CENTER FOR TRANSPORTATION RESEARCH

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

TEXAS TRANSPORTATION INSTITUTE

HOT-MIX ASPHALTIC CONCRETE

A REFRESHER COURSE

WINTER 1982-83

HOT-MIX ASPHALTIC CONCRETE

-A Refresher Course-

by

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Winter 1982-83

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* Interlayers

ASPHALT CONCRETE

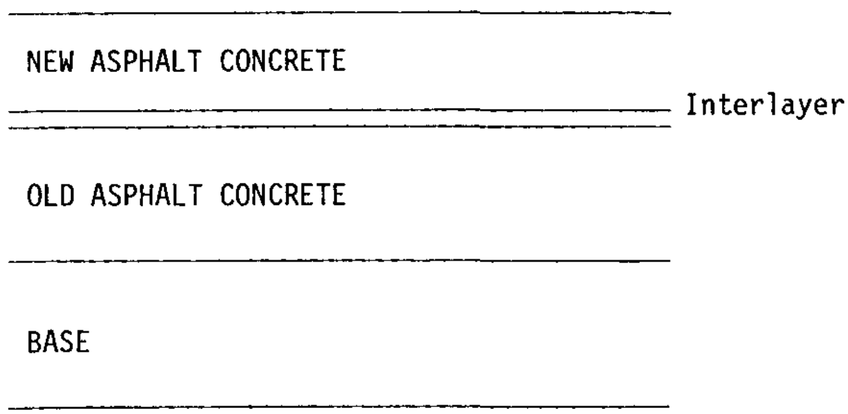
BLACK BASE

BASE

OPEN GRADED

OLD ASPHALT CONCRETE

BASE


NEW ASPHALT CONCRETE
Interlayer
OLD ASPHALT CONCRETE
BASE

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* Drum Mixers
* Vibratory Rollers
* Thin Overlays
* Air Quality Regulations

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* Magnitude of Load
* No. of Repetitions
* Tire Pressure

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* Aggregates
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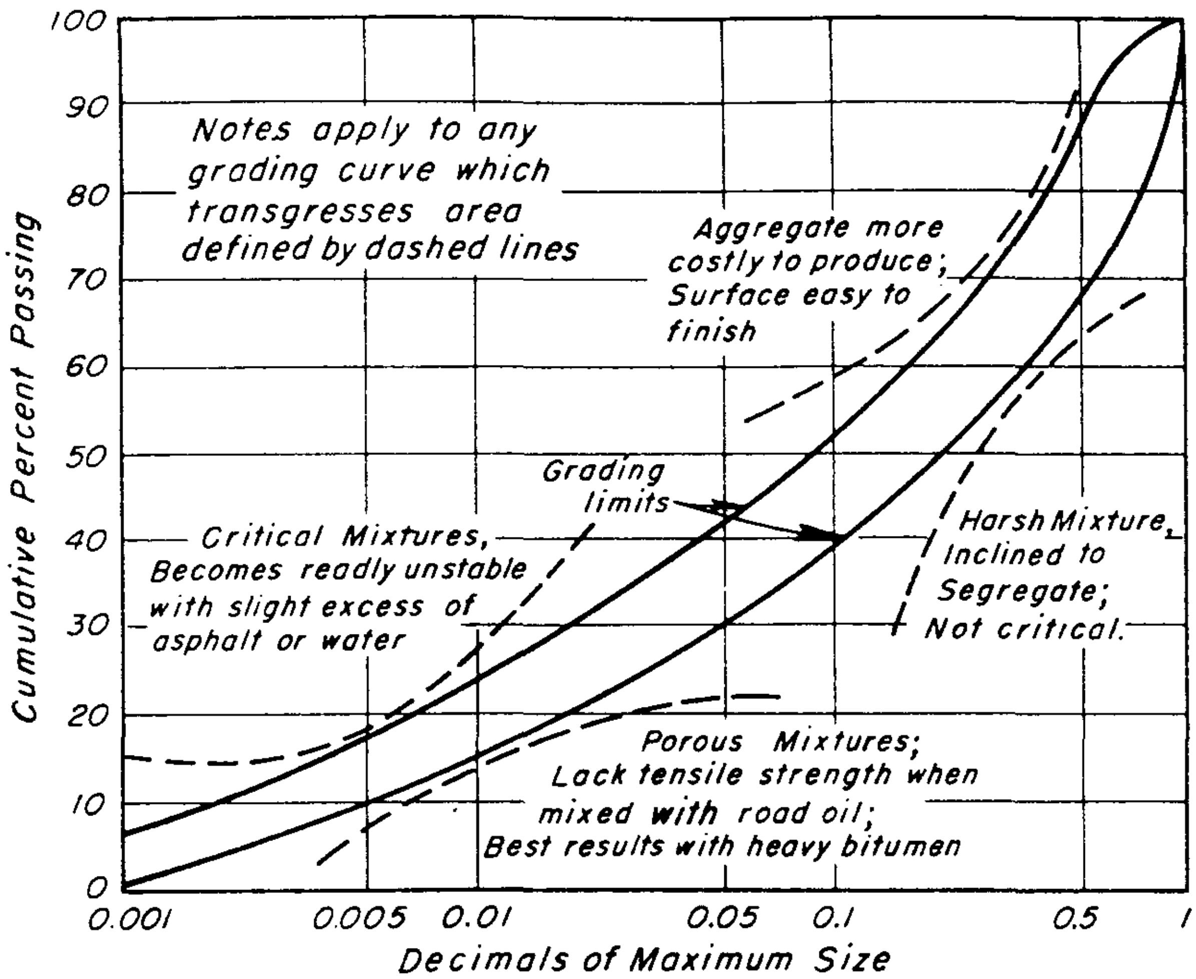


