40/60 and 60/80 almost correspond to AC-40 and AC-20, and the viscosity of 80/100 is slightly higher than that of AC-10. Comparing the viscosity after TFOT to the standards of AASHTO (less than 16000 for AC-40, less than 8000 for AC-20 and less than 4000 for AC-10), asphalt of which viscosity before TFOT satisfies AASHTO grade also satisfies the standard value after TFOT.

Table 4.33 Viscosity at 60°C after TFOT (Poise)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	7650	9120	5460	1570	20.5
60/80	23	4210	5900	2500	972	23.1
80/100	11	3330	4650	2110	698	23.0

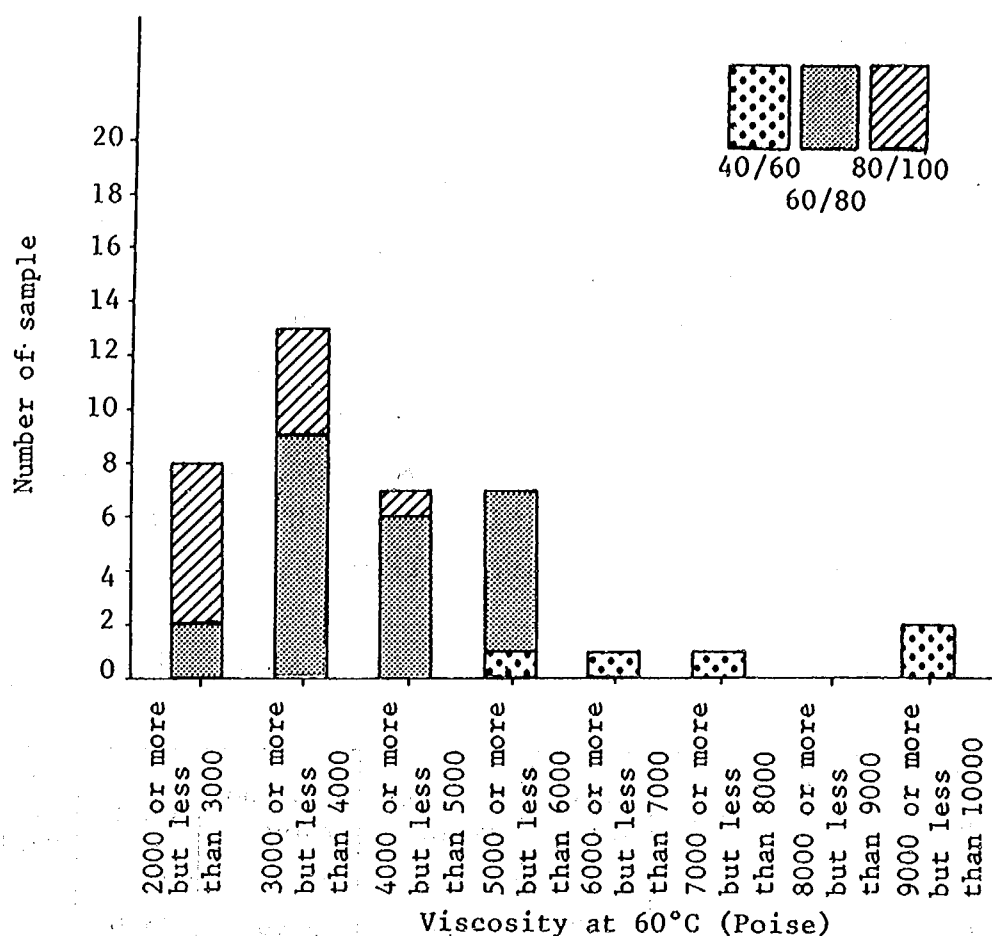


Fig. 4.40 Viscosity at 60°C after TFOT

Viscosity ratio (viscosity at 60°C after TFOT)/(viscosity at 60°C before TFOT) are shown in Table 4.34. Fig. 4.41 shows the relationship between the viscosity before TFOT and the viscosity after TFOT, which has a high correlation coefficient of 0.96. Mean value of the grades 40/60, 60/80 and 80/100 is respectively 1.91, 2.04 and 2.22. It is known that the viscosity at 60°C increases almost twice after TFOT.

Table 4.34 Viscosity Ratio at 60°C after TFOT

(%)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	1.91	2.05	1.78	0.11	5.8
60/80	23	2.04	2.57	1.51	0.27	13.3
80/100	11	2.22	2.58	1.85	0.25	11.3

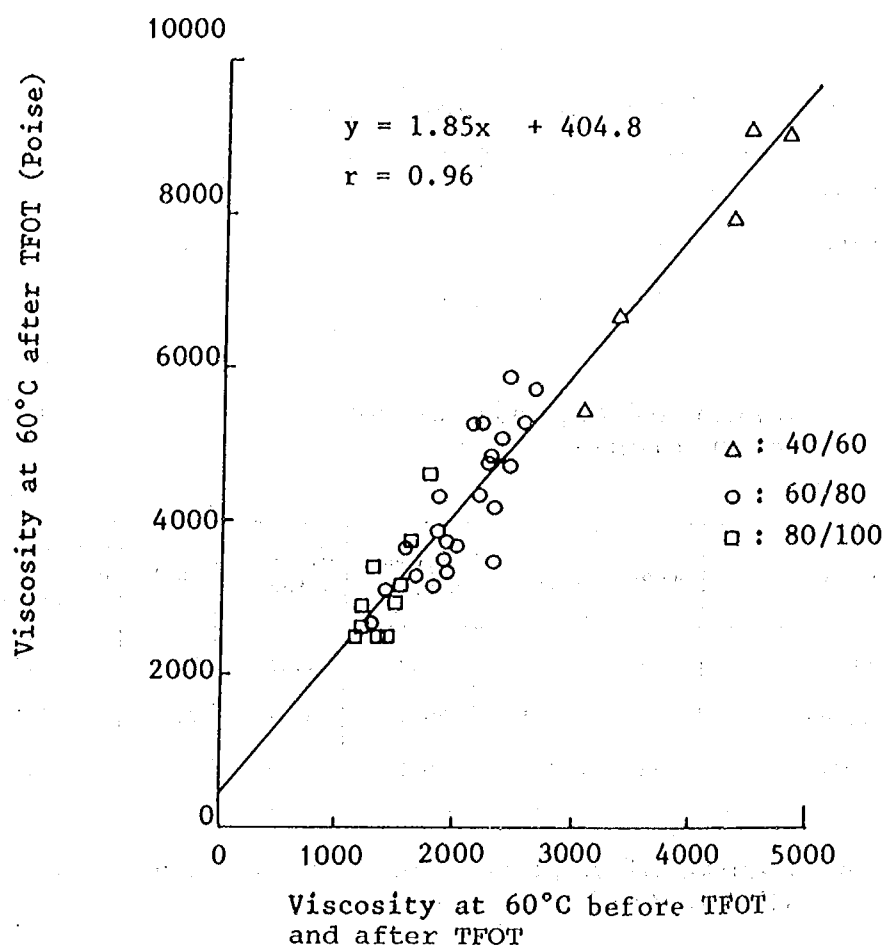


Fig. 4.41 Viscosity at 60°C before TFOT and after TFOT

4.15.7 Separation into Four Fractions

Results of the separation into four fractions after TFOT are shown in Tables 4.35 to 4.38 and Figs. 4.42 to 4.45. No obvious differences are recognized in any fraction between grades as same as the case of the separation test before TFOT.

Table 4.35 Result of Asphalt Separation Test after TFOT
(Asphalten)

(%)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	13.7	16.3	10.7	2.1	15.1
60/80	23	13.6	17.2	9.6	1.8	13.1
80/100	11	13.6	17.3	11.4	1.7	12.6

Table 4.36 Result of Asphalt Separation Test after TOFT
(Resin)

(%)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	23.4	25.2	22.0	1.2	5.3
60/80	23	24.6	28.1	21.2	1.9	7.7
80/100	11	24.1	26.3	22.5	1.3	4.7

Table 4.37 Result of Asphalt Separation Test after TFOT
(Aromatics)

(%)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	47.2	50.7	42.1	3.3	7.0
60/80	23	47.1	50.9	40.1	2.9	6.1
80/100	11	46.6	50.1	42.2	2.2	4.7

Table 4.38 Result of Asphalt Separation Test after TFOT
(Saturatus)

(%)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	13.4	18.2	11.5	2.8	20.7
60/80	23	13.3	16.4	9.2	1.8	13.8
80/100	11	15.1	16.4	13.1	1.0	6.7

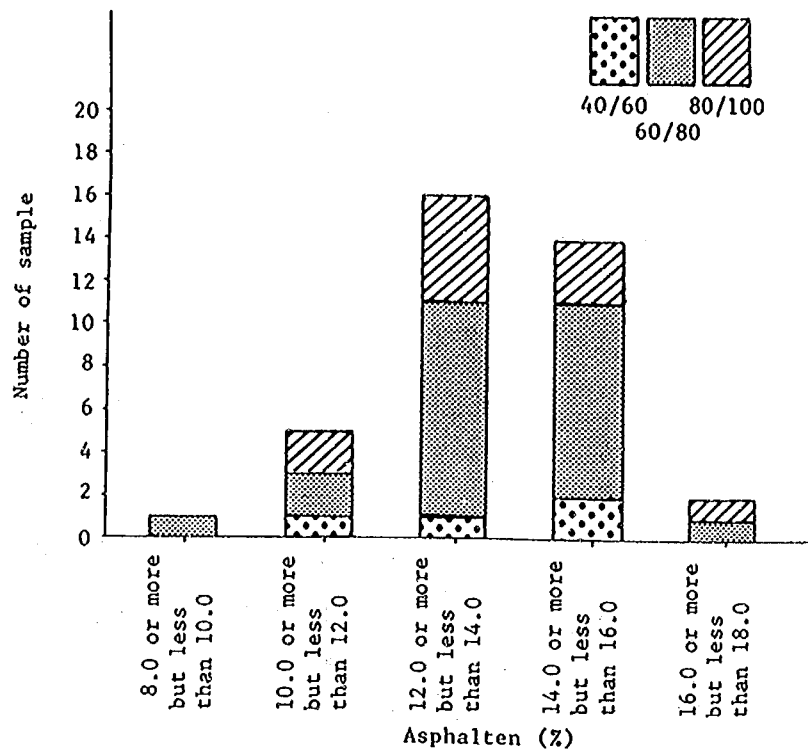


Fig. 4.42 Result of Asphalt Separation Test after TFOT (Asphalten)

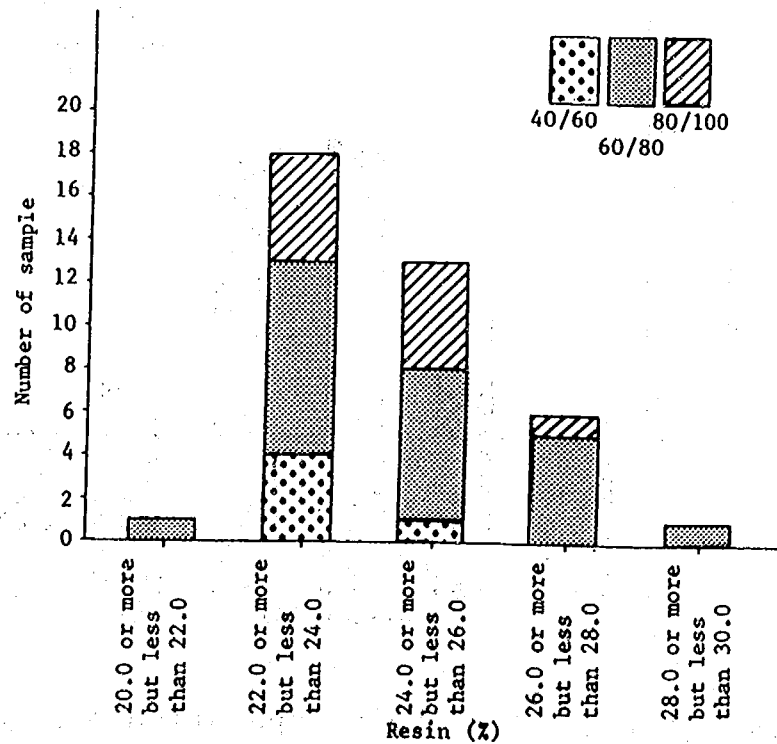


Fig. 4.43 Result of Asphalt Separation Test after TFOT (Resin)

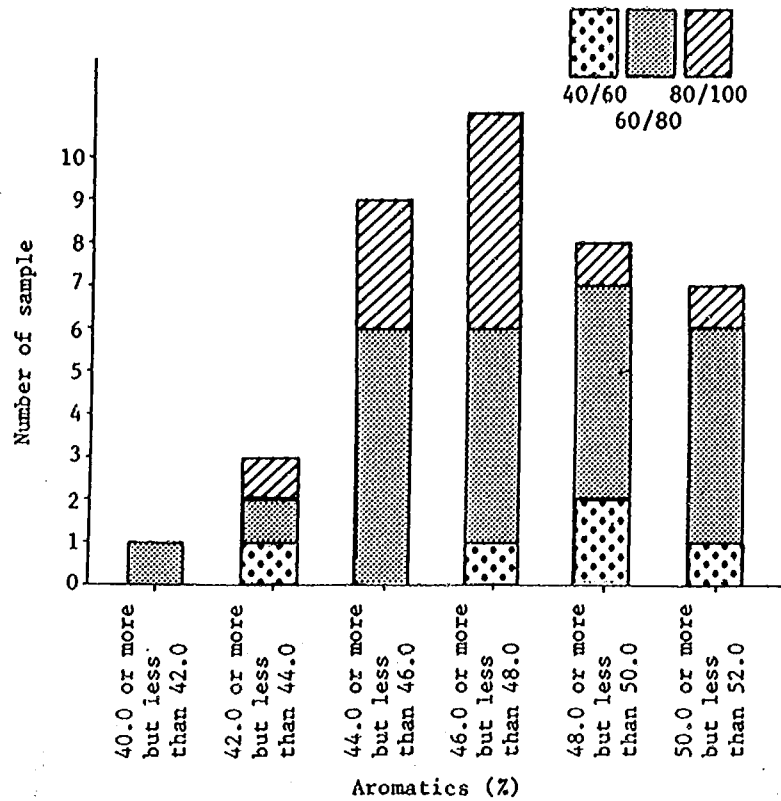


Fig. 4.44 Result of Asphalt Separation Test after TFOT (Aromatics)

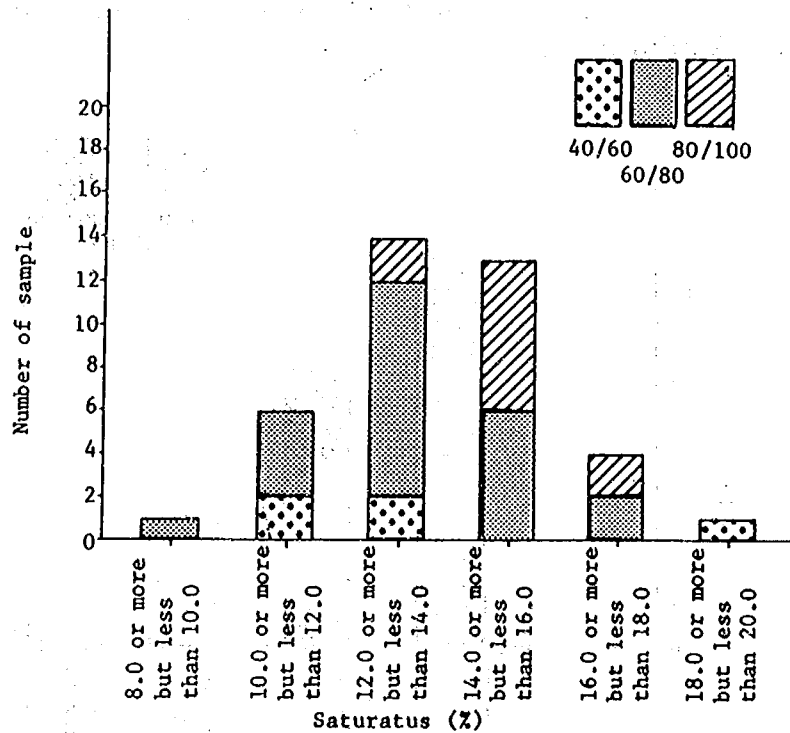


Fig. 4.45 Result of Asphalt Separation Test after TFOT (Saturatus)

Change in each fraction before and after TFOT is shown in Tables 4.39 to 4.42 and Figs. 4.46 to 4.49. The change in the amount of each fraction is as follows:

- o Asphalten: 0 to +4.2% (mean value; + 1.5%)
- o Resin : 0 to +4.4% (mean value; + 2.1%)
- o Aromatics: -4.9 to +1.3% (mean value; - 2.6%)
- o Saturatus: -4.0 to +0.2% (mean value; - 1.4%)

The asphalten and resin increase while aromatics and saturatus decrease, but the change in the amount of each fraction is not so significant. It is generally said that the changes in the fractions by oxidation occur in the direction of (aromatics→resin→asphalten), but the results show that the change of (aromatics→resin) is larger than other changes. Also, it is found that the amount of change in asphalten for 80/100 is larger than those for other grades. And the amounts of changes in resin and saturatus decrease as the grade becomes larger at the level of significance of 5%.

Multiple regression analysis are made for the relationship between the amount of change in each fraction by TFOT, penetration of residue in TFOT and the 60°C viscosity ratio. The multiple correlation coefficient is not so high with 0.51 and 0.38 respectively. In addition, the amount of each fraction after TFOT or the amount of change by TFOT has no obvious correlation to the other physical properties.

Table 4.39 Change of Asphalten Content in TFOT

(%)

Grades	Number	Mean value	Range	σ_{n-1}	Coefficient of variation
40/60	5	+1.24	+2.2 ~ +0.5	0.7	59.4
60/80	23	+1.21	+4.2 ~ 0	1.0	82.5
80/100	11	+2.38	+3.7 ~ +1.3	0.7	28.0

Table 4.40 Change of Resin Content in TFOT

(%)

Grades	Number	Mean value	Range	σ_{n-1}	Coefficient of variation
40/60	5	+3.60	+4.4 ~ +2.0	1.0	26.4
60/80	23	+1.96	+4.1 ~ 0	1.3	67.0
80/100	11	+1.62	+3.4 ~ +0.2	1.0	63.9

Table 4.41 Change of Aromatics Content in TFOT

(%)

Grades	Number	Mean value	Range	σ_{n-1}	Coefficient of variation
40/60	5	-3.56	-1.5 ~ -4.9	1.3	35.5
60/80	23	-2.06	+1.3 ~ -4.3	1.3	62.4
80/100	11	-3.36	-1.2 ~ -4.8	1.2	35.0

Table 4.42 Change of Saturatus Content in TFOT

(%)

Grades	Number	Mean value	Range	σ_{n-1}	Coefficient of variation
40/60	5	-2.30	-0.4 ~ -3.3	1.3	57.8
60/80	23	-1.66	-0.4 ~ -4.0	1.1	64.2
80/100	11	-0.54	+0.2 ~ -1.4	0.5	97.7

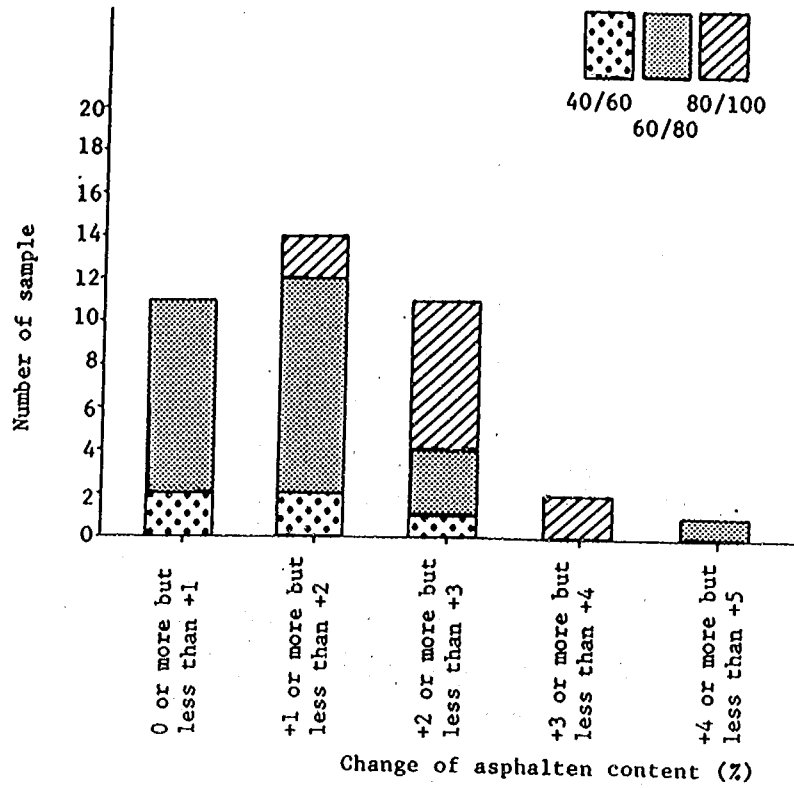


Fig. 4.46 Change of Asphalten Content in TFOT

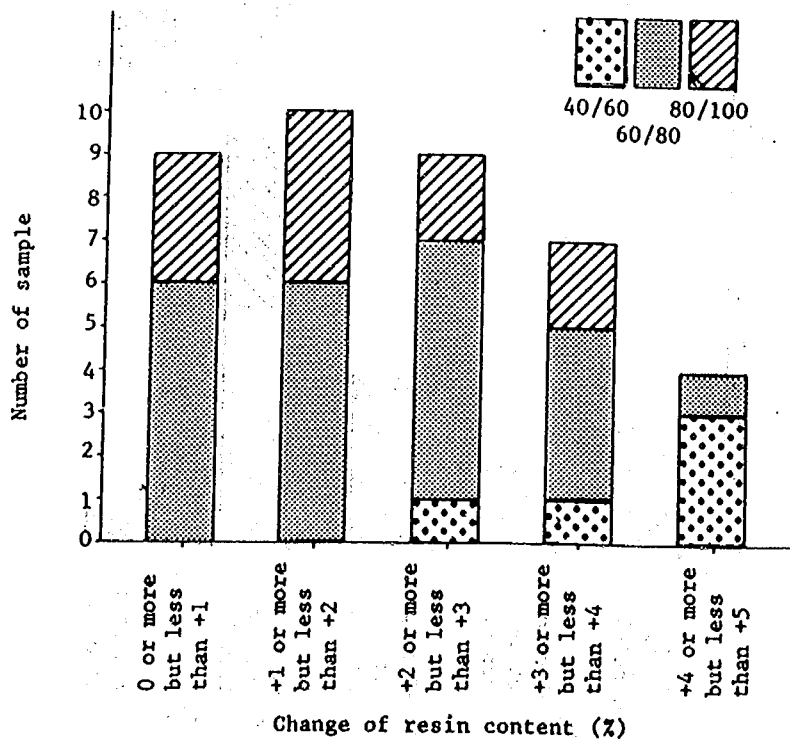


Fig. 4.47 Change of Resin Content in TFOT

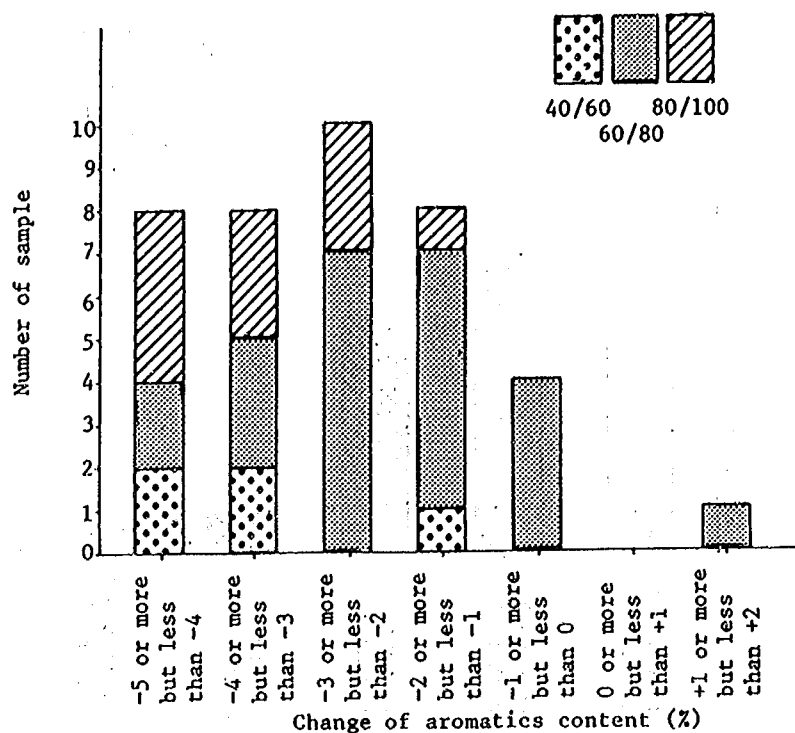


Fig. 4.48 Change of Aromatics Content in TFOT

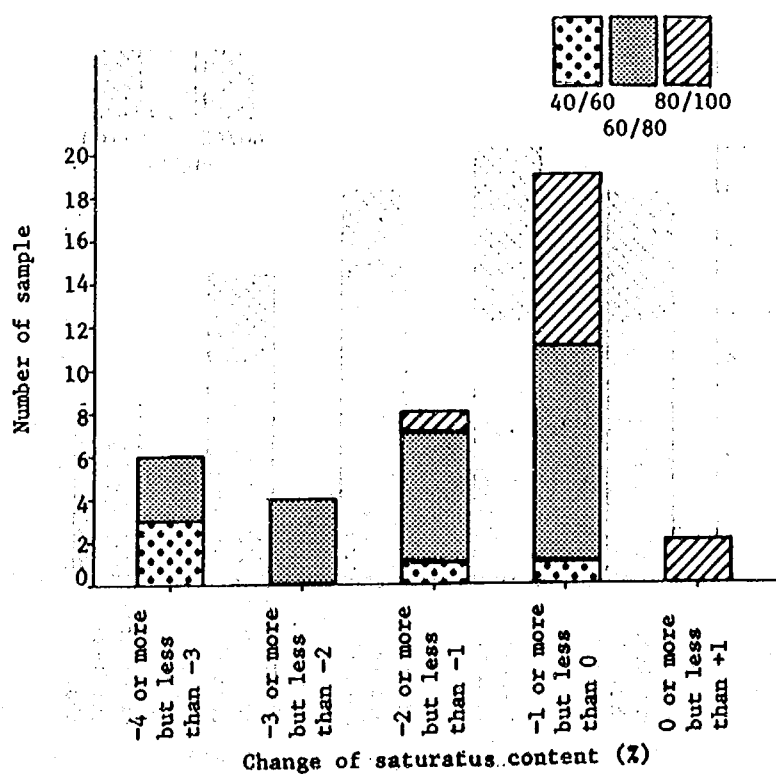


Fig. 4.49 Change of Saturatus Content in TFOT

4.16 Rolling Thin-Film Oven Test (RTFOT)

4.16.1 Outline of Test Method

The test method of the rolling thin-film oven test is prescribed in ASTM D 2278. Outline of the test method is as follows;

- 1) An asphalt sample of 35 g is taken in a cylindrical glass container 140 mm high and 64 mm in diameter.
- 2) The container is placed in a vertical plate which can rotate at the speed of 15 rpm in a thermostatic oven at 163°C.
- 3) Fresh air with 163°C is jetted from nozzles into the container at a rate of 4 liters/min. in each turn.
- 4) Test is continued for 75 minutes under these conditions.

This method is different from the TFOT in that asphalt flows in the state of a thin film (5 to 10 μ) along the inner wall surface of the glass container, and the new surface of sample is always in contact with air. Since RTFOT is conducted on asphalt formed to very thin films, the testing time can be reduced to 75 minutes when compared to 5 hours for TFOT.

4.16.2 Mass Change

Results of the mass change in RTFOT are shown in Table 4.43 and Fig. 4.50. The mass decreased in 1 specimen of 40/60, 5 specimens of 60/80 and 4 specimens of 80/100. However, asphalt from the same refinery tends to have the same mass change value regardless of grade, and this is considered to be caused by the difference in refining method or crude oil. The same tendency is also recognized in the thin-film oven test.

Table 4.43 Mass Change in RTFOT

(%)

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	0.04	0.12	-0.10	0.089	201
60/80	23	0.05	0.17	-0.24	0.093	196
80/100	11	0.01	0.11	-0.14	0.090	661

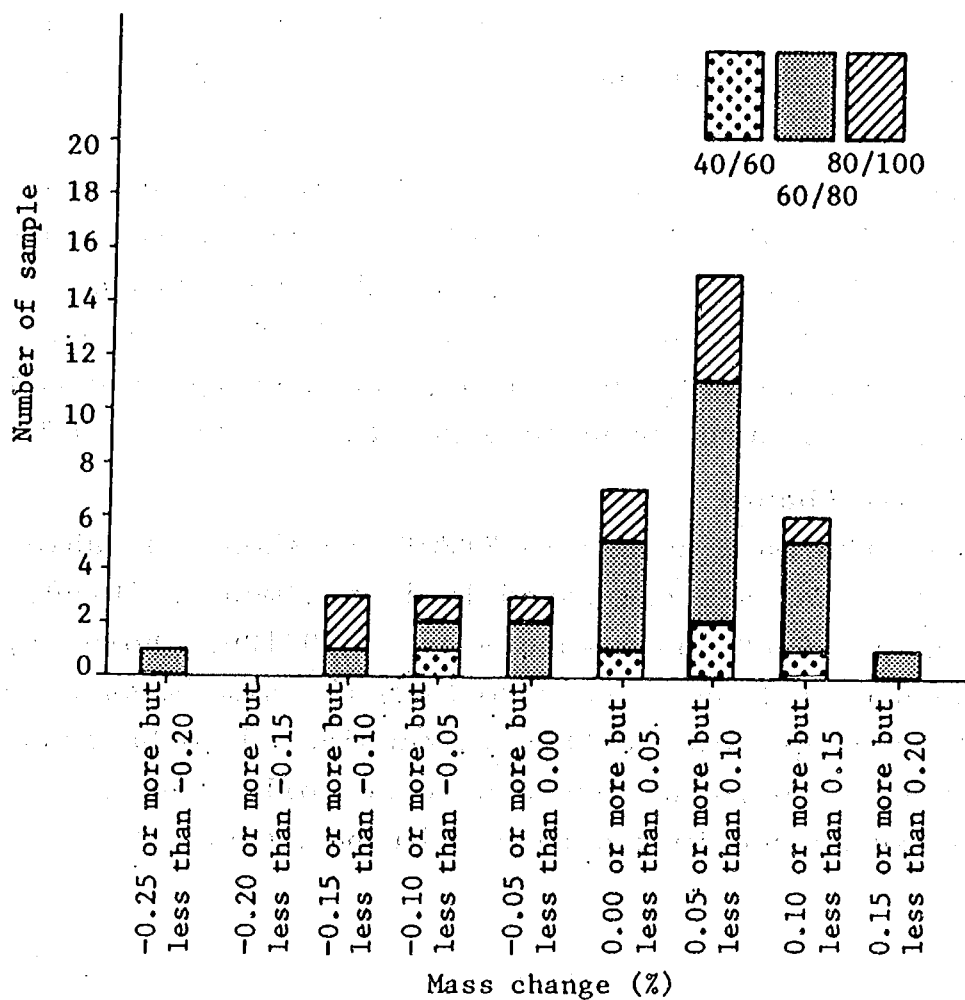


Fig. 4.50 Mass Change in RTFOT

4.16.3 Penetration

Penetration after RTFOT are shown in Table 4.44 and Fig. 4.51, and penetrations of residue in RTFOT are shown in Table 4.45 and Fig. 4.52.

The range of the penetration of residue between the maximum and minimum values for 60/80 is 15.5% and this is considerably large when compared to other grades. This has occurred because several specimens have unusual values and, if they are excluded, the results are within the range of 62 to 68%. These unusual values have no correlation with other test values, and the cause of these unusual values is not clear.

Table 4.44 Penetration after RTFOT

(1/100cm)						
Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	34.0	36	33	1.4	4.2
60/80	23	44.8	52	39	2.8	6.4
80/100	11	55.9	60	50	3.0	5.3

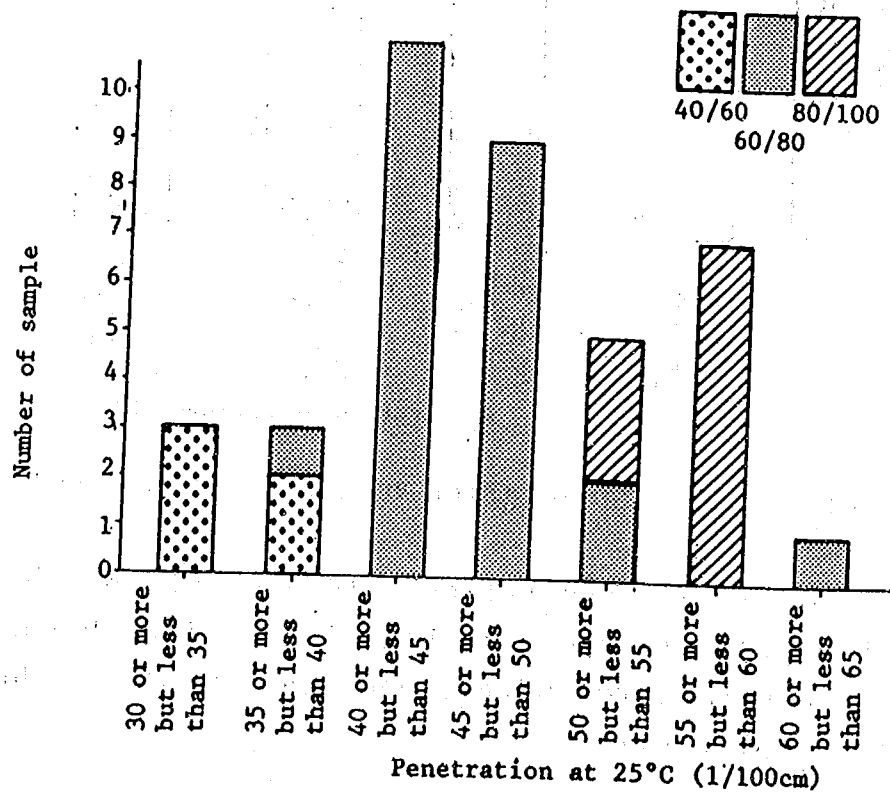


Fig. 4.51 Penetration after RTFOT

Table 4.45 Penetration of Residue in TFOT

(%)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	68.3	70.2	64.7	2.4	3.4
60/80	23	65.8	74.6	59.1	3.4	5.2
80/100	11	62.9	66.1	60.0	2.2	3.6

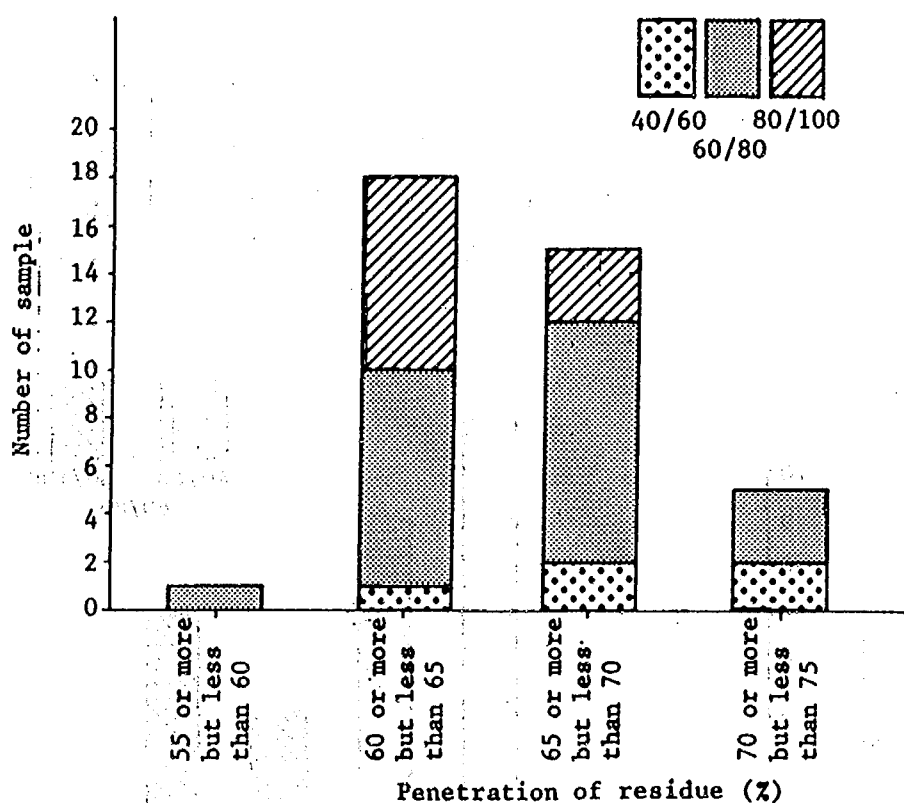


Fig. 4.52 Penetration of Residue in RTFOT

Relation between the penetration before RTFOT and the penetration of residue is shown in Fig. 4.53. Though there is some dispersion in values for 60/80, penetration of residue decrease as asphalt becomes softer.

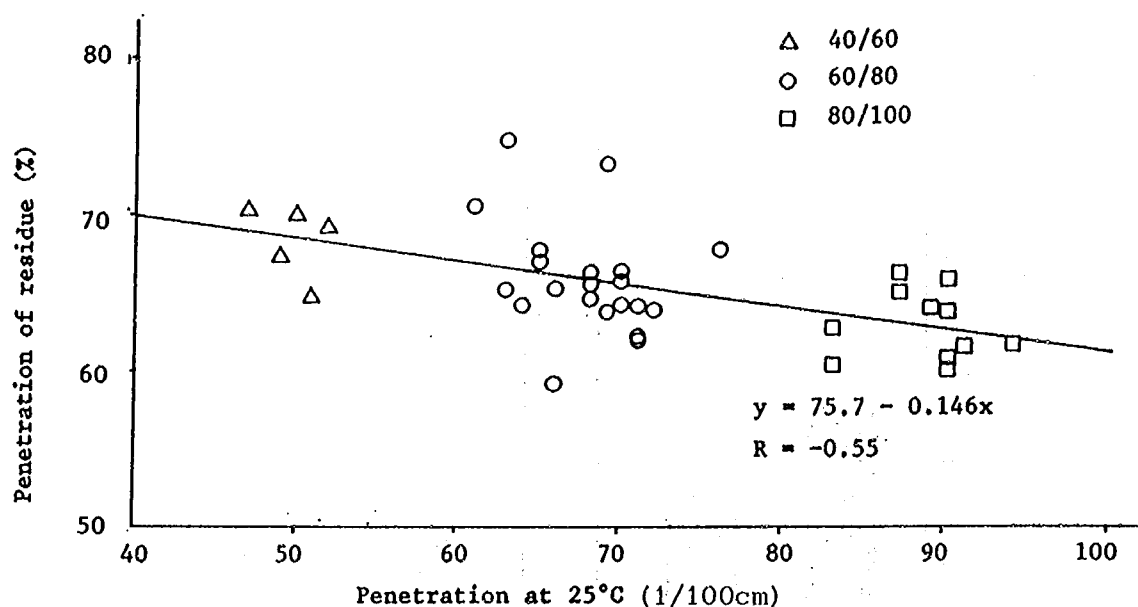


Fig. 4.53 Penetration before RTFOT Versus Penetration of Residue in RTFOT before RTFOT

4.16.4 Softening Point

The results of the softening point test after RTFOT are shown in Table 4.46 and Fig. 4.54. Also, the softening point change rate in RTFOT are shown in Table 4.47.

Mean value of the change rate is almost the same for all grades, and there is no difference at the level of significance of 5%.

Table 4.46 Softening Point after RTFOT

(°C)

Grades	Number	Mean value	Maximum value	Minimum value	σ _{n-1}	Coefficient of variation
40/60	5	56.3	58.0	54.0	1.5	2.6
60/80	23	52.6	55.0	49.5	1.2	2.3
80/100	11	49.9	52.5	49.0	1.1	2.2

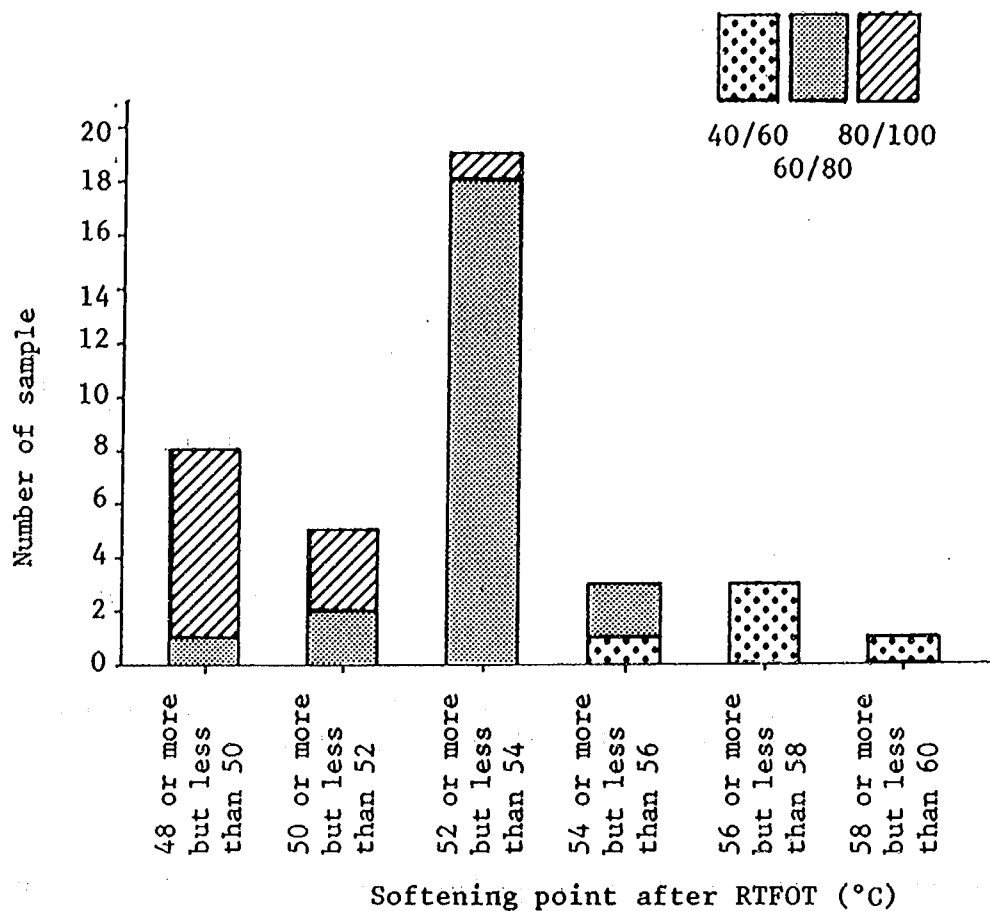


Fig. 4.54 Softening Point after RTFOT

Table 4.47 Softening Point Change Rate in TFOT

(%)

Grades	Number	Mean value	Maximum value	Minimum value	On-1	Coefficient of variation
40/60	5	110.2	110.9	109.1	0.8	0.7
60/80	23	109.9	113.4	107.2	1.7	1.6
80/100	11	108.8	111.7	106.5	1.7	1.6

4.16.5 Penetration Index (PI)

Penetration index (PI) after RTFOT are shown in Table 4.48 and Fig. 4.55. Also, Fig. 4.56 shows the relationship between penetration, the softening point and PI after RTFOT. The PI decreases as the grade becomes larger.