Figure C10. Grading Chart Illustrating Grading Specifications Established to Avoid Undesirable Conditions. (California Division of Highways)

IMPROVE QUALITY OF BINDER

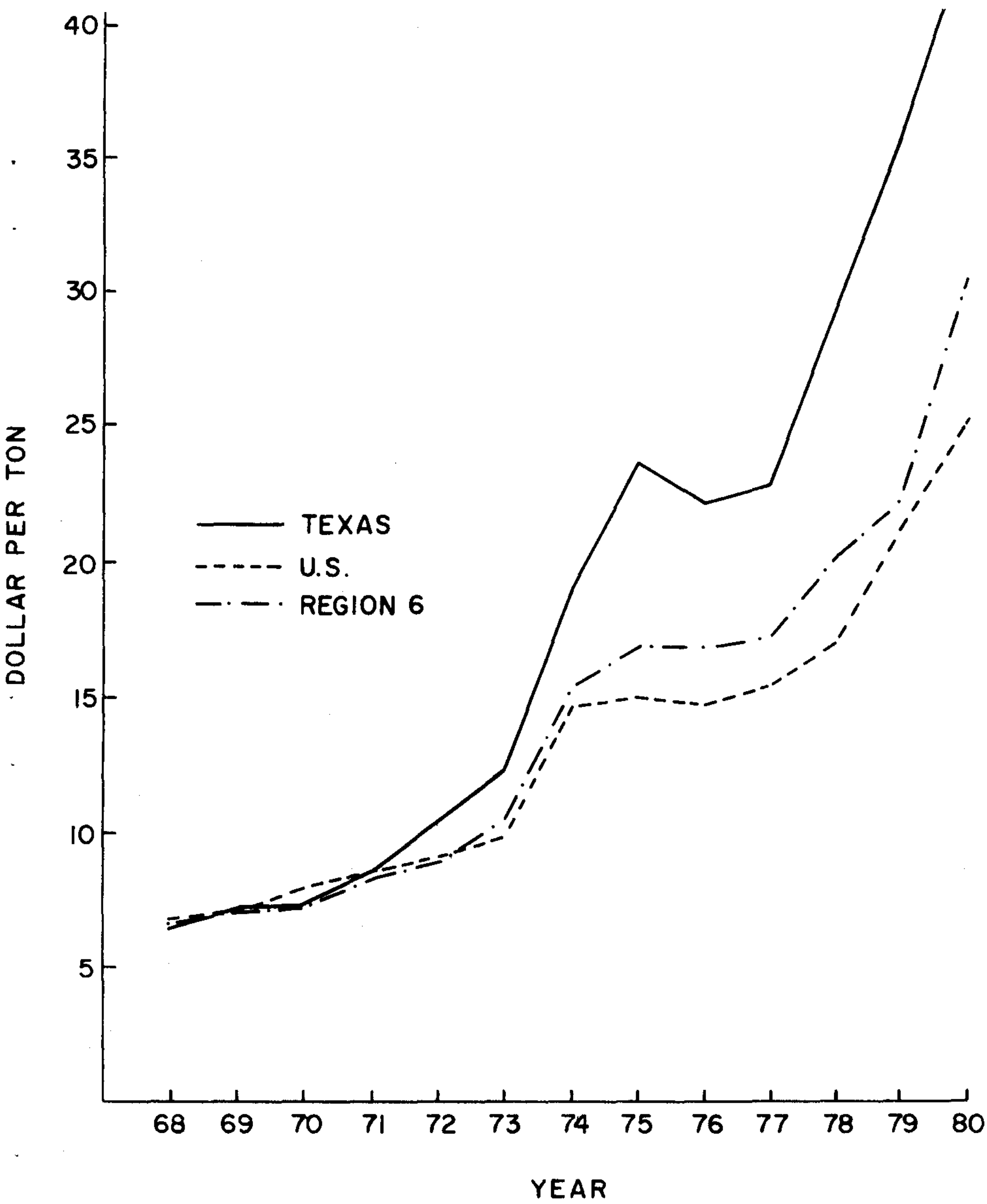


FIGURE 5. AVERAGE ANNUAL CONTRACT PRICE FOR BITUMINOUS CONCRETE

(AFTER REFERENCE 1)

Refining Asphalt

Atmospheric Distillation

Distillation at Reduced Pressure

Air Blowing

Solvent Refining

CRUDE OIL

1,450 Crude Oil Streams Available in Free World

975 Crude Oil Streams Presently Used in Free World

190 Crude Oil Streams Are Suitable for Manufacturing Asphalt

$\sim$ 40 Crude Oil Streams Used in Given Region of U.S.,

East Coast, West Coast, Gulf Coast, Etc.