Table 4.48 Penetration Index (PI) after RTFOT

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	-0.61	-0.32	-0.97	0.26	42.9
60/80	23	-0.84	-0.22	-1.35	0.25	30.2
80/100	11	-0.98	-0.50	-1.20	0.33	37.5

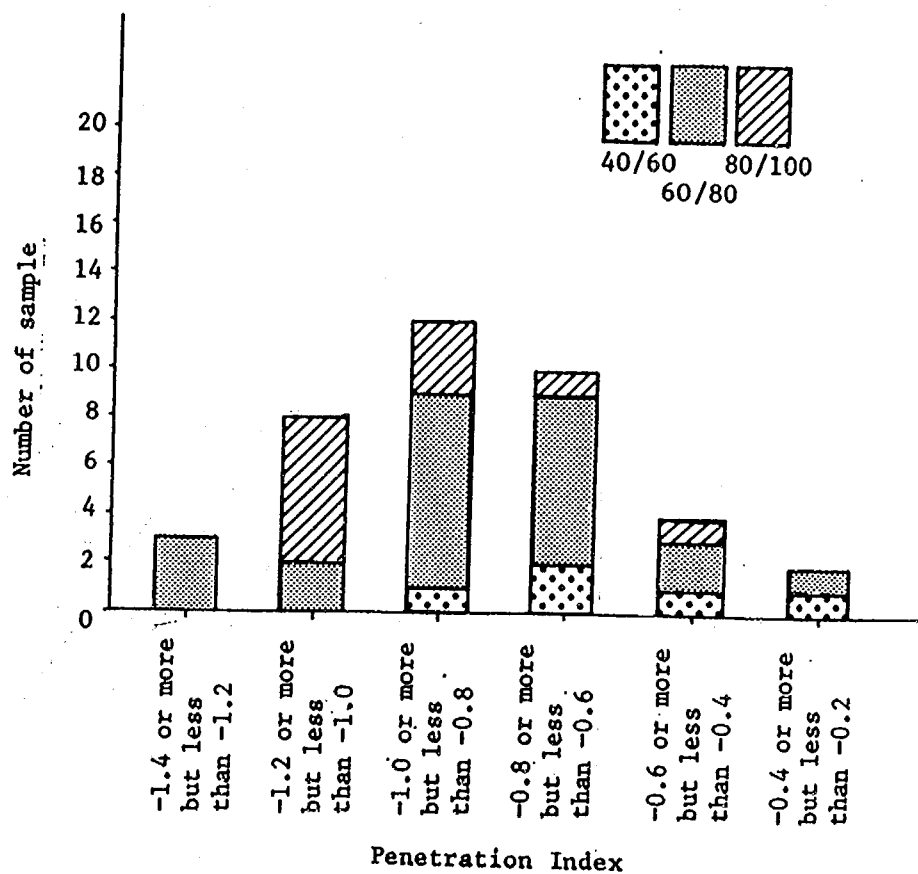


Fig. 4.55 Penetration Index after RTFOT

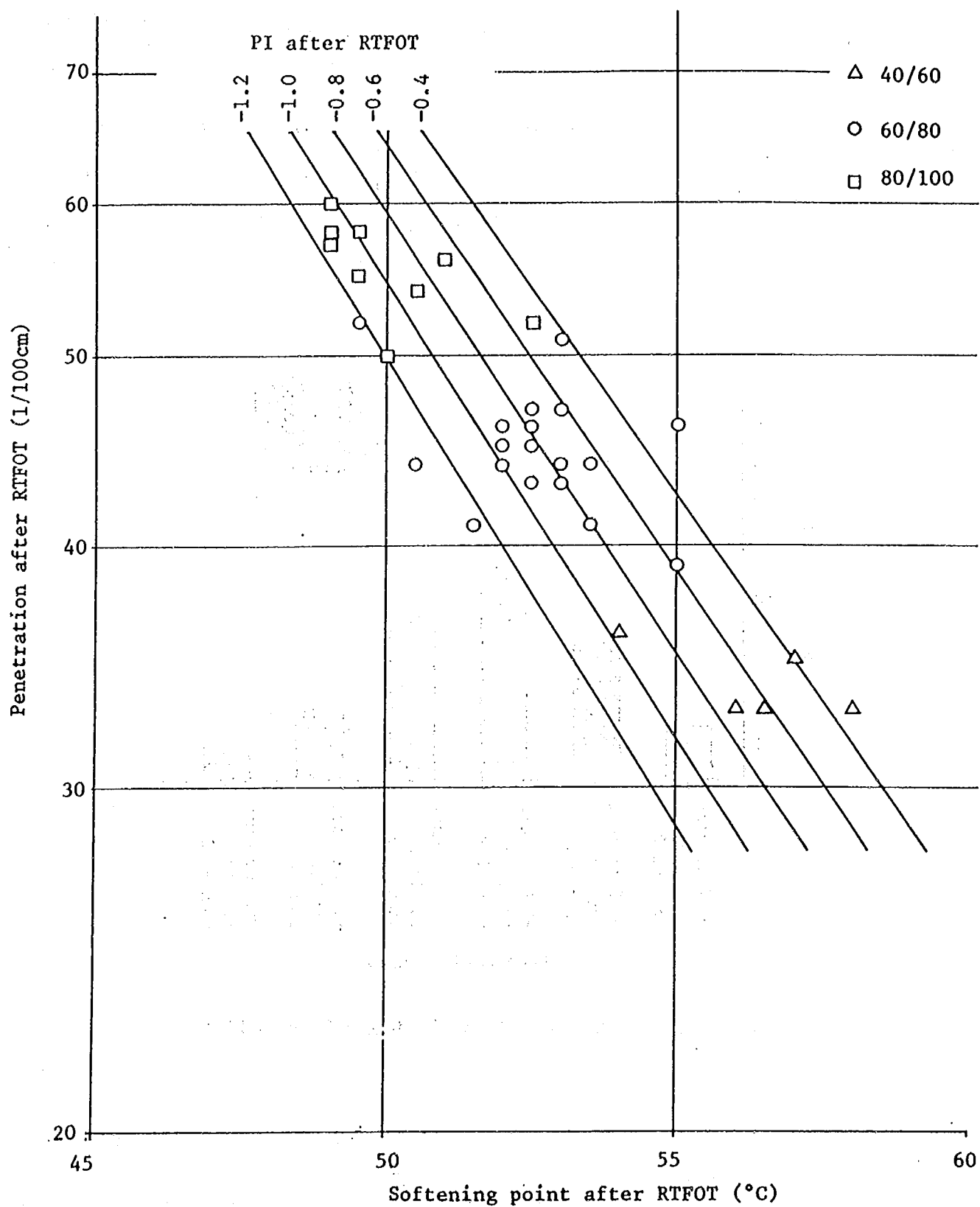


Fig. 4.56 Penetration, Softening Point and PI after RTFOT

Table 4.49 shows the mean values of PI of each asphalt grade before and after RTFOT. Mean value of PI changing rate for the grade 80/100 has a difference from other grades at the level of significance of 5%, and the PI of 80/100 becomes lower compared to other grades. This probably occurs because the softening point rise is small when compared to the penetration drop. This tendency is as same as in the case of TFOT.

Table 4.49 Comparison of Mean Values of PI before and after RTFOT

Grades	Before RTFOT	After RTFOT	Difference
40/60	-0.94	-0.61	0.33
60/80	-1.03	-0.84	0.19
80/100	-0.90	-0.98	-0.08

4.16.6 Ductility (15°C)

Results of the ductility test after RTFOT are shown in Table 4.50 and Fig. 4.57.

All specimens have values in the range from 0 to 60 cm and the mean is 15.0 cm for grade 40/60, 75% of specimens have values in the range from 20 to 100 cm and the mean is 58.8 cm for grade 60/80, and 80% of specimens have values in the range from 60 to 140+ cm and the mean is 96.5 cm for grade 80/100. As same as the case of TFOT, the mean of ductility after RTFOT tends to increase as the grade becomes larger. However, Fig. 4.57, shows that the ductility after RTFOT is distributed in a wide range, and the difference of ductility between specimens can be recognized even in the same grade.

Table 4.50 Ductility at 15°C after RTFOT

(cm)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	15.0	27	7	9.7	64.5
60/80	23	58.8	140+	11	38.8	66.0
80/100	11	96.5	140+	27	38.2	39.6

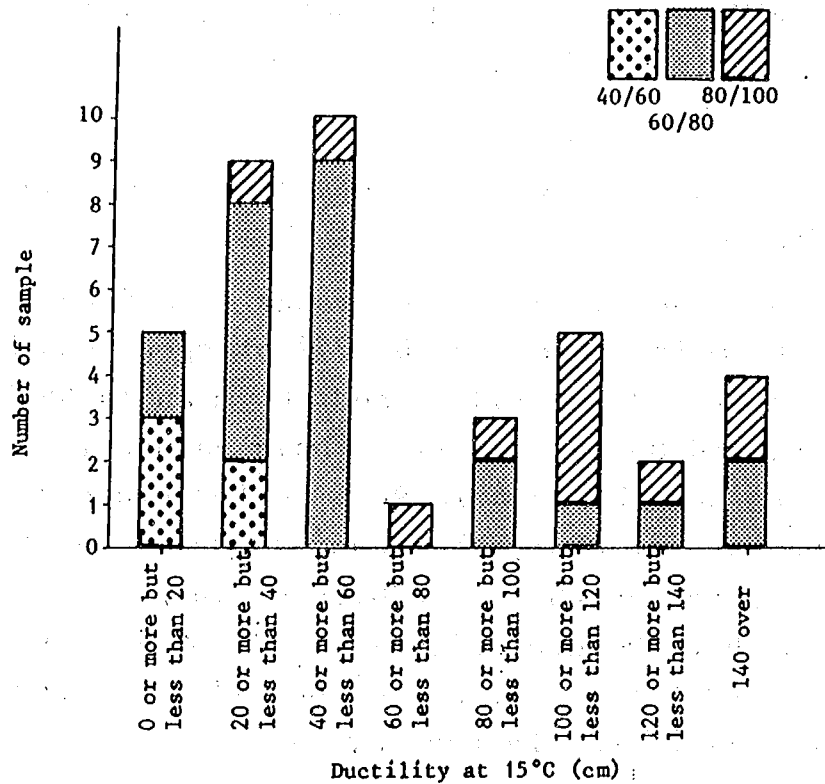


Fig. 4.57 Ductility at 15°C after RTFOT

The means of the coefficient of variation in one duatility test before RTFOT after RTFOT are shown in Table 4.51. As for the case of TFOT, the dispersions after RTFOT tend to decrease than before RTFOT.

Table 4.51 Coefficients of Variation of Ductility at 10°C of Original Asphalt and Ductility at 15°C after RTFOT (%)

Grades	Coefficient of variation of original asphalt (10°C)	Coefficient of Variation after TFOT (15°C)
40/60	49.3	9.0
60/80	20.2	14.8
80/100	21.7	11.5

4.16.7 Viscosity at 60°C

Results of viscosity at 60°C after RTFOT are shown in Table 4.52 and Fig. 4.58. Mean values of the results for the grades 40/60, 60/80 and 80/100 are 10120, 4585 and 3080 poise respectively. AASHTO's standard also prescribes the standards for viscosity after RTFOT, and the results classified in accordance with the AASHTO's standards are shown in Fig. 4.59. The number of specimens corresponding to each AR grade is 46% for AR-40 in 80/100 grade, 10% for AR-80 in 60/80 grade and 3% for AR-160 in 40/60 grade. The correspondence is not so good as the case where the viscosity at 60°C of original asphalt are applied to AC grade.

Table 4.52 Viscosity at 60°C after RTFOT

(Poise)

Grades	Number	Mean value	Maximum value	Minimum value	on-1	Coefficient of variation
40/60	5	10120	12200	6920	2440	24.1
60/80	23	4585	6350	2570	951	20.8
80/100	11	3076	4320	2510	556	18.1

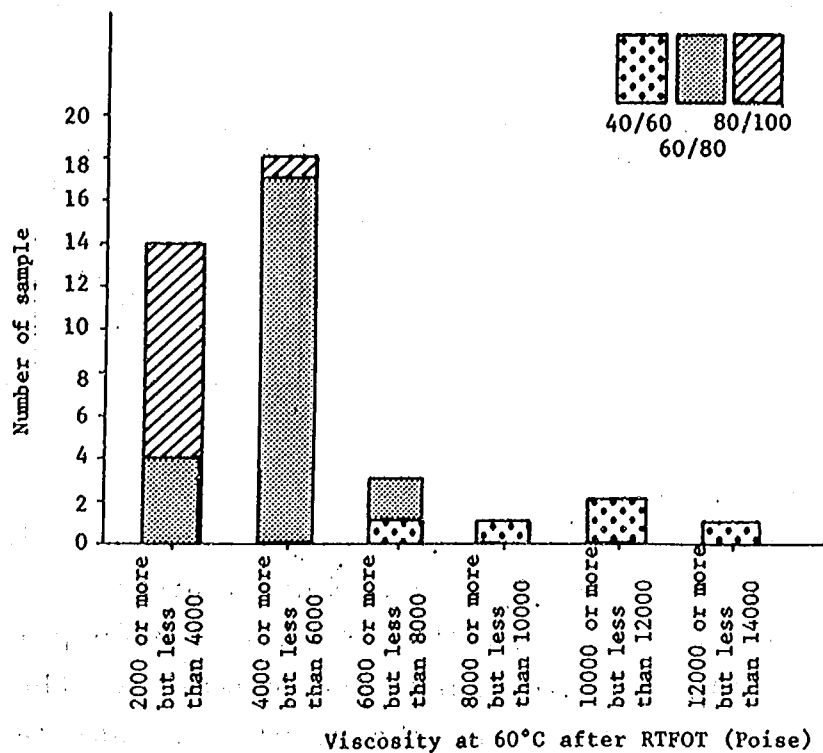


Fig. 4.58 Viscosity at 60°C after RTFOT

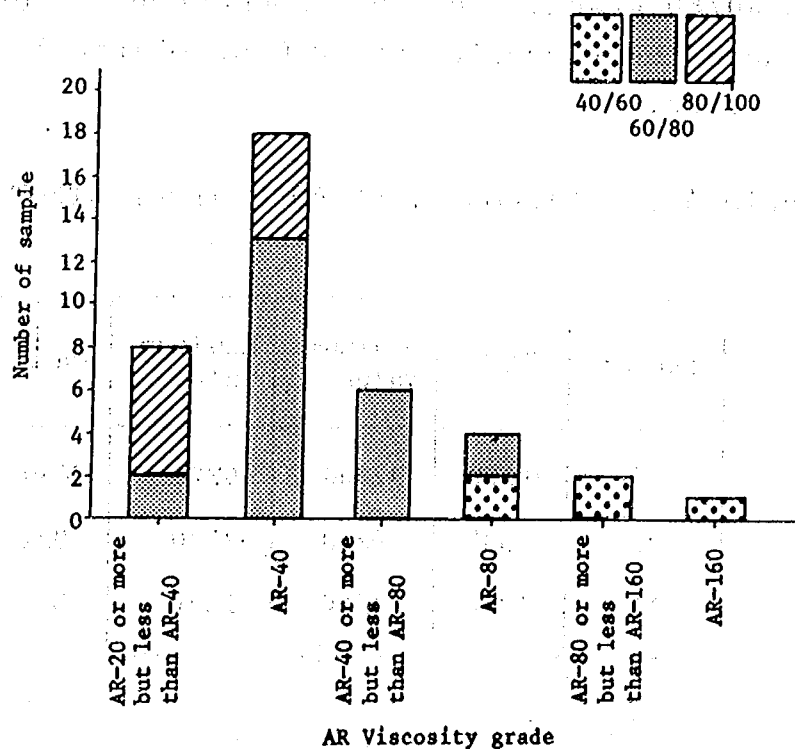


Fig. 4.59 Classified Viscosity at 60°C after RTFOT According to AASHTO Viscosity specification

Results of viscosity ratio by RTFOT are shown in Table 4.53. Also, Fig. 4.60 shows the relationship between viscosity at 60°C of original asphalt and the viscosity after RTFOT, and the correlation coefficient is 0.97. It can be seen that the viscosity after RTFOT increases by 2.3 times on average compared to the original asphalt.

Table 4.53 Viscosity Ratio at 60°C RTFOT

Grades	Number	Mean value	Maximum value	Minimum value	σ_{n-1}	Coefficient of variation
40/60	5	2.52	2.75	2.28	0.21	8.3
60/80	23	2.23	2.87	1.66	0.31	13.9
80/100	11	2.19	2.58	1.85	0.21	9.6

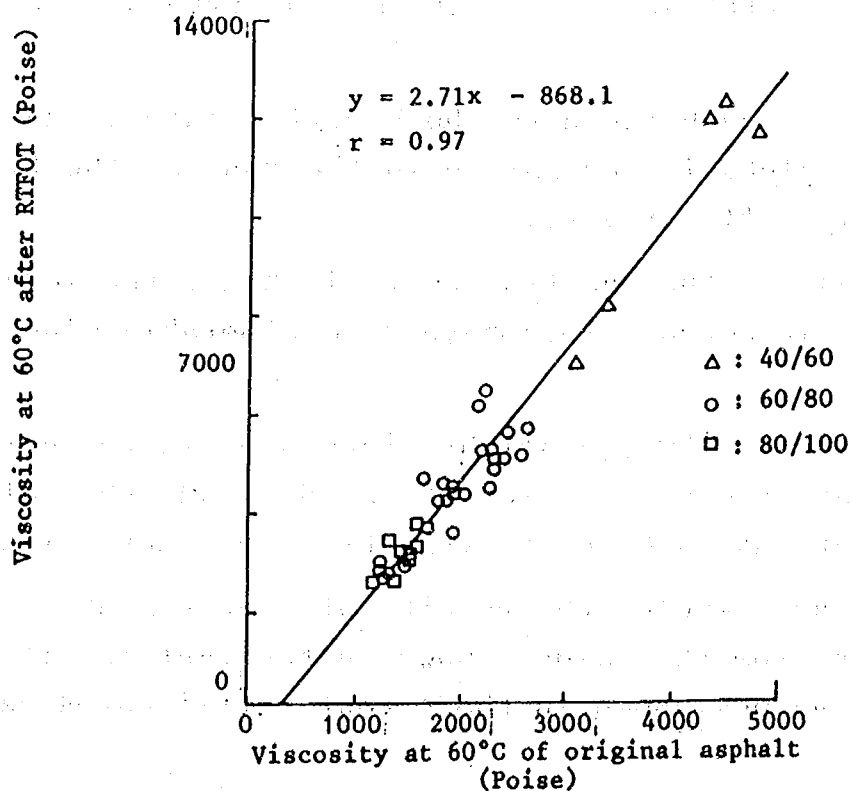


Fig. 4.60 Viscosity at 60°C of Original Asphalt Versus Viscosity at 60°C after RTFOT

5. Relation between Test Results and Test Certificates

Results of a comparison between the values shown in the test certificates and the measured values are shown in Figs. 5.1 to 5.10. Where the multilaboratory precision is prescribed, its range is also shown by dotted lines.

In the case of penetration, the three specimens do not satisfy the tolerance, and the relationship between values of test certificate and the test results is close to the straight line of $y = x$.

In the case of the softening point, all specimens satisfy tolerance but many points are located below $y = x$. In short, the measured values are slightly lower than the values of the test certificate.

Also, the correlation of penetration index (PI) of Fig. 5.3 is low.

In the case of high-temperature viscosity or solubility in trichloroethane, some specimens do not satisfy the tolerance but both certificate values and measured values are almost the same.

Some difference between the both certificate values and measured values is recognized in the case of the flash point and the specific gravity.

In the case of the penetration ratio after the loss-on heating test, the measured values have a considerably wide distribution.

In the case of TFOT, a slight dispersion is recognized in both mass change and penetration of residue, but the values of test certificate has a wider distribution in penetration of residue.

However, as a whole, the results of measurement are not greatly different from the values shown in the test certificates, and thus the values shown in these test certificates can be trusted.

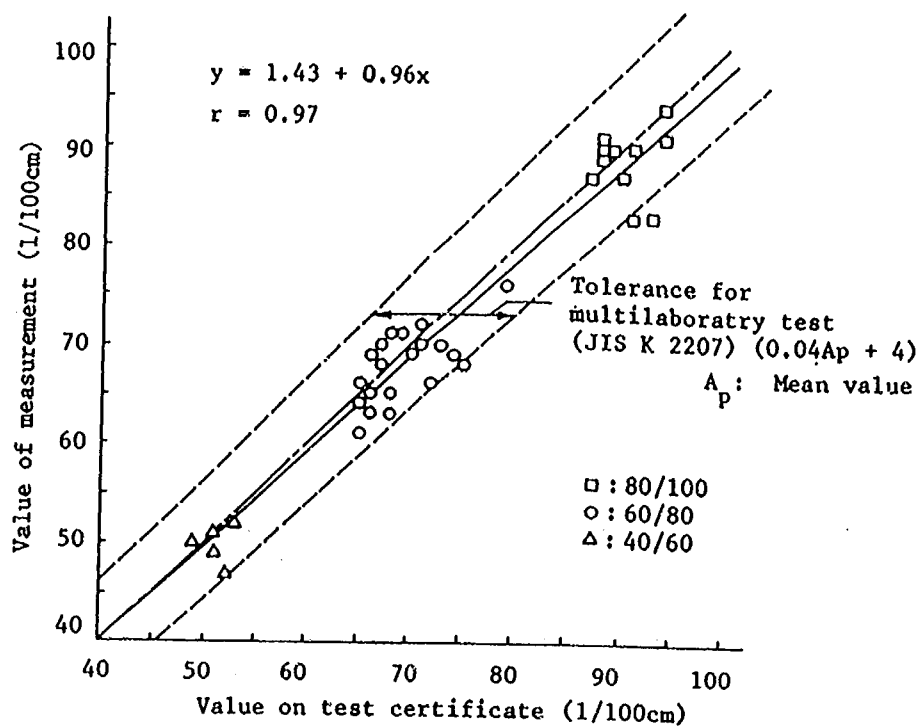


Fig. 5.1 Values on Test Certificate Versus Values of Measurement (Penetration)

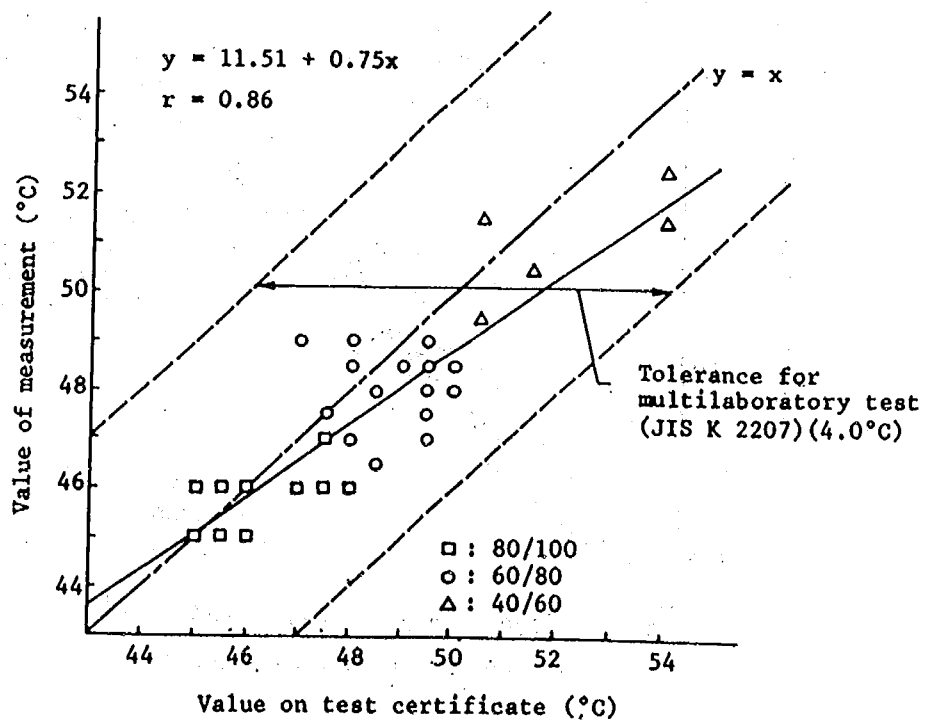


Fig. 5.2 Values on Test Certificate Versus Values of Measurement (Softening Point)

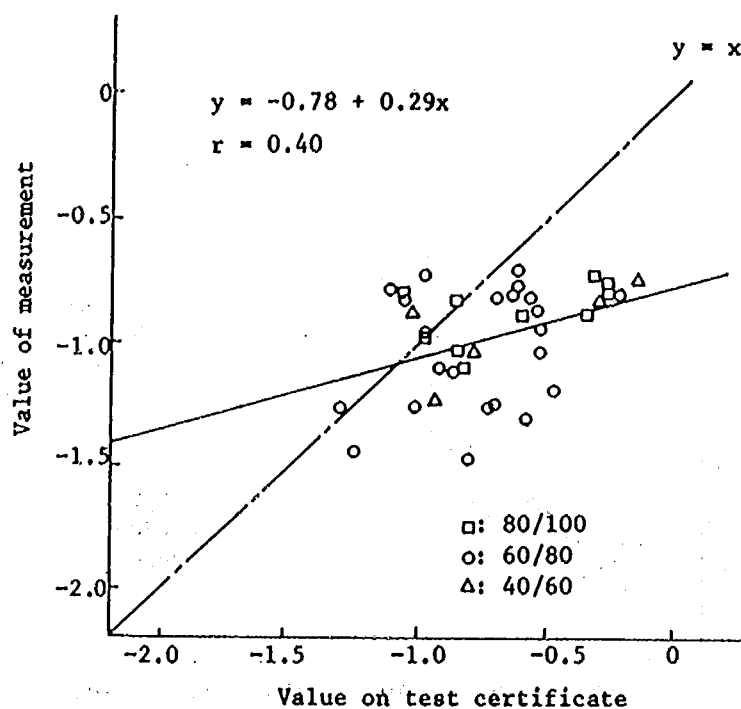


Fig. 5.3 Values on Test Certificate Versus Values of Measurement (Penetration Index)

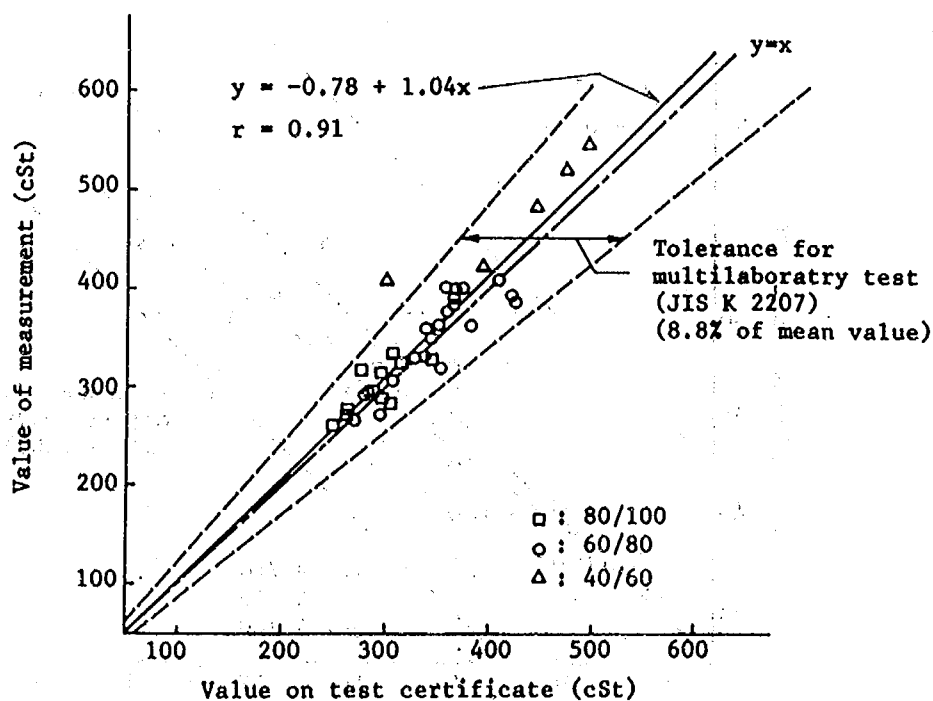


Fig. 5.4 Values on Test Certificate Versus Values of Measurement (High Temperature Kinematic Viscosity; 140°C)

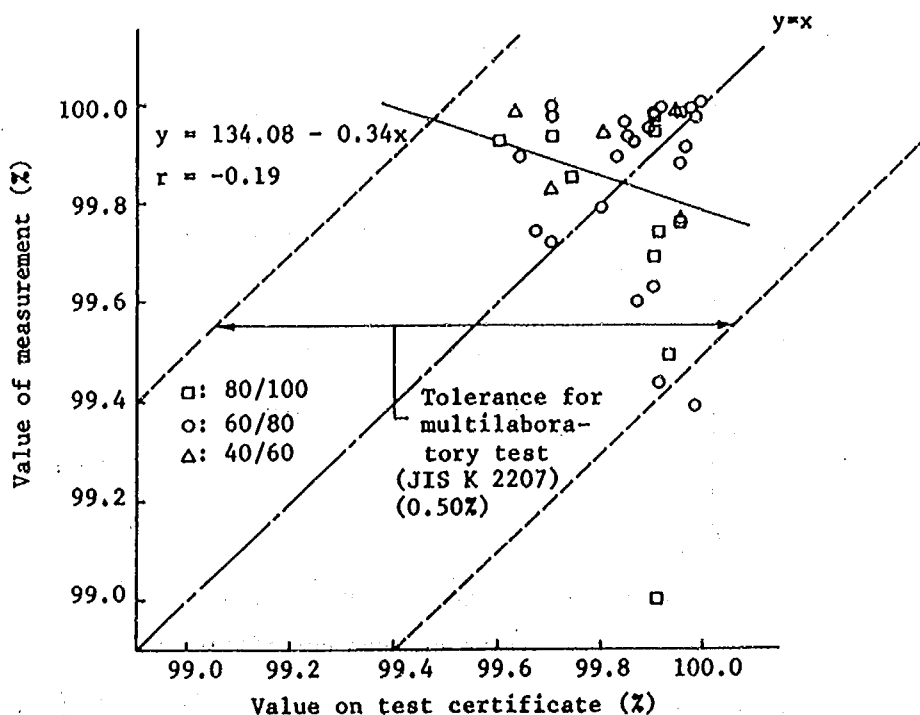


Fig.5.5 Values on Test Certificate Versus Values of Measurement (Solubility in Trichloroethane)

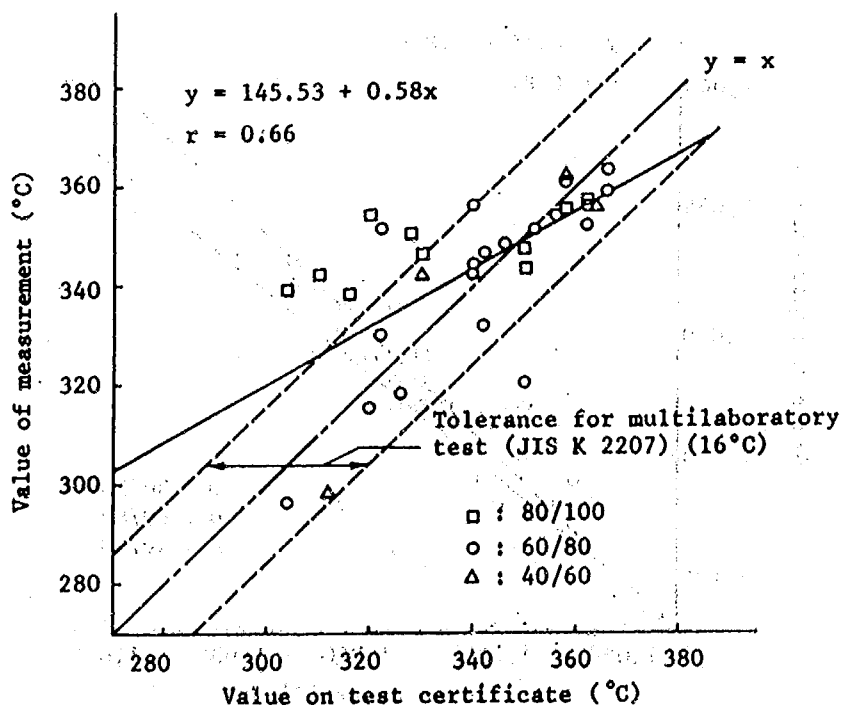


Fig. 5.6 Values on Test Certificate Versus Values of Measurement (Flash Point)

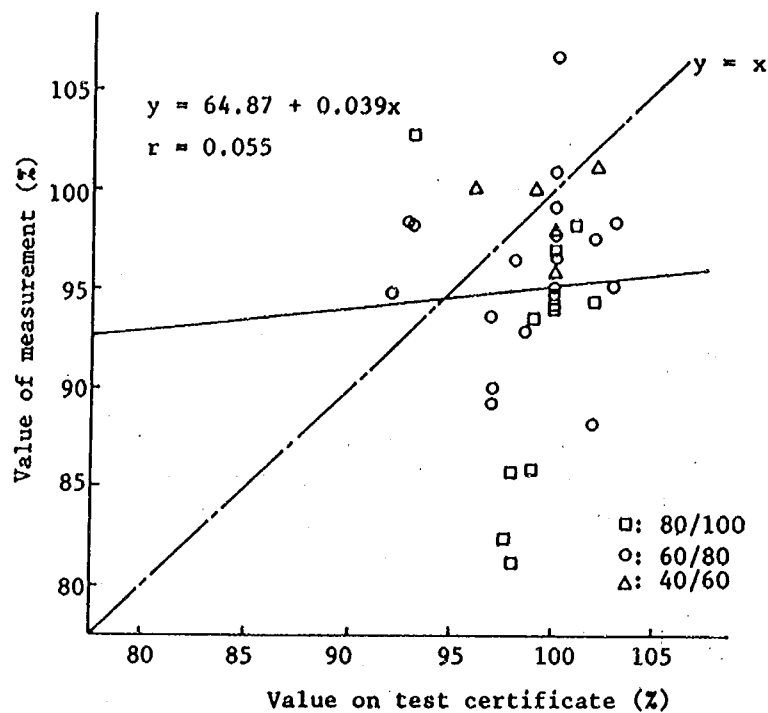


Fig. 5.7 Values on Test Certificate Versus Values of Measurement (Penetration Ratio after Loss-on-heating Test)

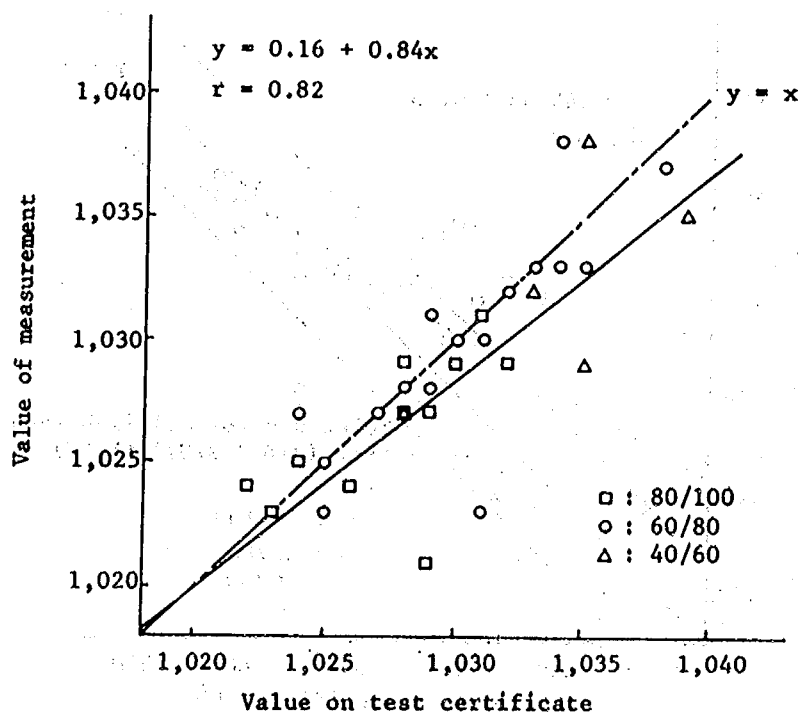


Fig. 5.8 Values on Test Certificate Versus Values of Measurement (Specific Gravity)

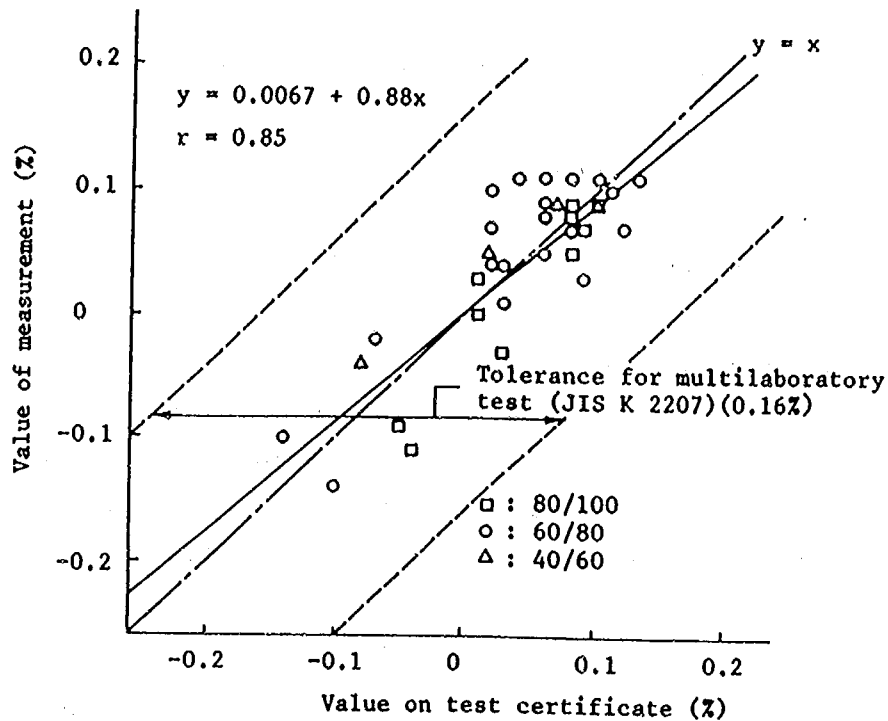


Fig. 5.9 Values on Test Certificate Versus Values of Measurement (Mass Change in TFOT)

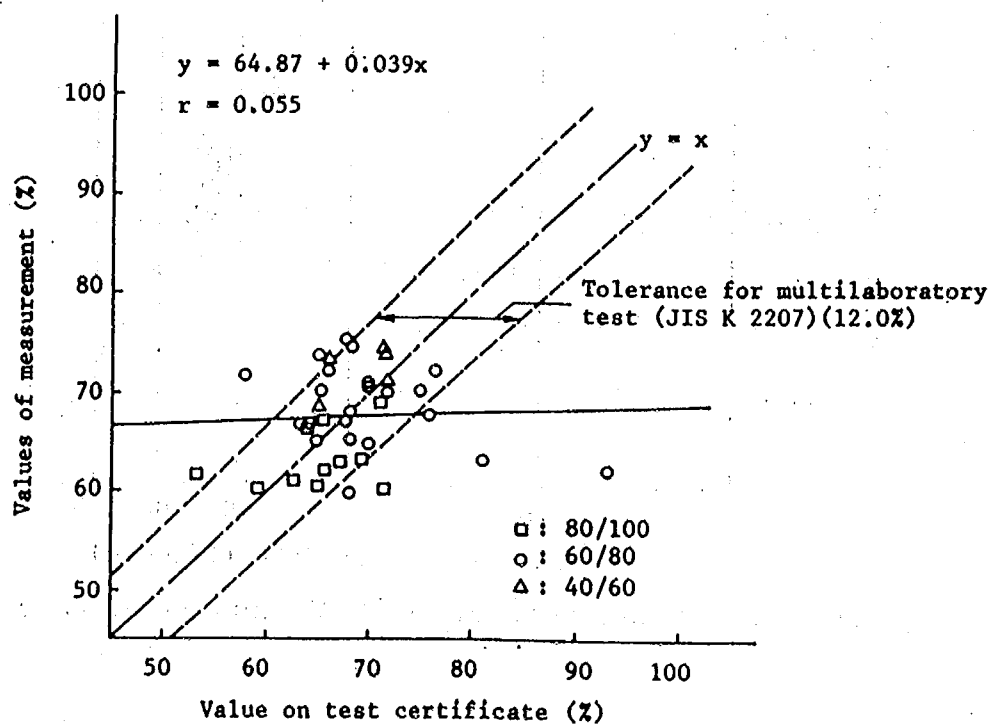


Fig. 5.10 Values on Test Certificate Versus Values of measurement (Penetration of Residue in TFOT)

6. Relationships between Properties

6.1 Viscosity at 60°C, Penetration and Softening Point

Values of the viscosity at 60°C and penetration are plotted in logarithm in Fig. 6.1. The correlation coefficient is 0.89 and both values have a good correlation. It is normally said that the relationship between them has different straight lines depending on the kind of the crude oil or other things. Fig. 6.2 shows the values of viscosity at 60°C for specimens having high, low and intermediate values plotted for each refinery, in which values from each refinery tend to make an individual straight line. Values of viscosity and penetration are classified by the value of PI and plotted in Fig. 6.3, but no obvious difference is recognized between them.

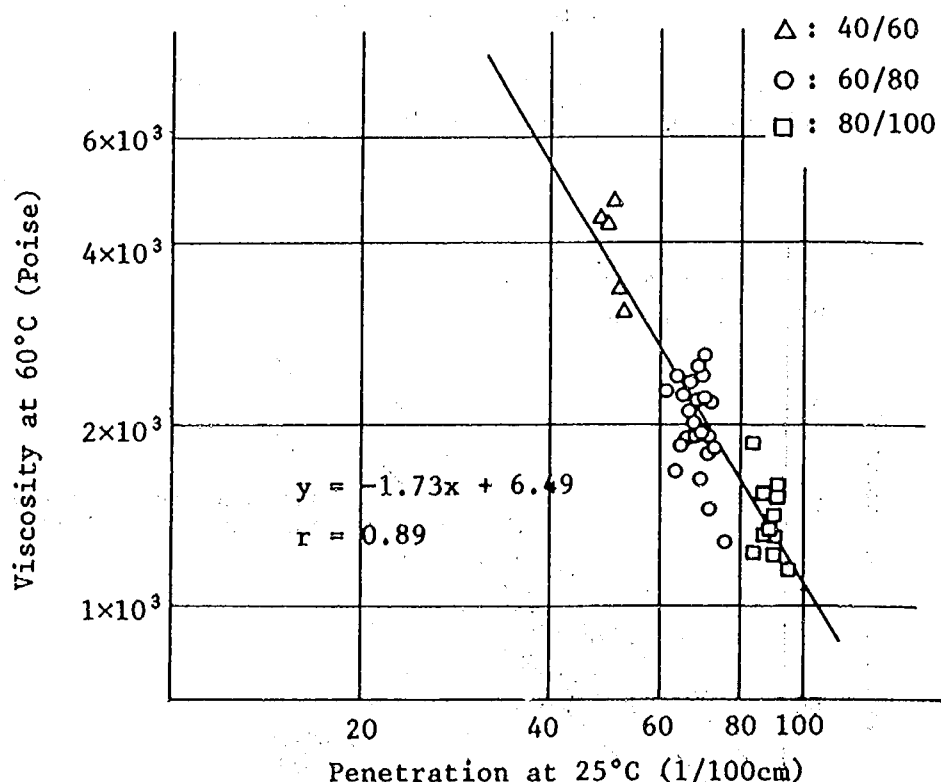


Fig. 6.1 Viscosity at 60°C Versus Penetration

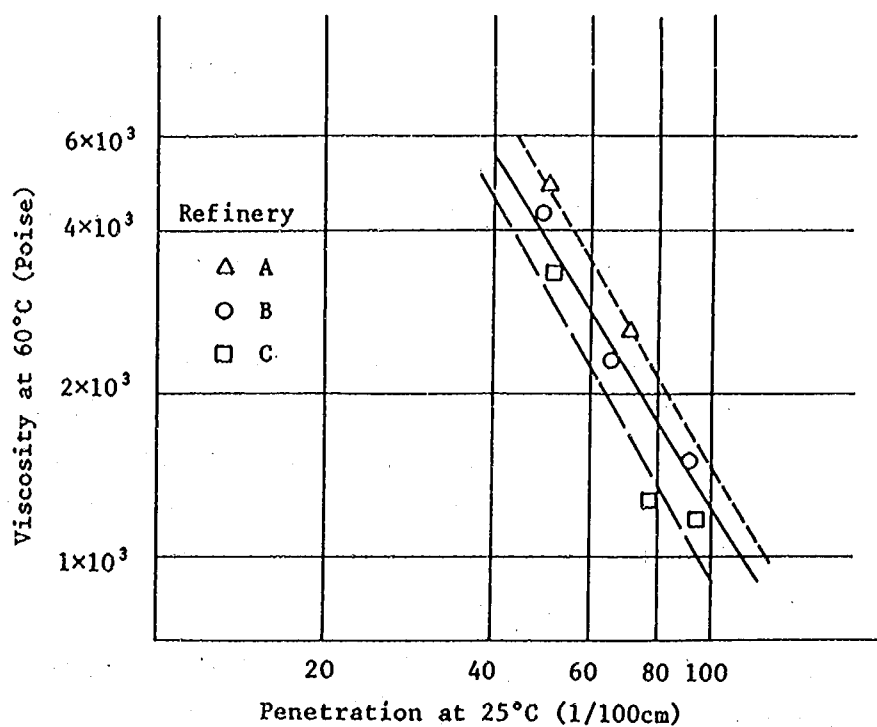


Fig. 6.2 Viscosity at 60°C Versus Penetration by Refinery

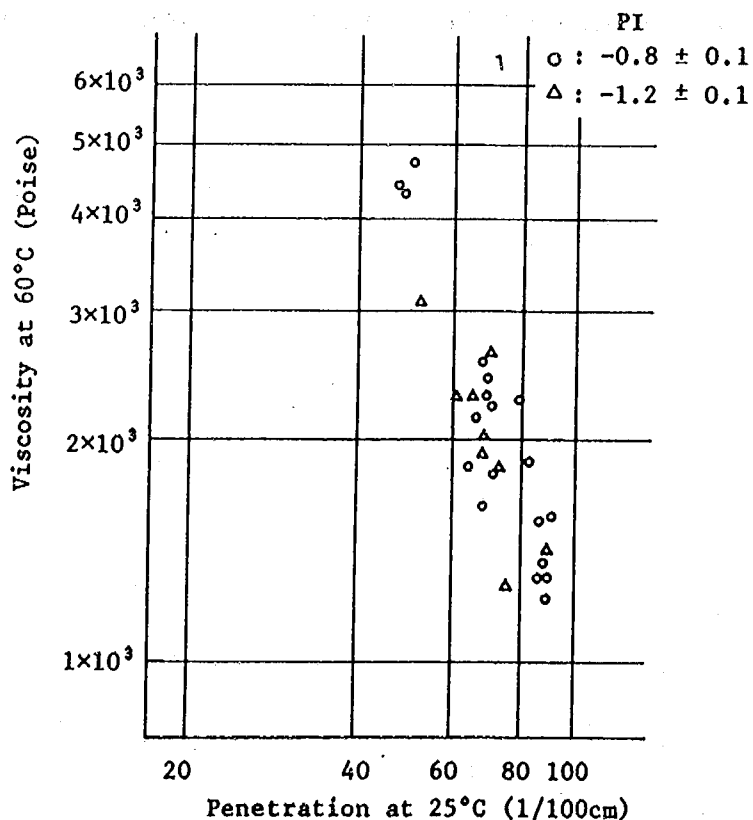


Fig. 6.3 Viscosity at 60°C Versus Penetration Classified by PI Value

Values of the softening point and viscosity at 60°C are plotted in semi-logarithmic scale in Fig. 6.4. The correlation is good with a correlation coefficient of 0.9. As a reference, examples of the straight lines of premix type rubberized asphalt, semi-blown asphalt and recycled asphalt are also shown in the figure. Each asphalt type has a high correlation, but different asphalt types forms different straight lines. Viscosity at 60°C, penetration and softening point, are measured at different temperature, and this difference is considered to make the difference in temperature susceptibility or the degree of none-Newton viscosity. These influences vary for different asphalt types so that different asphalt types make different straight lines.