PETROLEUM, ASPHALT AND TARS

A. Petroleum

Includes

- Asphalt Base
- Mixed Base
- Paraffin Base

- Gasoline
- Naptha
- Kerosene
- Diesel
- Lube Oil
- Asphalt & Or Wax

1. Amount of constituents depends on crude.

2. Some crudes have very little (<5%) asphalt or wax.

3. In general >25% asphalt in a crude will make it economical to refine for asphalt.

4. As low as 10% in some cases.

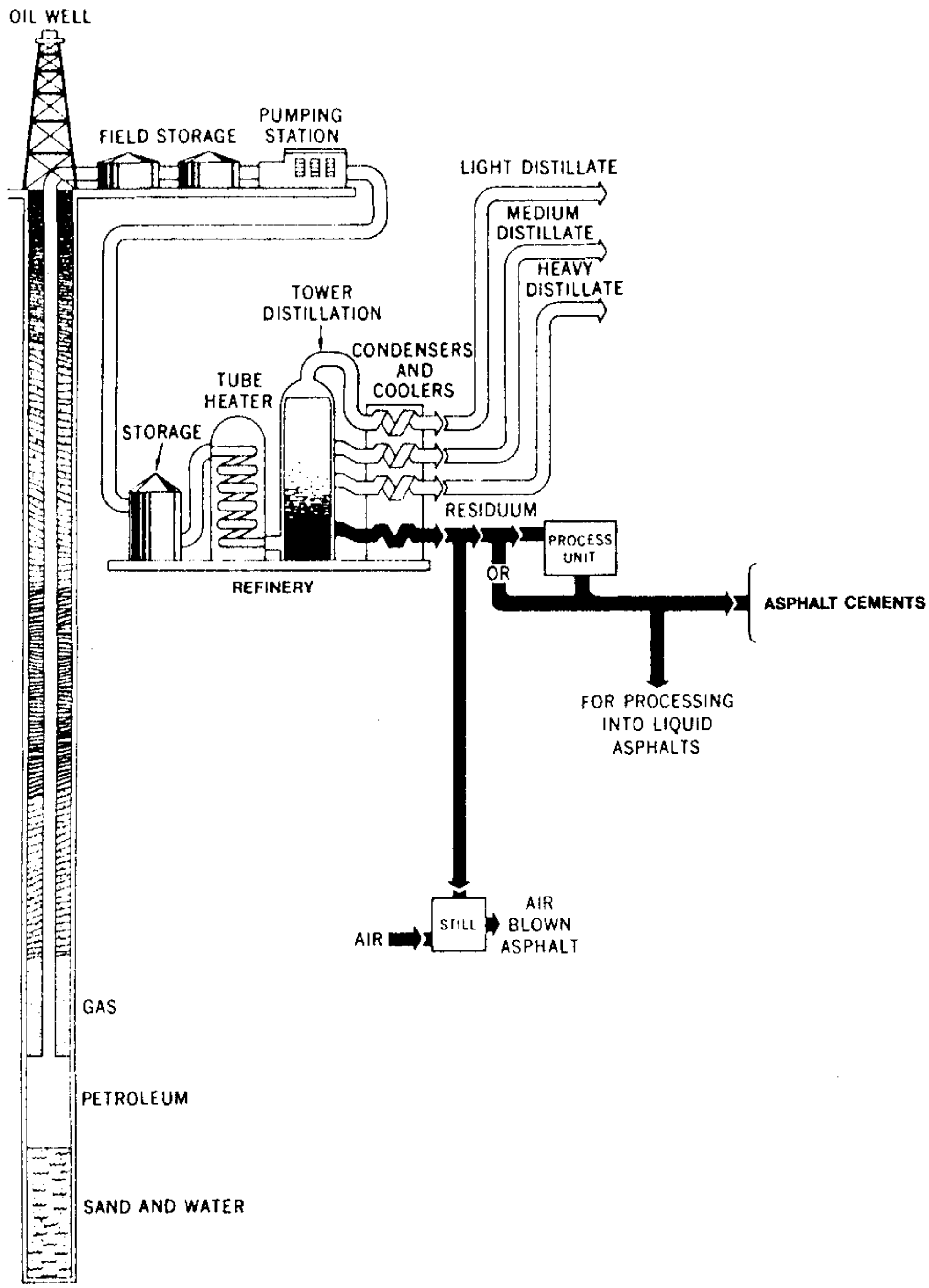
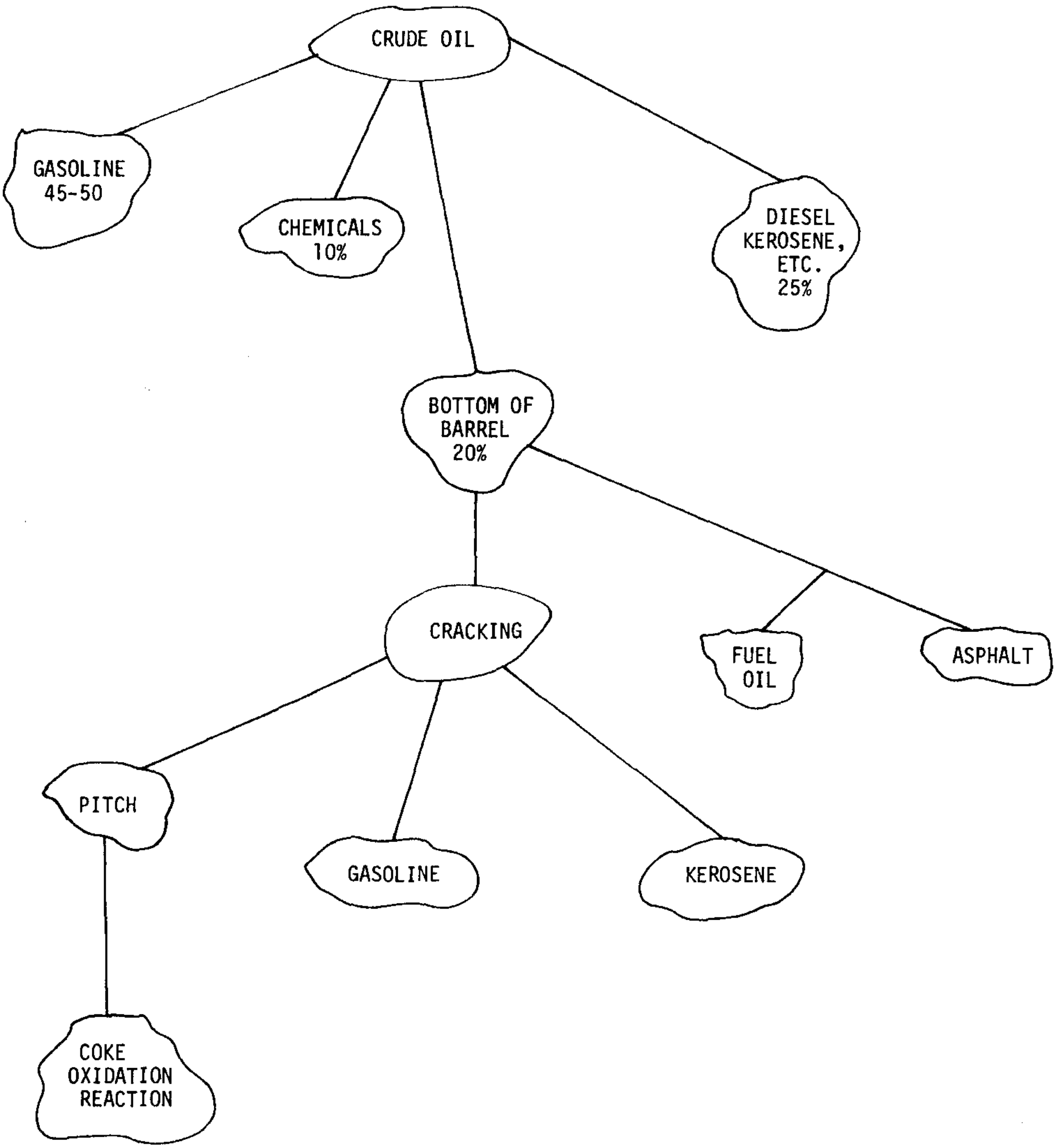