Fig. 6.5 shows values of viscosity at 60°C and the softening point of the same specimens shown in Fig. 6.2. When the same crude oil is used in the same refinery, the straight line seems to vary depending on the crude oil and the refining method, but this tendency is not certain because the number of plotted values and the ranges of the viscosity and softening point are small.

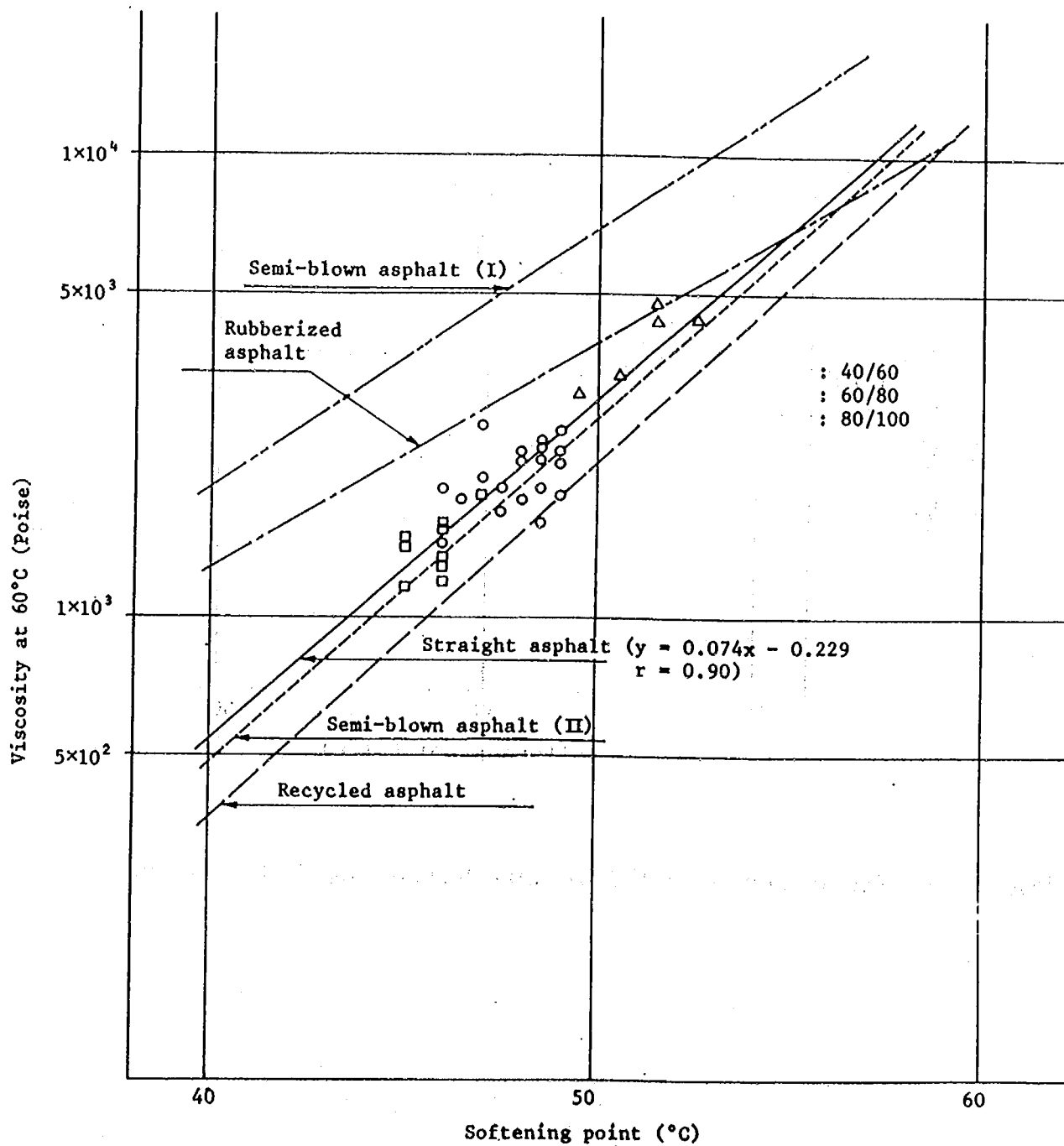


Fig. 6.4 Softening Point Versus Viscosity at 60°C

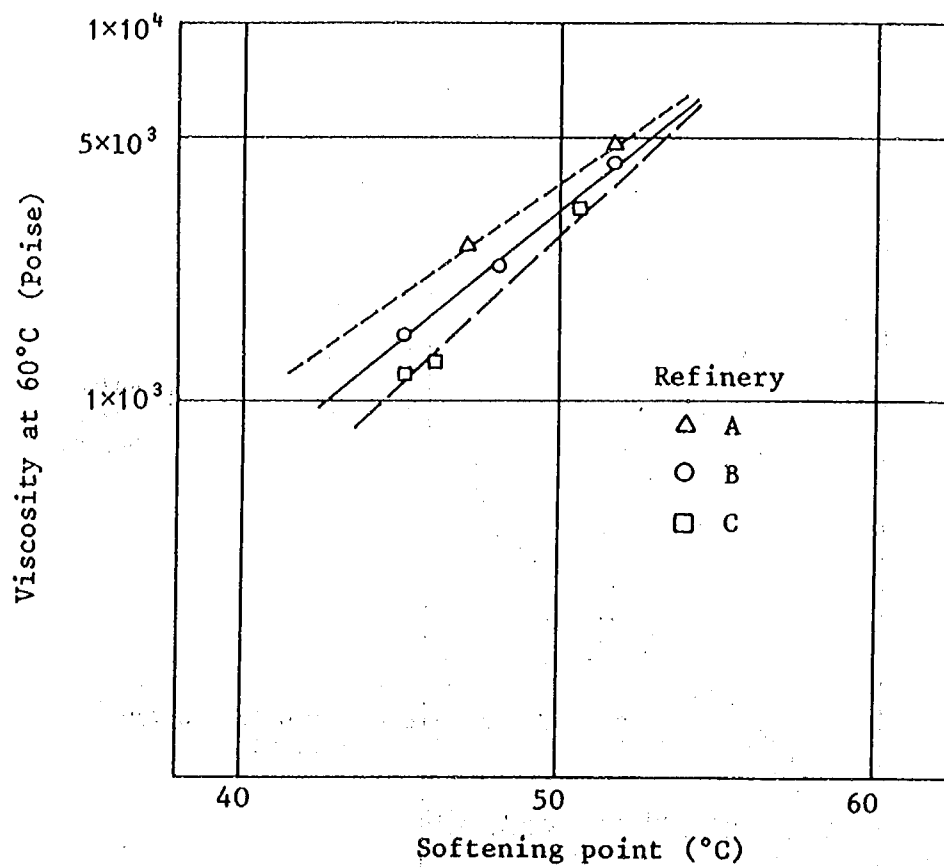


Fig. 6.5 Viscosity at 60°C Versus Softening Point by Refinery

6.2 Four Fractions and other Properties

The relationship between each fraction of the original asphalt (asphalten, resin, aromatics and saturatus) and other test values are analyzed, and the results shown in Table 6.1. The specific gravity has relatively high correlations with each three fractions of asphalten, resin and saturatus. There is no obvious relation between other properties and each fraction.

Table 6.1 Coefficients of Correlation between Original Asphalt Fraction Contents and Other Properties

Item	Asphalten	Resin	Aromatics	Saturatus
Penetration	-0.27	0.24	-0.04	-0.27
Softening point	0.47	-0.47	0.05	0.47
PI	0.54	-0.50	-0.03	0.54
Penetration (reciprocal)	0.22	-0.27	0.09	0.22
log (penetration)	-0.26	0.27	-0.07	-0.26
Specific gravity	0.68	-0.58	0.29	0.68
Flash point	-0.36	0.25	0.65	-0.36
log (viscosity at 60°C)	0.40	-0.50	0.11	0.40
Mass change in thin-film oven test	0.04	-0.05	0.54	0.04
Volatilization loss in loss-on-heating test	0.15	-0.24	0.11	0.15

The multiple correlation between each fraction and other test values was also calculated and the results are shown in Table 6.2. Multiple correlation coefficients between four fractions, and the specific gravity or the flash-point are relatively high, and each multiple correlation equation is shown in Table 6.3.

The multiple correlation coefficient between specific gravity and four fractions is 0.89. The multiple correlation between

four fractions and the flash-point is 0.76 but, according to the coefficients shown in Table 6.3, it is known that the amount of asphalten is hardly related to the flash point.

There is Iijima's formula for the relation between the softening point and four fractions, and it is said that there is a certain correlation between them. However, the correlation is not so good in the present test.

Table 6.2 Multiple Regression between 4 Fraction Contents and Test Values

Item	Coefficient of Multiple Regression
Penetration	0.33
Softening point	0.57
PI	0.66
Specific gravity	0.89
Flash point	0.76
log (viscosity at 60°C)	0.62

Table 6.3 Coefficients of Multiple Regression Formulas of 4 Fraction Contents with Specific Gravity and Flash Point

Item y	a_0	a_1	a_2	a_3	a_4
Specific gravity	1.06	8.5×10^{-4}	-7.2×10^{-4}	-8.7×10^{-5}	-1.6×10^{-3}
Flash point	93.5	0	3.56	3.65	-0.78

$$y = a_0 + a_1 \text{Ast} + a_2 \text{Re} + a_3 \text{Ar} + a_4 \text{Sa}$$

Ast: Asphalten (%)

Re : Resin (%)

Ar : Aromatics (%)

Sa : Saturatus (%)

6.3 Loss-on Heating Test and Thin-Film Oven Test

6.3.1 Mass Change

The relationship between mass change in the loss-on heating test and in the thin-film oven test is shown in Fig. 6.6.

About 85% of the specimens have mass change values in the range from -0.05 to 0.05 in loss-on heating test. However, the mass changes in the TFOT are dispersed in the range from -0.14 to 0.11 so that correlation coefficient between them is 0.37.

The mass change by heating is considered to be affected by both decrement due to evaporation of light portion and increment due to oxidation. In the present test results, about 80% of the specimens tend to increase the mass after TFOT. This probably occurs because in TFOT the asphalt film thickness is small and the surface area is large. So the increment due to oxidation in TFOT is larger than in the loss-on-heating test. However, 8

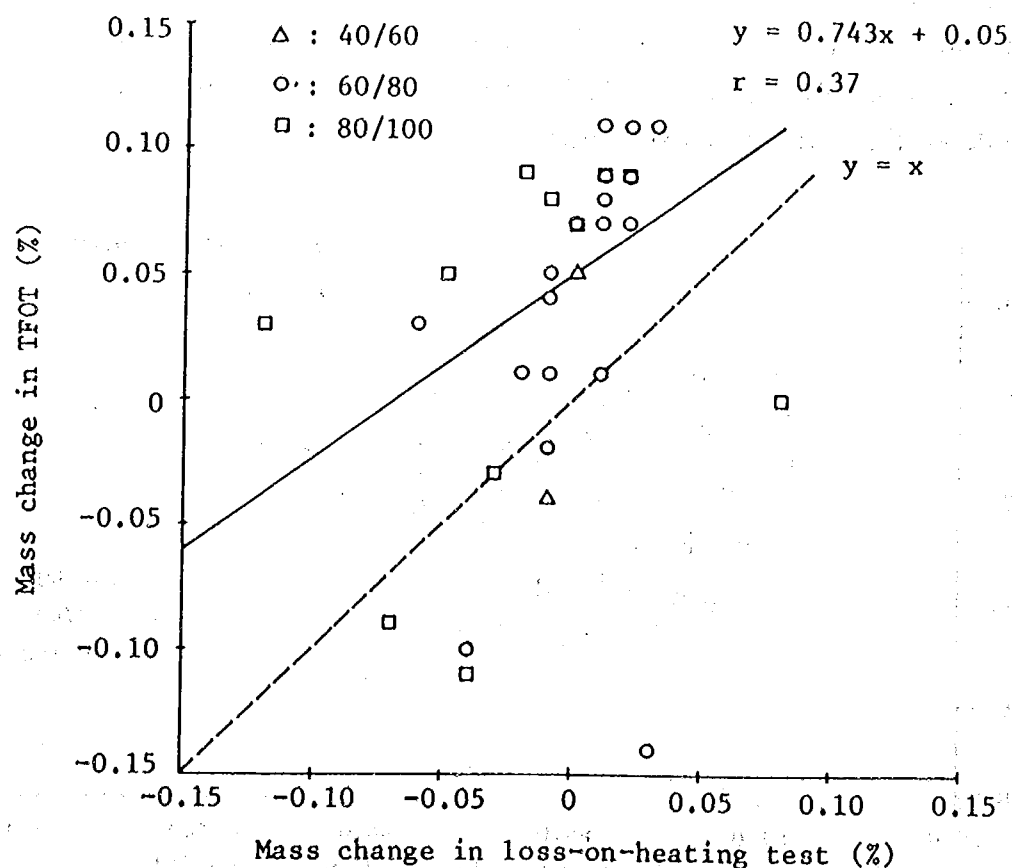


Fig. 6.6 Mass Change in Loss-on-heating Test and TFOT

specimens indicate increments in the loss-on heating test but decrements in the TFOT, or decrements in loss-on heating test and further decrements in TFOT. These specimens are considered to have a large amount of evaporative content. These results mean that the film thickness in heating affects not only the degree of oxidation but also the degree of evaporation. In conclusion, both the effects of decrement due to evaporation and increment due to oxidation occur more strongly in TFOT than loss-on heating test.

6.3.2 Penetration

The relation between the penetration of residue after loss-on heating test $[(\text{penetration of stirred specimen after heating})/(\text{penetration before heating}) \times 100]$ and after TFOT is shown in Fig. 6.7. Values of penetration of residue after the loss-on heating test are in the range of 82 to 103%, but values after TFOT are in the range of 59 to 76%. This result indicates that the testing conditions in TFOT is severer than in loss-on heating test. The correlation between the penetration of residue in both tests is not high with the correlation coefficient of 0.34 and thus both the tests should be considered as different tests.

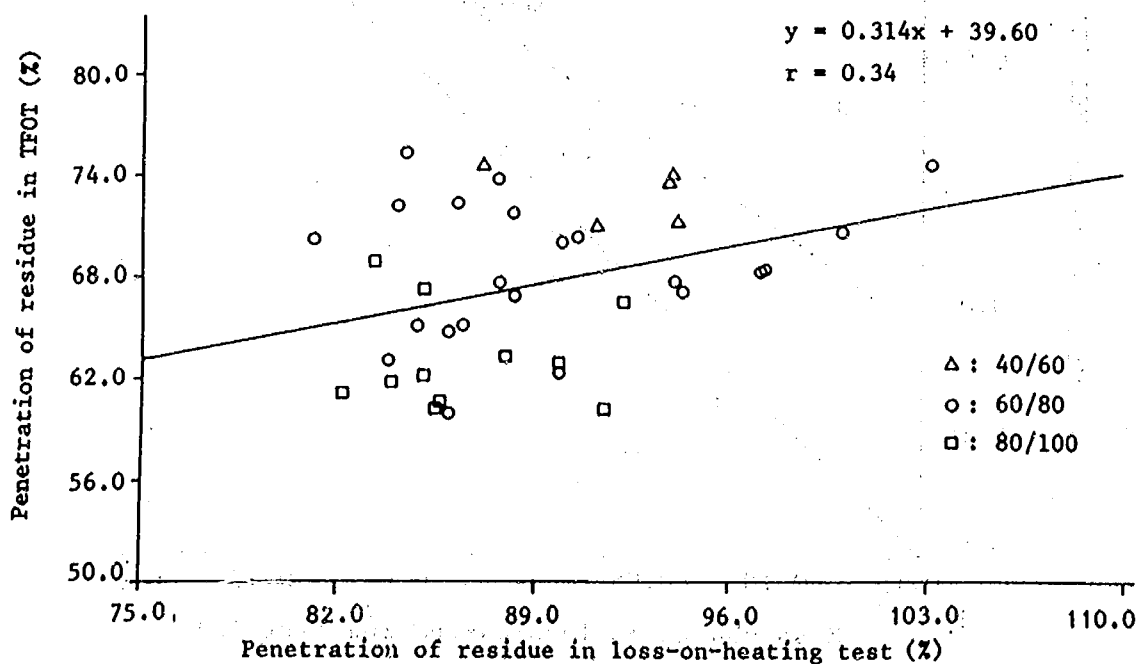


Fig. 6.7 Penetration of Residue by Loss-on-heating Test and TFOT

6.4 Thin-Film Oven Test and Rolling Thin-Film Oven Test

The thin-film oven test is essentially for estimating the degree of deterioration of asphalt during mixing in plants. The test time in the rolling thin-film oven test is shorter than TFOT by further reducing the film thickness and blowing air. Various physical properties after both test methods are compared to each other.

6.4.1 Mass Change

The relationships between mass change in both tests are shown in Fig. 6.8. The correlation coefficient is 0.95 and the gradient of correlation formula suggests that the mass change in RTFOT is 1.3 times larger than that in TFOT. Also, the specimen having decrement in TFOT almost has further decrement in RTFOT, and the same tendency can be recognized in the case of increment.

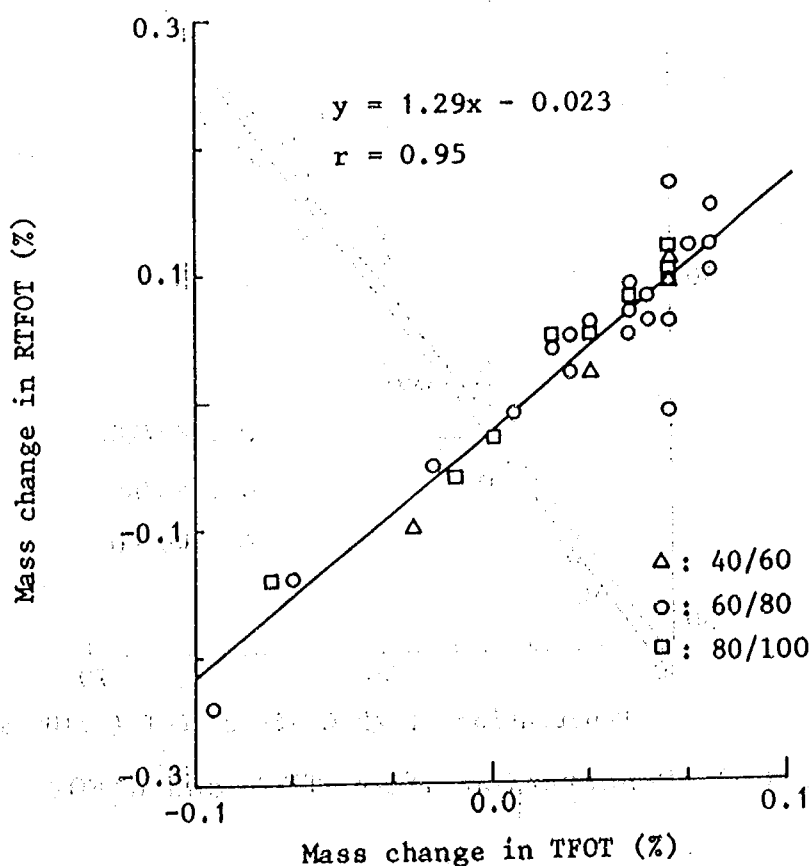


Fig. 6.8 Mass Change in TFOT and RTFOT

6.4.2 Penetration

The relationship for the penetration between in the TFOT and RTFOT is shown in Fig. 6.9 and the relationship for the penetration of residue is shown in Fig. 6.10. It is generally said that the correlation between penetrations after the two tests is high. In the present test, the correlation is also high and the correlation coefficient is 0.95 as shown in Fig. 6.9. However, the correlation coefficient between penetrations of residue in the two tests is relatively small or 0.74 as shown in Fig. 6.10, and the differences of values in the two tests are large. Also, many points are below the straight line of $y = x$ as shown in Fig. 6.10 and, in view of the penetration of residue, RTFOT has severer effect on asphalt property than TFOT.

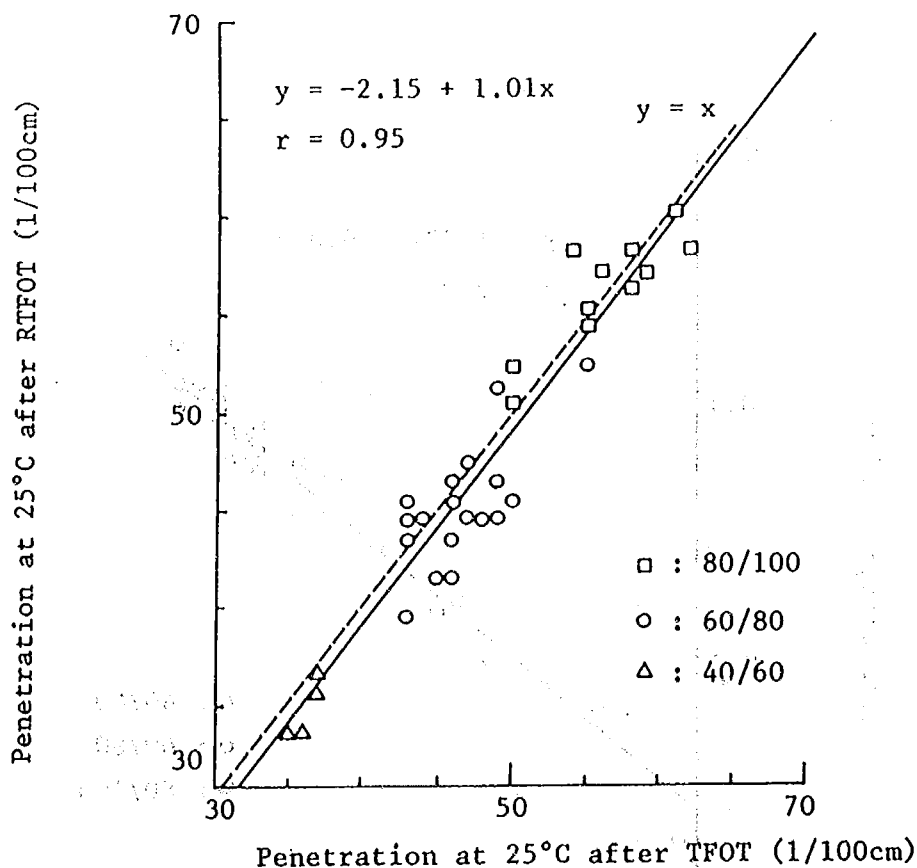


Fig. 6.9 Penetration after TFOT and RTFOT

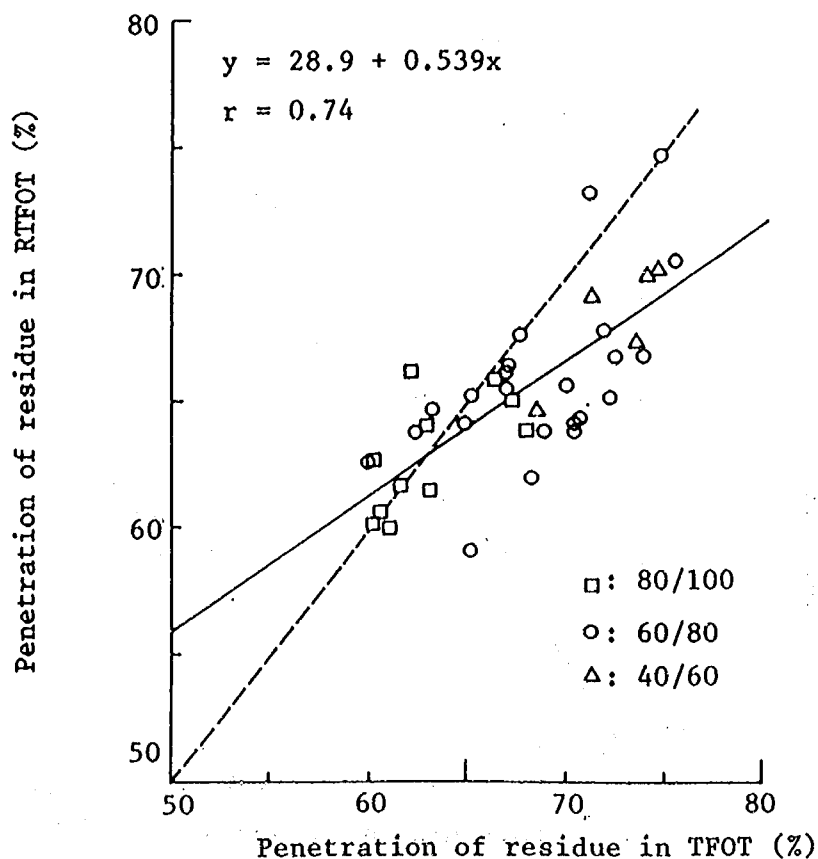


Fig. 6.10 Penetration of Residue in TFOT and RTFOT

6.4.3 Softening Point

The relationship between the softening points after TFOT and after RTFOT is shown in Fig. 6.11. The correlation coefficient is 0.93, but many specimens have a higher softening point after RTFOT than after TFOT. Therefore, as for the case of the penetration residue, RTFOT has slightly severer effect on asphalt property than TFOT.

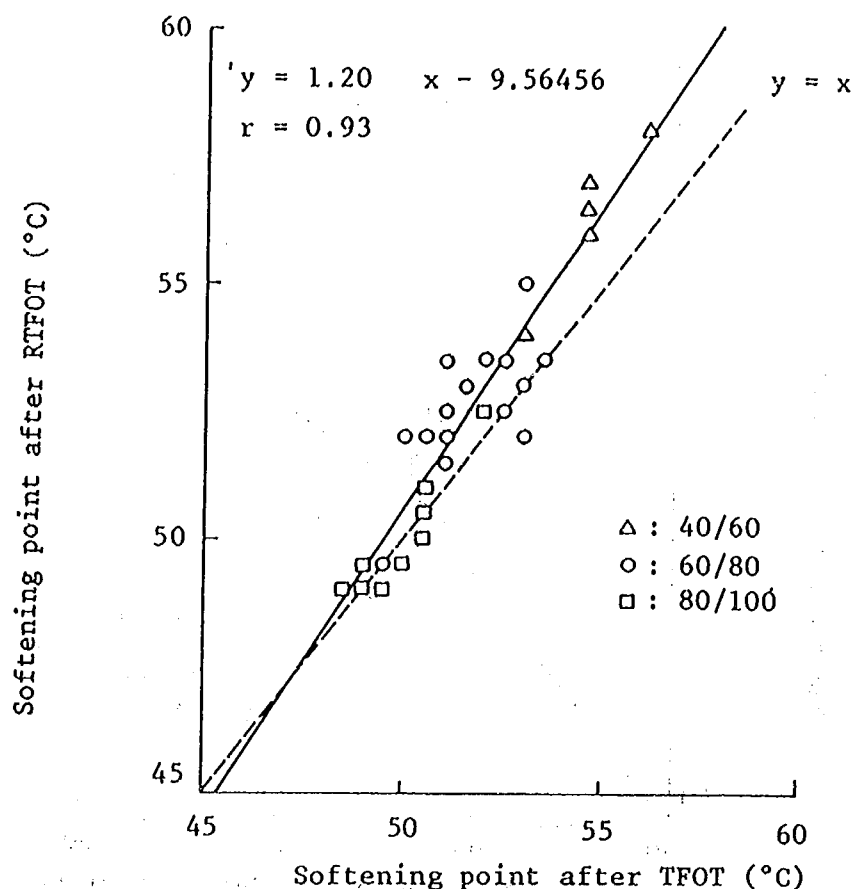


Fig. 6.11 Softening Point after TFOT and RTFOT

6.4.4 Ductility (15°C)

Fig. 6.12 shows the ductility (15°C) after TFOT and after RTFOT. The correlation between ductilities (15°C) after the two tests is good and the correlation coefficient is 0.92 (dotted line). However, both values are not exactly the same values, and many points are located below the straight line of $y = x$. That is, the ductility after RTFOT tends to have smaller value than the ductility after TFOT, and thus RTFOT also gives a severer effect on the ductility than the TFOT. There are two specimens that have relatively large differences in the results between the two tests.

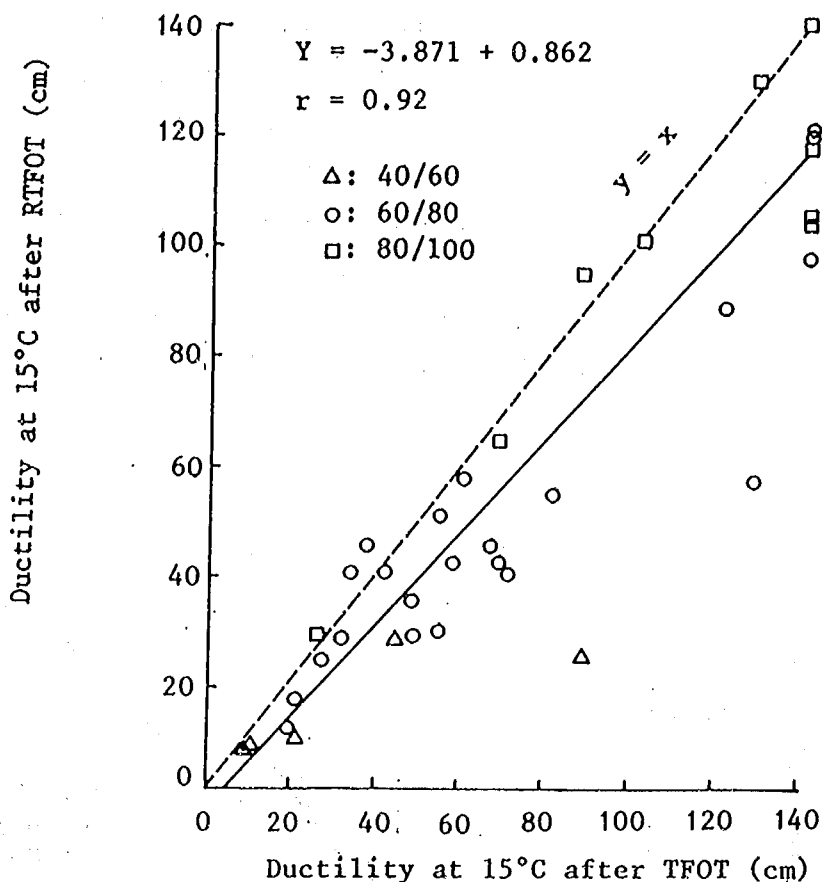


Fig.6.12 Ductility at 15°C after TFOT and RTFOT

6.4.5 Viscosity at 60°C

Fig. 6.13 shows the relation between the viscosity at 60°C after TFOT and after RTFOT. The correlation between the two values is high at 0.95. However, on an average, the viscosity after RTFOT is about 1.15 times as high as the viscosity after TFOT. From this result, RTFOT also gives slightly severer effect on viscosity than TFOT. The relation between the 60°C viscosity ratio in TFOT and in RTFOT is shown in Fig. 6.14. On an average, 60°C viscosity ratio in RTFOT is slightly higher than the viscosity ratio in TFOT, but no clear relation between the two values is recognized.

The viscosity ratio after RTFOT is relatively larger than the viscosity ratio after TFOT for all specimen in the case of 40/60. In the case of 60/80, the viscosity ratio after RTFOT also tends to become larger than the viscosity ratios after TFOT. The viscosity ratios after the two tests are almost the same in the case of 80/100. The new asphalt surface is always

exposed to air and asphalt is fully stirred in RTFOT. While, in TFOT, the film thickness is larger and asphalt with a high viscosity can spread less from the surface to inside than RTFOT. These differences are considered to make the difference between viscosity ratios after the two tests. Therefore, the two tests make more different effect on high viscosity asphalt than low viscosity asphalt. The same tendency is recognized for the penetration after TFOT and RTFOT as explained previously.

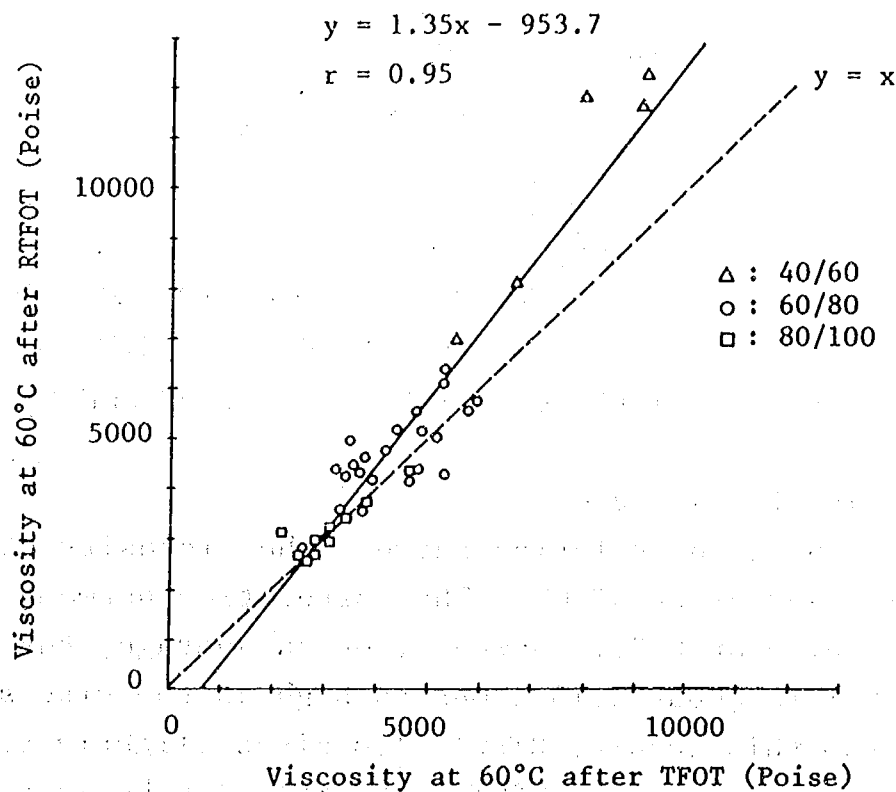


Fig. 6.13 Viscosity at 60°C after TFOT and RFTOT

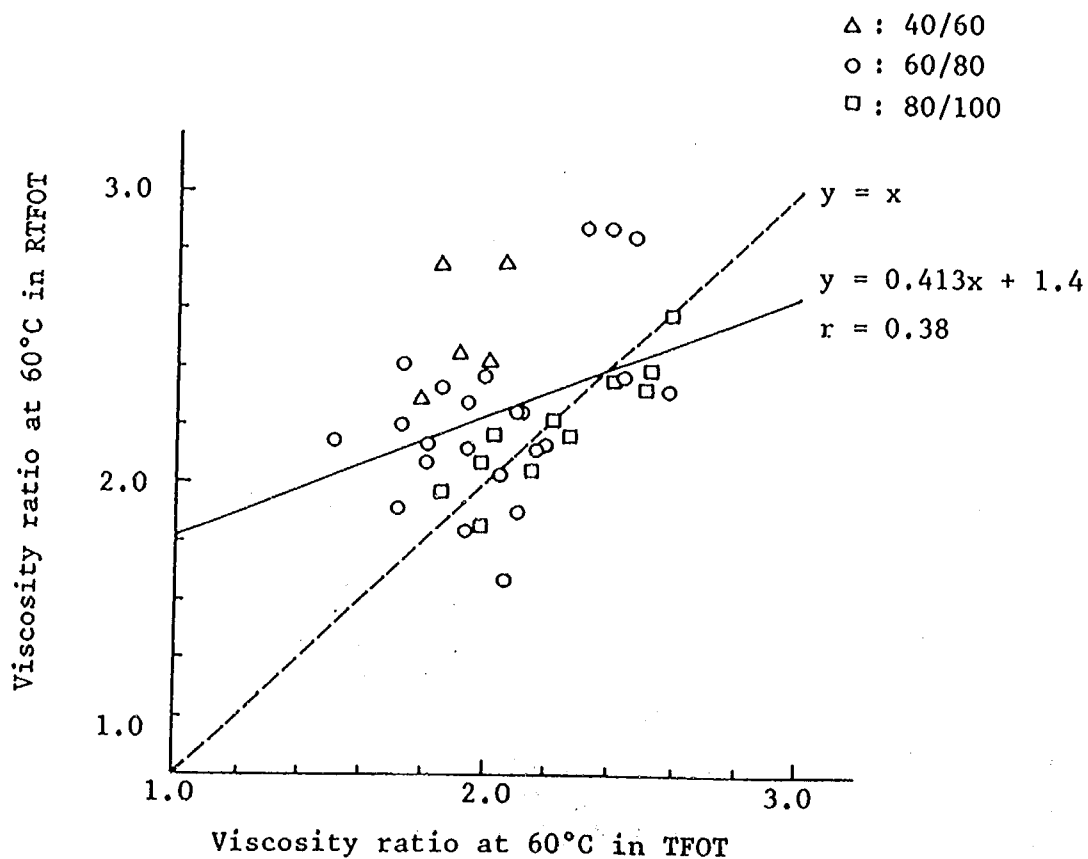


Fig. 6.14 Viscosity Ratio in TROT and RTFOT

6.5 Viscosity at 60°C and Softening Point after Oven Test

The relation between the viscosity at 60°C and the softening point after TFOT and after RTFOT are shown in Fig. 6.15. There is a good correlation between the two values, and the oven test does not make any change in this tendency.

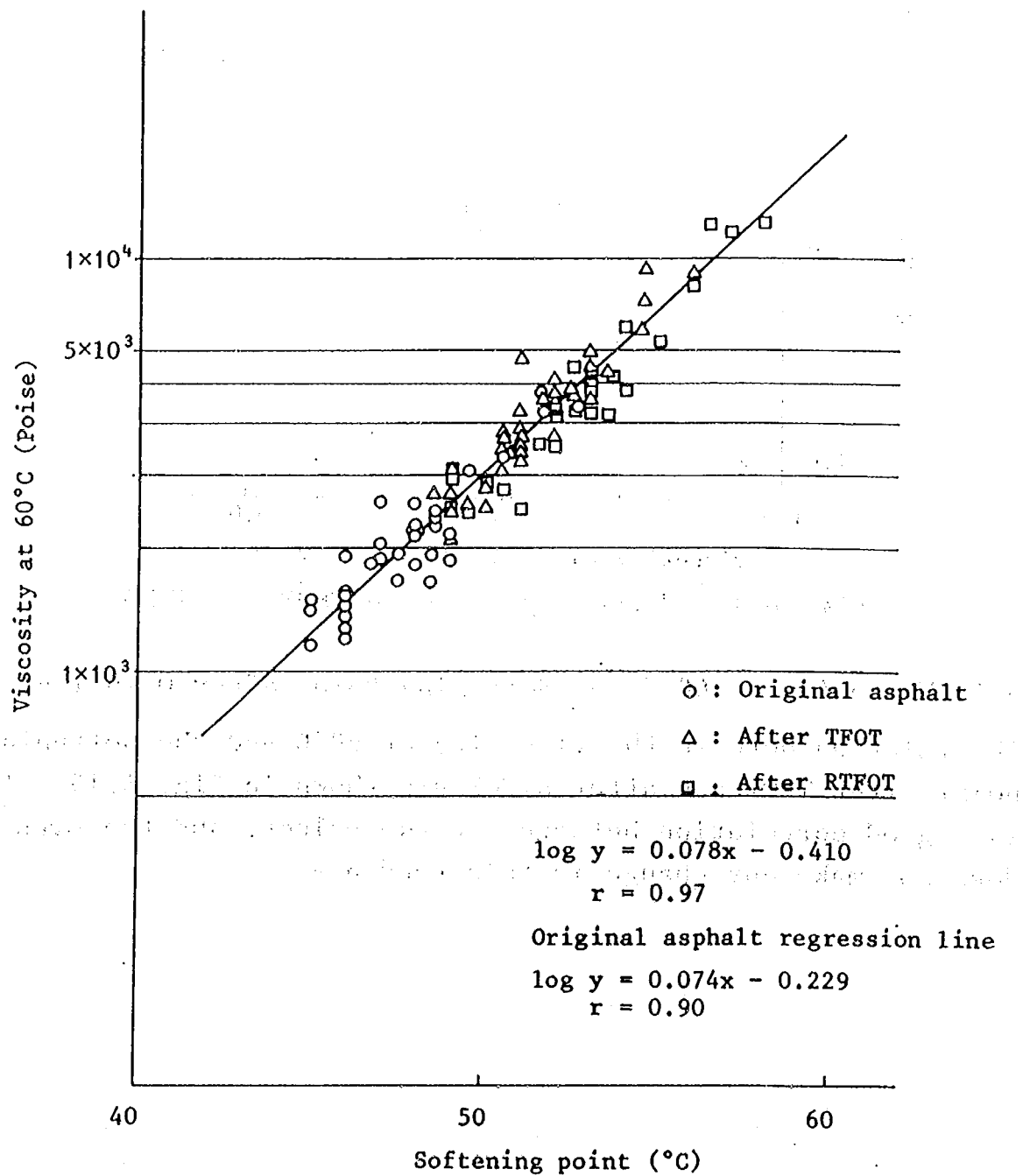


Fig. 6.15 Viscosity at 60°C Versus Softening Point after TFOT and RTFOT, and before Oven Test of Original Asphalt

6.6 Ductility before and after the Oven Test

Fig. 6.16 show the relation between ductility (10°C) before oven test and ductility (15°C) after TFOT, and Fig. 6.17 shows the relation between ductility (10°C) before oven test and ductility (15°C) after RTFOT. The correlation coefficient between the ductility after TFOT and the ductility before oven test is 0.72, but some specimens have great differences. There is also a high correlation with the correlation coefficient of 0.84 between the ductility after RTFOT and the ductility before oven test. Since there are good correlations between the ductility (10°C) before oven test and the ductility (15°C) after oven tests, the transition region of ductility between brittleness and viscosity is considered to shift to a higher temperature by heating.

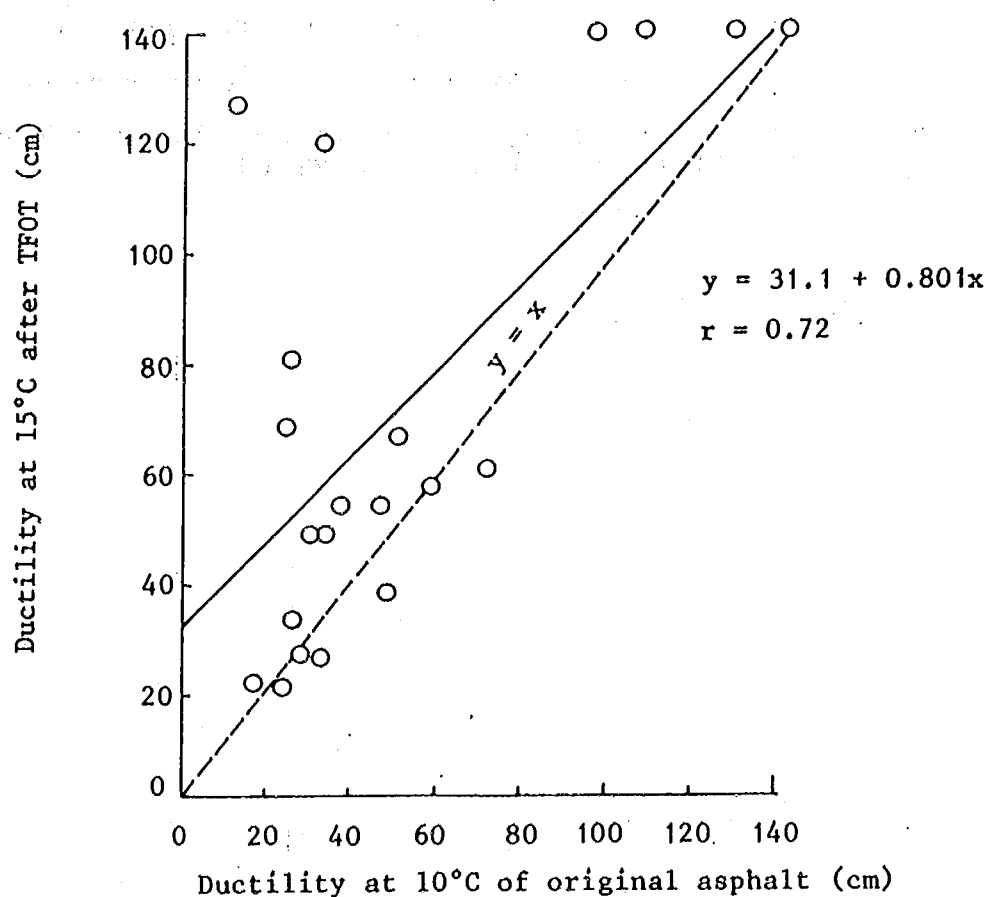


Fig. 6.16 Ductility at 10°C of Original Asphalt Versus Ductility at 15°C after TFOT (60/80)

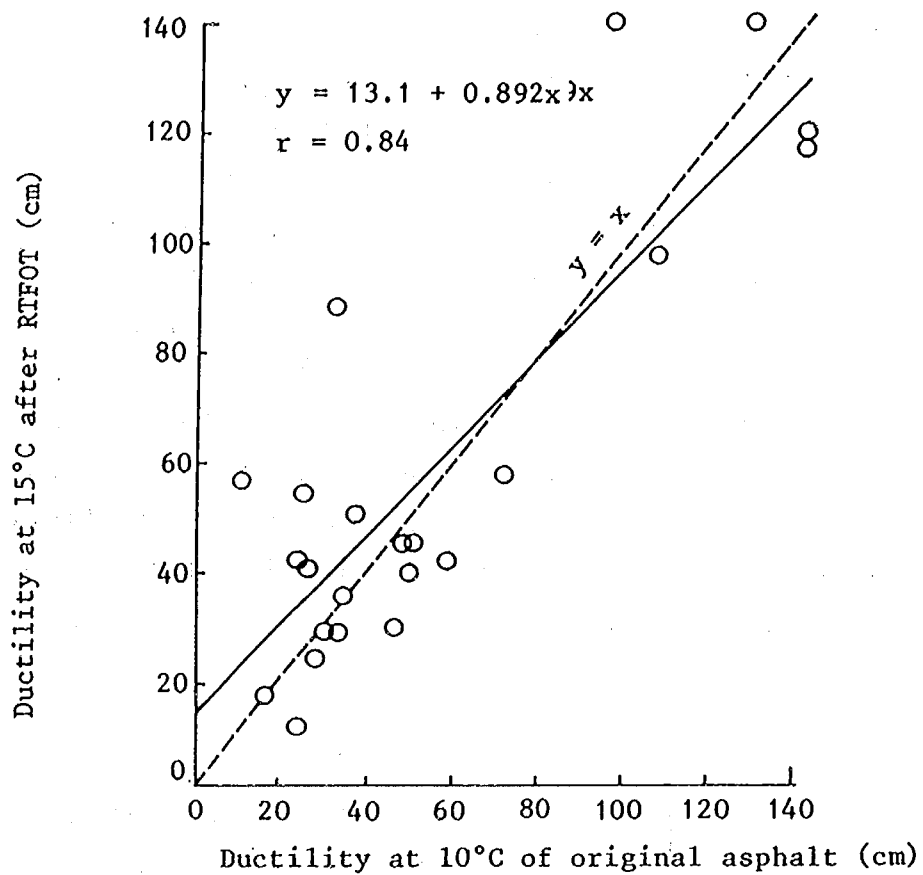


Fig. 6.17 Ductility at 10°C of Original Asphalt Versus Ductility at 15°C after RTFOT

7. Relations between Test Results and Standard Values

The fitness of test values to standard values prescribed in JIS are examined, and the results are shown in Tables 7.2 to 7.4.

Test values almost satisfy the standard values. Test items such as the mass change in the loss-on heating test and ductility test (10°C) have large coefficients of variation, but other test items prescribed in JIS have the coefficients of variation less than 20%.

The standards range in JIS are reviewed and the results are shown in Table 7.1. These are obtained from the following formulas:

Both side standard:

$$A = \frac{Su - Sl}{\sigma n - 1}$$

One side standard:

$$A = \frac{S - \bar{X}}{\sigma n - 1}$$

Where, Su : Upper limit of standard value

Sl : Lower limit of standard value

S : Standard value

$\bar{X}$: Mean value

$\sigma n - 1$: Standard deviation

Value of A is considered to be 6 to 8 for both side standard and 3 to 4 for one side standard, and thus each current standard range in JIS is considered to be appropriate.

Table 7.1 Results of Calculation of Specification Ranges
(Value A)

Grades	40/60	60/80	80/100
Penetration (25°C)	10.4	5.7	5.9
Softening point	7.0	7.8	13.3
Solubility in trichloroethane	9.0	4.8	5.9
Flash point	3.2	4.8	8.4
Specific gravity	8.0	8.0	8.7
Penetration ratio after Loss-on-heating test	2.5	3.2	2.6
Mass change in TFOT	9.6	8.2	7.8
Penetration of residue in TFOT	5.9	3.4	4.3

Table 7.2 Test Results Versus Specified Values of JIS (40/60)

Items		Specified Values of JIS	Number of Samples	Mean Values	$\sigma_n - 1$	Coefficients of Variation	$\mu \pm 2\sigma$	$\mu + 2\sigma$ or more	$\mu - 2\sigma$ or less	Out of Specification
Penetration (25°C)	1/10 mm	40 - 60	5	50	1.9	3.9	53.8 ~ 46.2	0	0	0
Softening point	°C	47.0 - 55.0	5	51.1	1.1	2.2	53.4 ~ 48.8	0	0	0
Penetration Index		-	5	-0.94	0.2	20.4	-1.32 ~ -0.56	0	0	-
Ductility (15°C)	cm	10 or more	5	-	-	-	-	-	-	0
Ductility (10°C)	cm	-	5	11	5.6	52.1	22 ~ 0.5	0	0	-
Solubility in trichloroethane	X	99.0 or more	5	99.90	0.1	0.1	100 ~ 99.7	0	0	0
Flash point	°C	260 or more	5	340	25.0	7.4	390 ~ 290	0	0	0
Specific gravity (25/25°C)		1.000 or more	5	1.032	0.004	0.4	1.040 ~ 1.024	0	0	0
Viscosity at 60°C	poise	-	5	3980	737	18.5	5460 ~ 2510	0	0	-
High temperature viscosity at 120°C	cSt	-	5	1520	200	13.1	1920 ~ 1120	0	0	-
High temperature viscosity at 140°C	cSt	-	5	475	59.8	12.6	595 ~ 356	0	0	-
High temperature viscosity at 160°C	cSt	-	5	192	22.2	11.6	236 ~ 147	0	0	-
High temperature viscosity at 180°C	cSt	-	5	92.8	10.2	10.9	113 ~ 72.5	0	0	-
Volatilization loss in loss-on-heating testing	X	-	5	0.006	0.011	190	0.03 ~ 0.02	0	0	-
Penetration ratio after loss-on-heating testing	X	under 110	5	99.0	4.5	2.1	108 ~ 90.3	0	0	0
Mass change in TFOT	X	under 0.6	5	0.056	0.06	100	0.17 ~ 0.06	0	0	0
Penetration of residue in TFOT	X	58 or more	5	72.4	2.5	3.4	77.2 ~ 67.5	0	0	0
Penetration after TFOT	1/10 mm	-	5	36.0	1.0	2.8	38.0 ~ 34.0	0	0	-
Softening point after TFOT	°C	-	5	54.5	1.1	2.0	56.6 ~ 52.4	0	0	-
PI after TFOT		-	5	-0.86	0.2	22.3	-0.48 ~ -1.25	1	0	-

Table 7.2 (cont'd)

Items	Specified Values of JIS	Number of Samples	Mean Values	$\sigma - 1$	Coefficients of Variation	$\mu \pm 2\sigma$	$\mu + 2\sigma$ or more	$\mu - 2\sigma$ or less	Out of Specification
Viscosity at 60°C after TFOT poise	-	5	7646	1570	20.5	10790 ~ 4506	0	0	-
Viscosity ratio at 60°C in TFOT	-	5	1.91	0.1	5.8	2.13 ~ 1.69	0	0	-
Ductility at 15°C after TFOT cm	-	5	34.4	33.1	96.3	101 ~ 0	0	0	-
Loss in RTFOT %	-	5	0.044	0.09	201	0.022 ~ -0.13	0	0	-
Penetration of residue in RTFOT %	-	5	62.3	2.3	3.4	72.9 ~ 63.7	0	0	-
Penetration after RTFOT 1/10 cm	-	5	34.0	1.4	4.2	36.8 ~ 31.2	0	0	-
Softening point after RTFOT °C	-	5	56.3	1.5	2.6	59.1 ~ 53.5	0	0	-
PI after RTFOT	-	5	-0.61	0.26	42.9	-0.09 ~ -1.13	0	0	-
Viscosity at 60°C after RTFOT poise	-	5	10120	2440	24.1	14500 ~ 5236	0	0	-
Viscosity ratio at 60°C in RTFOT	-	5	2.52	0.21	8.1	2.94 ~ 2.10	0	0	-
Ductility at 15°C after RTFOT cm	-	5	15.0	9.7	64.5	34.3 ~ 0	0	0	-

Table 7.3 Test Results Versus Specified Values of JIS (60/80)

Items		Specified Values of JIS	Number of Samples	Mean Values	σ - 1	Coefficients of Variation	$\mu \pm 2\sigma$	$\mu + 2\sigma$ or more	$\mu - 2\sigma$ or less	Out of Specification
Penetration (25°C)	1/10 cm	60 ~ 80	23	67	3.5	5.2	74.0 ~ 60.0	0	0	0
Softening point	°C	44.0 ~ 52.0	23	47.8	1.0	2.1	50.0 ~ 45.5	0	0	0
PI		-	23	-1.03	0.2	22.8	-0.56 ~ -1.50	0	0	-
Ductility (15°C)	cm	100 or more	23	140+	-	-	-	-	-	0
Ductility (10°C)	cm	-	23	-	-	-	-	-	-	-
Solubility in trichloroethane	%	99.0 or more	23	99.85	0.2	0.2	100 ~ 99.5	0	2	0
Flash point	°C	260 or more	23	342	16.8	4.9	376 ~ 308	0	1	0
Specific gravity (25/25°C)		1.000 or more	23	1.030	0.004	0.4	1.034 ~ 1.026	1	4	0
Viscosity at 60°C	poise	-	23	2060	355	17.2	2770 ~ 1350	0	1	-
High temperature viscosity at 120°C	cSt	-	23	1007	133	13.2	1273 ~ 741	0	0	-
High temperature viscosity at 140°C		-	23	353	43.4	12.3	440 ~ 266	0	0	-
High temperature viscosity at 160°C		-	23	148	16.9	11.5	182 ~ 114	0	1	-
High temperature viscosity at 180°C		-	23	74.7	8.1	10.9	90.9 ~ 58.5	0	0	-
Volatilization loss in loss-on-heating test	%	-	23	0.003	0.022	851	0.05 ~ 0.04	0	1	-
Penetration ratio after loss-on-heating test	%	under 110	23	96.0	4.4	4.6	105 ~ 87.1	1	0	0
Loss in TFOT	%	under 0.6	23	0.056	0.07	117	0.19 ~ 0.08	0	2	0
Penetration of residue in TFOT	%	55 or more	23	68.6	4.0	5.8	76.6 ~ 60.6	0	1	0
Penetration after TFOT	1/10 cm	-	23	46.7	2.9	6.3	52.6 ~ 40.8	0	0	-
Softening point after TFOT	°C	-	23	51.6	1.1	2.1	53.8 ~ 49.5	0	0	-
PI after TFOT		-	23	-0.96	0.2	21.1	-0.56 ~ -1.37	1	0	-

Table 7.3 (cont'd)

Items	Specified Values of JIS	Number of Samples	Mean Values	On - 1	Coefficients of Variation	$\mu \pm 2\sigma$	$\mu + 2\sigma$ or more	$\mu - 2\sigma$ or less	Out of Specification
Viscosity at 60°C after TFOT poise	-	23	4210	9720	23.1	6154 ~ 2266	0	0	-
Viscosity ratio at 60°C in TFOT	-	23	2.04	0.3	13.3	2.58 ~ 1.50	0	0	-
Ductility at 15°C after TFOT cm	-	23	74.6	44.1	59.1	-	-	-	-
Mass change in RTFOT %	-	23	0.049	0.09	191	0.24 ~ -0.14	0	2	-
Penetration of residue in RTFOT %	-	23	66.3	3.5	5.3	73.0 ~ 59.1	2	0	-
Penetration after RTFOT 1/10 cm	-	23	44.9	2.9	6.4	50.6 ~ 39.2	1	1	-
Softening point after RTFOT °C	-	23	52.6	1.2	2.3	55.0 ~ 50.2	2	1	-
PI after RTFOT	-	23	-0.84	0.26	30.4	-0.33 ~ -1.35	0	1	-
Viscosity at 60°C after RTFOT poise	-	23	4585	951	20.8	6487 ~ 2683	0	1	-
Viscosity ratio at 60°C in RTFOT	-	23	2.23	0.31	13.9	2.85 ~ 1.61	0	3	-
Ductility at 15°C after RTFOT cm	-	23	-	-	-	-	-	-	-

Table 7.4 Test Results Versus Specified Values of JIS (80/100)

Items		Specified Values of JIS	Number of Samples	on - 1	Mean Values	Coefficients of Variation	$\mu \pm 2\sigma$	$\mu + 2\sigma$ or more	$\mu - 2\sigma$ or less	Out of Specification
Penetration (25°C)	1/10 cm	80 ~ 100	11	89	3.4	3.8	95.8 ~ 82.2	0	0	0
Softening point	°C	42.0 ~ 50.0	11	46.0	0.6	1.3	47.0 ~ 45.0	0	0	0
PI		-	11	-0.90	0.1	14.3	-0.77 ~ -1.03	2	2	-
Ductility (15°C)	cm	100 or more	11	140+	-	-	-	-	-	0
Ductility (10°C)	cm	-	11	-	-	-	-	-	-	-
Solubility in trichloroethane	%	99.0 or more	11	99.86	0.2	0.1	100 ~ 99.6	0	2	0
Flash point	°C	260 or more	11	344	10.0	2.9	364 ~ 324	0	0	0
Specific gravity (25/25°C)		1.000 or more	11	1.026	0.003	0.3	1.023 ~ 1.029	1	1	0
Viscosity at 60°C	poise	-	11	1410	204	14.5	1810 ~ 1000	1	0	-
High temperature viscosity at 120°C	cSt	-	11	800	76.4	9.5	6473 ~ 953	0	0	-
High temperature viscosity at 140°C		-	11	299	25.1	8.4	349 ~ 248	0	0	-
High temperature viscosity at 160°C		-	11	129	10.1	7.9	149 ~ 108	0	0	-
High temperature viscosity at 180°C		-	11	67.2	4.9	7.2	77.0 ~ 57.5	0	0	-
Volatilization loss in loss-on-heating test	%	-	11	0.003	0.06	248	0.11 ~ -0.11	0	1	-
Penetration ratio after loss-on-heating test	%	under 110	11	91.6	7.0	7.6	106 ~ 77.7	0	0	0
Loss in TFOT	%	under 0.6	11	0.025	0.07	298	0.17 ~ -0.12	0	0	0
Penetration of residue in TFOT	%	58 or more	11	63.2	3.0	5.8	69.2 ~ 57.0	0	0	0
Penetration after TFOT	1/10 cm	-	11	56.2	4.0	7.0	64.1 ~ 48.3	0	0	-
Softening point after TFOT	°C	-	11	49.8	1.0	2.1	51.8 ~ 47.7	1	0	-
PI after TFOT		-	11	-0.99	0.2	17.3	-0.65 ~ -1.34	0	0	-

Table 7.4 (cont'd)

Items	Specified Values of JIS	Number of Samples	Mean Values	on - 1	Coefficients of Variation	$\mu \pm 2\sigma$	$\mu + 2\sigma$ or more	$\mu - 2\sigma$ or less	Out of Specification
Viscosity at 60°C after TFOT poise	-	11	3033	698	23.0	4429 ~ 1637	1	0	-
Viscosity ratio at 60°C in TFOT	-	11	2.22	0.3	11.3	2.72 ~ 1.72	0	0	-
Ductility at 15°C after TFOT cm	-	11	-	-	-	-	-	-	-
Loss in RTFOT %	-	11	0.014	0.09	661	0.19 ~ -0.17	0	0	-
Penetration of residue in RTFOT %	-	11	62.9	2.2	3.6	67.3 ~ 58.4	0	0	-
Penetration after RTFOT 1/10 cm	-	11	55.9	3.0	5.3	61.8 ~ 50.0	0	0	-
Softening point after RTFOT °C	-	11	49.9	1.1	2.2	52.1 ~ 47.7	1	0	-
PI after RTFOT	-	11	-0.89	0.33	37.5	-0.22 ~ -1.56	1	0	-
Viscosity at 60°C after RTFOT poise	-	11	3076	556	18.1	4188 ~ 1964	1	0	-
Viscosity ratio at 60°C in RTFOT	-	11	2.19	0.21	9.6	2.61 ~ 1.77	0	0	-
Ductility at 15°C after RTFOT cm	-	11	-	-	-	-	-	-	-

8. Conclusion

8.1 Present Situation of the Quality of Straight Asphalt of Japan

It has been found that all asphalt refined in Japan satisfy the standard values prescribed in JIS and has sufficient quality. Also the test results have no great differences from the results of the investigation conducted by the Japan Road Association in 1972 (only the test items prescribed in JIS). However, it seems to be natural that every asphalt has similar values for only the test items prescribed in JIS. On the other hand, the test results of viscosity at 60°C, ductility at 10°C and ductility after TFOT and after RTFOT, which are not prescribed in JIS, show various values even in the same penetration grade, thereby indicating the difference of each specimen. From this, it will be necessary to examine even the test items not prescribed in JIS when discussing the asphalt quality.

8.2 Relation between the Test Certificates and Test Results.

In the comparison of the values of the test certificates with the test values, some test values of several specimens do not satisfy the tolerance (multilaboratory precision) prescribed in JIS. Even with respect to test items for which no tolerances are prescribed in JIS, some specimens have considerably different measured values from the test certificates. However, it can be generally said that each specimen has almost the same value between the certificate and the test, and thus the test certificate is reliable. But it is considered to be meaningful to periodically sample asphalt and investigate the properties.

8.3 Relations between Properties

There are a good correlation between the viscosity at 60°C and penetration, and between the viscosity at 60°C and softening point, but these relations vary depending on a kind of asphalt. The RTFOT has a severer effect on the properties than the TFOT except the penetration test. However, special advantages of the RTFOT over the TFOT have not been recognized.

In the comparison between fractions in the asphalt separation test and other properties, the specific gravity and the flash point have relatively good correlation with four fractions but other properties had no clear tendency, so that it seems to be difficult to judge the quality of asphalt from the result of the separation test.

Afterword

As a result of the study and tests conducted over 6 months, the present situation of all straight asphalt properties for roads currently being produced in Japan has been clarified.

Among various materials for pavement, the straight asphalt is now drawing researchers' attention especially for its quality and behavior. This is true not only in Japan but also in other countries and seems to be a common problem. For instance, the study on properties of the straight asphalt has been selected as one of the important theme of Strategic Highway Research Program (SHRP) in the U.S.A. Under such circumstances, this paper will be able to supply very useful information when the standards and test methods for straight asphalt are examined. On the other hand, the quality of asphalt must be considered in connection with the properties of asphalt mixture and also with the performance of the pavement in service. These are important problems to be tackled in future.

References

- 1) Japan Road Association; Manual for Design and Construction of Asphalt Pavement, 1980
- 2) Japanese Standards Association; JIS Handbook 12 Petroleum, 1984
- 3) Annual Book of ASTM STANDARDS, Road and Paving Materials, 1984

Appendix 1 Test Results (40/60, 80/100 Part 1)

Sample No.			40/60					80/100										
Items			1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	11
Penetration	25°C	1/10 mm	49	52	51	50	47	91	83	89	90	87	91	90	90	94	83	87
	5°C	1/10 mm	6	7	6	5	6	9	11	10	9	9	11	10	10	11	9	10
Softening point		°C	51.5	49.5	50.5	51.5	52.5	45.0	47.0	46.0	45.0	46.0	46.0	46.0	46.0	45.0	46.0	46.0
Penetration Index			-0.88	-1.23	-1.03	-0.83	-0.74	-1.07	-0.73	-0.83	-1.10	-0.89	-0.76	-0.80	-0.80	-0.98	-1.03	-0.89
Viscosity at 60°C	poise		4310	3060	3350	4760	4440	1500	1860	1360	1410	1550	1570	1310	1220	1160	1300	1220
High temperature viscosity	120°C cSt		1620	1300	1330	1610	1760	858	908	805	825	871	893	769	737	714	691	731
	140°C		519	422	408	481	546	316	333	295	314	323	327	288	281	270	261	276
	160°C		209	171	171	188	220	135	164	130	132	140	143	127	121	118	112	119
	180°C		99.7	83.7	84.5	89.3	107	69.6	71.6	67.0	68.1	72.9	74.7	67.1	64.4	62.6	59.0	62.4
Ductility	15°C	cm	121	140+	140+	140+	108	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+
	10°C		9	15	4	18	8	140+	43	140+	140+	88	119	73	140+	140+	68	92
	7°C		-	-	-	-	-	27	8	12	10	10	10	10	13	16	8	10
Solubility in trichloroethane		%	99.77	99.83	99.94	99.99	99.98	99.98	99.76	99.94	99.97	99.93	99.85	99.0	99.49	99.74	99.91	99.92
Flash point	Flash point temperature	°C	362	356	342	299	341	355	347	343	354	357	323	339	342	346	338	350
	Foam									00							00	00
	Film						00	00	00	00	00	00	00	00	00	00	00	00
Loss-on-heating test	Volatilization loss	%	+0.02	+0.01	0	-0.01	+0.01	+0.02	0	+0.01	-0.03	-0.01	-0.02	-0.07	-0.12	-0.05	-0.04	+0.08
	Penetration	Mean	97.5	101.1	100.0	95.8	100.0	94.1	82.3	96.9	93.5	98.1	85.7	81.1	102.7	94.3	85.8	93.9
	ratio (X)	(Measurement point 1)	100	98	100	100	102	75	82	98	99	97	86	77	96	99	89	100
		(Measurement point 2)	100	98	100	94	105	95	88	98	99	99	90	78	95	101	70	88
		(Measurement point 3)	100	100	100	98	100	99	86	99	99	100	90	75	109	78	93	96
		(Measurement point 1)	96	102	100	91	98	98	84	95	84	103	89	84	92	103	76	89
		(Measurement point 2)	96	102	100	89	100	100	84	94	88	108	81	89	109	81	103	97
		(Measurement point 3)	96	102	100	100	98	94	84	96	81	100	78	80	104	101	79	93

Appendix 2 Test Results (40/60, 80/100 Part 2)

Sample No.		40/60					80/100										
Items		1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	11
Asphalt	Asphalten	12.5	8.5	14.0	11.6	15.8	10.2	15.8	10.0	9.0	8.8	12.7	11.7	11.0	10.8	11.8	11.9
separation	Saturatus	15.0	14.8	13.8	18.5	13.4	14.0	16.3	13.5	15.8	15.2	15.4	15.9	15.6	17.2	16.5	15.9
%	Aromatics	52.7	55.6	49.6	43.6	52.4	51.6	43.4	54.2	51.4	52.0	50.5	50.4	51.0	48.6	47.5	48.7
	Resin	19.5	20.8	21.8	21.5	18.4	21.9	21.2	21.6	23.7	23.3	20.9	21.8	22.2	23.2	23.8	23.6
	Recovery	99.6	99.7	99.2	95.1	99.9	97.7	96.6	99.3	99.9	99.3	99.5	99.8	99.8	99.8	99.5	100.1
Paraffin content	%	2.08	1.86	2.08	0.71	2.06	1.88	1.83	2.71	1.45	1.09	2.61	2.88	3.25	3.07	3.12	3.44
Spot test		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Specific gravity	(25/25°C)	1.035	1.029	1.032	1.027	1.037	1.029	1.029	1.031	1.023	1.021	1.029	1.027	1.027	1.024	1.025	1.024
Stripping test		5X*	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-
TFOT	Mass change %	+0.09	+0.09	+0.05	-0.04	+0.09	+0.09	+0.07	+0.09	-0.03	+0.08	+0.09	-0.09	+0.03	+0.05	-0.11	0.0
	Penetration 1/10 mm	36	37	35	37	35	61	50	56	55	59	58	55	62	58	50	54
	Penetration of residue %	73.5	71.2	68.6	74.0	74.5	66.5	60.2	62.9	60.6	67.3	63.2	61.6	68.9	61.7	60.2	62.1
	Softening point °C	54.5	53.0	54.5	54.5	56.0	48.5	52.0	49.0	49.0	49.0	50.5	50.5	49.0	49.5	50.5	50.0
	P.I.	-0.82	-1.13	-0.92	-0.80	-0.60	-1.12	-0.71	-1.19	-1.23	-1.07	-0.73	-0.85	-0.95	-0.98	-1.07	-1.02
	Viscosity at 60°C poise	7930	5460	6690	9030	9120	2780	4650	2690	3110	3070	3770	3380	2460	2620	3060	2780
	Viscosity ratio at 60°C	1.87	1.78	2.00	1.90	2.05	1.85	2.50	1.98	2.21	1.98	2.40	2.58	2.02	2.26	2.51	2.14
	Ductility (15°C) cm	21	44	10	88	9	140+	32	140+	140+	140+	87	41	140+	128	68	101
Asphalt	Asphalten	14.1	10.7	14.5	13.0	16.3	12.7	17.3	12.6	11.4	11.9	14.9	14.1	13.0	13.3	15.5	13.2
separation	Saturatus	11.9	11.5	13.4	18.2	12.0	13.9	15.3	13.1	14.8	14.2	14.6	16.1	15.6	15.8	16.4	15.6
%	Aromatics	48.6	50.7	46.1	42.1	48.6	49.4	42.2	50.1	47.5	47.8	46.7	45.7	46.1	45.5	44.7	46.6
	Resin	23.5	25.2	23.8	22.0	22.5	22.5	22.6	25.0	25.1	26.3	23.3	23.6	24.2	24.4	24.2	23.8
	Recovery	98.1	98.1	97.8	95.3	99.4	98.4	97.4	100.7	99.7	100.2	99.4	99.4	98.7	99.1	100.0	99.2
Spot test		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RTFOT	Mass change %	+0.09	+0.09	+0.02	-0.10	+0.12	+0.06	+0.08	+0.11	-0.05	+0.06	+0.10	-0.14	+0.05	+0.05	-0.14	-0.3
	Penetration 1/10 mm	33	36	33	35	33	60	52	57	55	57	56	54	58	58	50	58
	Penetration of residue %	67.3	69.2	64.7	70.0	70.2	65.9	62.7	64.0	60.7	65.0	61.5	60.0	63.9	61.7	60.2	66.1
	Softening point °C	56.5	54.0	56.0	57.0	58.0	49.0	52.5	49.0	49.5	49.0	51.0	50.5	49.5	49.0	50.0	49.5
	P.I.	-0.62	-0.97	-0.72	-0.40	-0.32	-1.03	-0.50	-1.15	-1.11	-1.15	-0.69	-0.90	-0.98	-0.11	-1.20	-0.98
	Viscosity at 60°C poise	11800	6990	8060	11600	12200	2950	4320	2510	3100	3190	3690	3380	2630	2510	2910	2650
	Viscosity ratio at 60°C	2.74	2.28	2.41	2.44	2.75	1.97	2.32	1.85	2.21	2.06	2.35	2.58	2.16	2.16	2.39	2.04
	Ductility (15°C) cm	9	27	8	24	7	140+	27	140+	103	104	94	89	119	130	64	100

* Meaning less than 5X

Appendix 3 Test Results (60/80, Part 1)

Sample No.			60/80																						
Items			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Penetration	25°C	1/10 mm	65	65	63	76	68	69	70	61	72	68	63	70	71	69	66	64	66	65	70	68	71	71	69
	5°C	1/10 mm	9	10	8	10	9	10	11	9	10	8	10	10	7	8	9	7	7	6	7	9	8	8	8
Softening point	°C		48.0	49.0	47.5	46.0	47.5	48.5	48.5	48.0	46.5	47.0	48.5	46.0	46.0	48.0	49.0	49.0	48.5	48.5	47.0	49.0	48.5	48.0	48.5
P. I			-1.10	-0.83	-1.31	-1.26	-1.12	-0.81	-0.77	-1.25	-1.26	-1.26	-1.04	-1.47	-1.44	-0.95	-0.79	-0.87	-0.92	-0.96	-1.19	-0.71	-0.73	-0.87	-0.81
Viscosity at 60°C	poise		2300	2290	1680	1270	1620	1930	2210	2300	1830	2020	2430	1900	1450	2190	2140	1850	2370	1920	2630	2560	2270	1790	2430
High temperature viscosity	120°C cSt		1190	1200	832	784	859	1070	1090	1160	857	984	1120	893	751	1080	1040	920	1090	990	1000	1100	1110	907	1140
	140°C		400	401	292	273	295	363	361	383	305	349	393	318	267	382	374	329	389	358	359	398	386	330	408
	160°C		162	164	123	118	124	152	150	159	129	147	166	137	114	159	154	139	162	151	144	167	165	138	169
	180°C		80.5	86.1	63.9	60.9	62.8	77.3	73.4	78.7	66.4	75.1	83.4	69.6	58.7	80.9	77.5	70.3	81.3	77.9	72.9	83.8	82.4	70.5	84.8
Ductility	15°C		140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+	140+
	10°C		106	30	32	127	50	49	17	11	24	71	58	140+	95	46	24	34	26	25	140+	48	37	33	28
	7°C		0			5								9						16					
Solubility in trichloroethane	I		99.88	99.63	99.93	99.89	99.92	99.60	99.76	99.91	99.94	99.99	99.97	99.99	99.97	99.96	99.98	99.44	99.95	99.79	99.99	99.39	99.72	99.89	100.0
Flash point	Flash point temperature °C		361	346	351	332	344	348	320	354	342	352	347	318	359	356	315	351	356	363	296	343	333	346	330
	Froth																								
	Film																								
Loss-on-heating test	Volatilization loss %		+0.02	+0.03	-0.06	-0.02	-0.01	+0.01	0	+0.01	-0.01	+0.01	0	-0.01	+0.01	-0.01	-0.04	+0.01	+0.02	+0.02	-0.03	+0.01	+0.03	-0.02	-0.01
	Penetration ratio (X)		96.5	99.1	106.6	97.8	97.5	92.9	92.9	95.0	89.9	88.2	90.0	95.1	89.2	102.8	96.4	94.8	98.3	98.2	94.7	98.3	100.8	97.6	93.6
	(Measurement point 1)		93	102	111	100	97	94	90	90	91	88	86	94	88	102	93	91	95	96	91	100	98	100	98
	(Measurement point 2)		98	102	123	100	95	92	95	93	93	88	94	94	87	104	98	95	96	96	94	95	102	97	58
	(Measurement point 3)		95	102	106	97	98	92	87	95	91	94	97	96	90	104	98	97	98	100	97	95	103	98	100
	(Measurement point 1)		102	93	104	96	98	94	102	95	87	83	94	96	90	100	96	93	100	98	92	98	100	97	79
	(Measurement point 2)		98	96	98	91	97	89	94	95	87	89	72	96	91	100	98	95	98	95	98	100	102	93	100
	(Measurement point 3)		96	95	100	100	98	97	84	93	103	84	95	96	90	98	96	93	100	98	94	100	100	95	102

Appendix 4 Test Results (60/80, Part 2)

Sample No.		60/80																						
Items		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Asphalt separation Z	Asphalten	12.9	13.8	9.0	9.8	11.1	11.5	16.4	11.6	11.4	9.4	11.7	14.0	9.9	12.2	15.0	13.4	12.5	11.1	10.9	15.3	14.5	12.9	12.8
	Saturatus	13.1	14.8	15.6	18.2	16.5	15.5	16.1	13.4	15.8	13.6	13.1	13.1	14.8	14.8	16.5	14.3	12.7	13.8	18.1	12.4	13.8	16.2	15.1
	Aromatics	51.6	49.2	46.7	48.8	46.3	49.1	44.3	52.8	46.0	50.0	51.5	49.6	51.4	50.3	47.4	49.0	53.1	52.7	43.0	50.6	51.0	49.2	49.9
	Resin	22.9	21.2	28.0	22.9	24.7	22.8	22.6	21.8	24.7	25.7	22.0	23.3	23.5	22.1	21.2	22.7	22.8	21.4	20.2	22.0	20.4	21.1	22.1
	Recovery	100.5	99.0	99.1	99.6	98.4	98.9	99.3	99.6	98.0	98.6	98.2	99.8	99.6	99.4	100.0	99.3	101.0	99.0	91.9	100.3	99.7	99.3	99.8
Paraffin content	Z	2.30	2.25	2.00	2.07	2.54	1.72	1.55	2.16	2.50	2.11	1.69	2.21	2.76	1.67	2.17	2.84	1.55	2.14	0.43	2.00	1.71	2.68	2.14
Spot test																								
Specific gravity	(25/25°C)	1.033	1.032	1.023	1.023	1.027	1.031	1.031	1.032	1.028	1.023	1.033	1.037	1.028	1.028	1.031	1.031	1.030	1.030	1.025	1.038	1.033	1.027	1.029
Stripping Test		5X-*	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-	5X-
TFOT	Mass change	+0.09	+0.11	+0.03	+0.07	-0.02	+0.09	+0.07	+0.10	+0.04	+0.08	+0.07	+0.04	+0.11	+0.05	-0.10	+0.07	+0.11	+0.11	-0.14	+0.09	+0.11	+0.01	+0.09
	Penetration 1/10 mm	48	47	46	55	46	49	49	46	49	46	47	50	49	49	43	45	43	44	47	43	46	43	43
	Penetration of residue Z	73.8	72.3	72.2	71.8	66.9	71.0	70.0	75.4	68.1	66.9	74.6	70.7	68.3	70.3	65.2	70.3	65.2	67.7	67.1	63.2	64.8	59.9	62.3
	Softening point °C	51.0	52.5	51.0	49.5	51.0	52.0	53.0	51.0	50.5	51.0	52.5	51.0	50.0	51.5	53.0	52.0	52.0	50.5	51.0	53.5	52.0	53.0	53.0
	P.I.	-1.04	-0.74	-1.14	-1.11	-1.14	-0.76	-0.52	-1.14	-1.12	-1.14	-0.74	-0.95	-1.24	-0.88	-0.82	-0.95	-1.05	-1.35	-1.09	-0.70	-0.90	-0.82	-0.82
	Viscosity at 60°C poise	4160	4830	3260	2590	3330	3740	5290	3470	3170	3660	4710	3510	2500	4350	5270	3890	5130	3700	5730	5280	4760	4600	5900
	Viscosity ratio at 60°C	1.81	2.11	1.94	2.04	1.73	2.31	2.39	1.51	1.73	1.81	1.94	1.85	1.72	1.99	2.46	2.10	2.16	1.93	2.18	2.06	2.10	2.57	2.43
	Ductility (15°C) cm	140+	48	120	140+	66	70	21	127	68	60	57	140+	140+	54	20	48	33	80	140+	37	54	26	27
Asphalt separation Z	Asphalten	14.3	14.8	10.9	12.7	12.6	12.9	17.2	12.9	13.4	9.6	15.9	15.1	11.1	12.5	15.1	13.4	13.7	12.0	12.3	15.3	14.6	14.6	14.8
	Saturatus	12.6	13.8	15.2	16.0	15.5	13.9	15.2	11.0	14.2	12.9	10.4	9.2	10.8	12.6	13.0	12.7	13.5	13.0	16.4	11.8	12.5	14.5	14.3
	Aromatics	49.5	47.6	45.1	44.5	44.1	46.7	42.7	50.5	44.0	49.1	50.0	50.9	50.1	48.4	45.8	46.3	49.4	50.5	40.1	49.7	46.7	45.0	47.4
	Resin	23.1	23.1	28.1	26.2	27.4	24.8	23.8	24.3	26.7	25.7	23.4	24.3	27.4	25.9	25.1	26.8	23.6	24.1	21.2	22.1	22.3	23.9	22.4
	Recovery	99.5	99.3	99.3	99.4	99.6	98.3	98.9	98.6	98.3	97.3	99.7	99.5	99.4	99.4	99.0	99.2	100.2	99.5	89.9	98.8	96.0	98.0	98.8
Spot test																								
RTFOT	Mass change	+0.17	+0.15	+0.04	+0.09	-0.06	+0.09	+0.06	+0.12	+0.02	+0.08	+0.07	+0.05	+0.12	+0.06	-0.14	+0.05	+0.10	+0.10	-0.24	+0.06	+0.12	-0.01	-0.01
	Penetration 1/10 mm	44	44	41	52	45	51	46	43	46	45	47	45	44	44	39	41	43	44	47	44	46	45	44
	Penetration of residue Z	66.9	66.9	65.1	67.8	65.5	73.2	65.7	70.5	63.9	66.2	74.6	64.3	62.0	63.8	59.1	64.1	65.2	67.7	66.4	64.7	64.1	62.7	63.8
	Softening point °C	52.0	53.5	51.5	49.5	52.0	53.0	55.0	52.5	52.0	52.5	53.5	52.0	50.5	53.0	55.0	53.5	53.0	52.0	52.5	53.5	52.5	52.0	53.0
	P.I.	-1.00	-0.65	-1.27	-1.23	-0.95	-0.43	-0.22	-0.93	-0.90	-0.83	-0.74	-0.95	-1.35	-0.77	-0.59	-0.81	-0.82	-1.00	-0.74	-0.65	-0.78	-0.95	-0.77
	Viscosity at 60°C poise	4750	5120	3540	2570	4240	4610	6350	4920	4400	4300	5510	4410	2770	5160	6100	4140	5000	3520	5580	5060	4320	4150	5730
	Viscosity ratio at 60°C	2.07	2.24	2.11	2.02	2.20	2.85	2.87	2.14	2.40	2.13	2.27	2.32	1.91	2.36	2.85	2.24	2.11	1.83	2.12	1.98	1.90	2.32	2.36
	Ductility (15°C) cm	94	28	88	140+	44	39	16	56	41	57	41	120	140+	29	11	34	40	54	117	44	50	28	23

* Meaning less than 5X

Appendix 5 Properties on Test Certificates (40/60)

Grade	40/60				
Sample No.	1	2	3	4	5
Test date (1985)	7.23	8.1	6.28	8.12	7.27
Penetration (25°C) 1/10mm	51	53	51	49	52
Softening point °C	50.5	50.5	51.5	54.0	54.0
Ductility (15°C) cm	150+	100+	150+	100+	140+
Solubility in trichloroethane X	99.95	99.7	99.8	99.94	99.63
Flash point °C	358	364	330	312	300+
Mass change in TFOT X		+0.10	+0.07	+0.02	-0.08 +0.10
Penetration of residue in TFOT X	66.0	71.7	65.0	71.4	71.3
Penetration ratio after loss-on-heating test X	100	102	99	100	96
Specific gravity (25/25°C)	1.0386	1.0349	1.033	1.0276	1.0350
High temperature viscosity 120°C cSt	1430	1134	10.2 *	1350	1470
140°C	472	394	3.0 *	445	495
160°C	192	167	1.2 *	184	188
180°C	92.2	82	-	88.2	90.5

Appendix 6 Properties on Test Certificates (80/100)

Grade	80/100										
Sample No.	1	2	3	4	5	6	7	8	9	10	11
Test date (1985)	7.23	7.30	8.19	7.30	8.1	8.4	8.2	8.31	8.9	8.6	8.14
Penetration (25°C) 1/10mm	94	91	88	89	87	88	91	88	94	93	90
Softening point °C	45.5	47.5	46.0	46.0	47.0	48.0	45.0	48.0	45.0	45.5	47.5
Ductility (15°C) cm	150+	150+	100+	100+	100+	140+	130+	100+	150+	140+	150+
Solubility in trichloroethane %	99.95	99.95	99.90	99.90	99.90	99.7	99.74	99.93	99.91	99.90	99.60
Flash point °C	358	350	350	320	362	300+	304	310	330	316	328
Mass change in TFOT %	X	+0.10	+0.09	+0.10	+0.03	+0.08	+0.08	-0.05	+0.01	+0.08	-0.04 +0.01
Penetration of residue in TFOT %	64	71.4	67.0	65	65.5	69.3	62.6	71.0	53.1	59.1	65.6
Penetration ratio after loss-on-heating test %	100	97.7	100	99	101	98	98	93	102	99	100
Specific gravity (25/25°C)	1.0320	1.028	1.0308	1.0234	1.0288	1.0302	1.0294	1.0276	1.0220	1.024	1.0245
High temperature viscosity 120°C cSt	758	847	795	820	850	964	810	885	683	660.0	697
140°C	276	306	288	296	313	344	297	305	263	249.7	264
160°C	122	133	128	130	139	152	131	131	115	110.0	118
180°C	62.1	75.9	67.2	68.2	70	78.8	-	66.0	56.5	58.4	65.1

* Unit: Poise

Appendix 7 Test Certificates (60/80)

Grade	60/80											
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
Test date (1985)	7.23	9.18	7.3	8.7	8.6	6.29	7.30	8.19	7.26	8.1	8.4	8.5
Penetration (25°C) 1/10mm	66	66	68	79	75	70	67	65	71	67	66	73
Softening point °C	48.5	48.0	49.5	45.5	47.5	49.0	49.5	49.5	48.5	48.0	50.0	48.0
Ductility (15°C) cm	150+	150+	100+	150+	140+	150+	150+	100+	150+	100+	140+	150+
Solubility in trichloroethane %	99.95	99.90	99.85	99.83	99.86	99.87	99.95	99.96	99.67	99.7	99.70	99.97
Flash point °C	358	270+	352	342	340	346	350	356	340	362	300+	326
Mass change in IPOT %	+0.10	+0.04	+0.09	+0.12	-0.07	+0.10	+0.09	+0.11	+0.02	+0.06	+0.08	+0.03
Penetration of residue in IPOT %	65	66	76.5	57.9	63.2	70.0	71.6	67.7	68.1	64.2	68.2	69.9
Penetration ratio after loss-on-heating test %	100	100	100	100	102	98.6	98.5	100	97.0	102	97	102.9
Specific gravity (25/25°C)	1.035	1.032	1.025	1.023	1.024	1.031	1.031	1.032	1.028	1.031	1.033	1.038
High temperature viscosity 120°C cSt	1060	1000	777	732	780	1000	1100	1040	842	965	1230	1031
140°C	366	358	279	294	283	352	383	365	307	344	422	354
160°C	155	155	124	129	124.0	154	158	159	136	149	177	151
180°C	76.5	77.4	62.0	62.0	64.2	78.0	85.7	80.5	74.0	74.0	92.4	76.5

Appendix 7 (cont'd)

Grade		60/80										
Sample No.		13	14	15	16	17	18	19	20	21	22	23
Test date (1985)		8.2	7.24	8.2	8.30	7.15	6.19	8.10	8.	8.1	8.14	9.3
Penetration (25°C) 1/10mm		69	66	72	65	65	68	71	67	68	69	74
Softening point °C		47.0	50.0	47.0	49.5	50.0	48.0	49.5	49.5	48.0	49.5	50.0
Ductility (15°C) cm		150+	150+	130+	100+	150+	150+	100+	140+	140+	150+	100+
Solubility in trichloroethane %		99.98	99.84	99.90	99.91	99.89	99.8	99.91	99.98	99.70	99.64	99.99
Flash point °C		366	362	320	322	340	366	304	300+	300+	342	322
Mass change in TFOT %		+0.13	+0.06	-0.14	+0.02	+0.06	+0.08	-0.10	+0.06	+0.10	+0.03	+0.02
Penetration of residue in TFOT %		65.2	65.2	68.1	75	64.9	76.0	67.6	81.2	70.0	68.1	93.2
Penetration ratio after loss-on-heating test %		97	-	98	92	92.8	93	100	103	100	100	96.9
Specific gravity (25/25°C)		1.029	1.029	1.031	1.029	1.031	1.030	1.025	1.034	1.034	1.027	1.030
High temperature viscosity	120°C cSt	704	1020	993	960	995	937	990	1060	1250	926	1187
	140°C	270	365	358	330	365	339	337	383	425	337	410
	160°C	105.0	166	155	143	158	147	148	167	178	145	171
	180°C	55.7	83.5	77.6	71.0	78.0	73.6	71.2	84.2	82.0	75.6	85.7

Survey on Straight Asphalt Properties
in Japan

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要旨

Properties of all straight asphalt for road pavement in Japan were examined in 1985. This paper reports results of the survey, and has clarified current situation of the straight asphalt properties and problems of the specification.

キーワード : Pavement, Straight Asphalt, Quality Standards,
Physical Properties and Chemical Analysis

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