Figure 1. Petroleum asphalt flow chart for asphalt cement


CRUDE OIL
GASOLINE
45-50
CHEMICALS
10%
DIESEL
KEROSENE,
ETC.
25%
BOTTOM OF
BARREL
20%
CRACKING
FUEL
OIL
ASPHALT
PITCH
GASOLINE
KEROSENE
COKE
OXIDATION
REACTION

Texas State Department of Highways and Public Transportation-Standard Specifications for Asphalt Cement (1972)

Test	VISCOSITY GRADE									
	AC-3		AC-5		AC-10		AC-20		AC-40	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Viscosity, 140 F stokes	300±50		500±100		1000±200		2000±400		4000±800	
Viscosity, 275 F stokes	1.1		1.4		1.9		2.5		3.5	
Penetration, 77 F, 100g, 5 sec.	210		135		85		55		35	
Flash Point, C.O.C. F	425		425		450		450		450	
Solubility in trichloroethylene, percent	99.0		99.0		99.0		99.0		99.0	
Tests on residues from thin film oven test:										
Viscosity, 140 F stokes		900		1500		3000		6000		12000
Ductility, 77 F 5 cms per min, cms.	100		100		70		50		30	
Spot test	Negative for all grades									

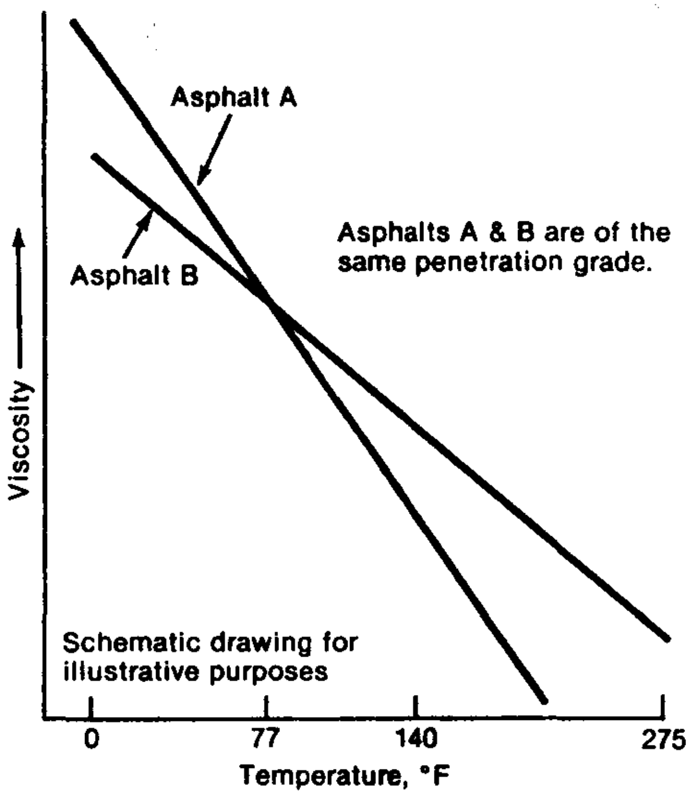


Figure 4 — Variation in viscosity of two penetration graded asphalts at different temperatures.

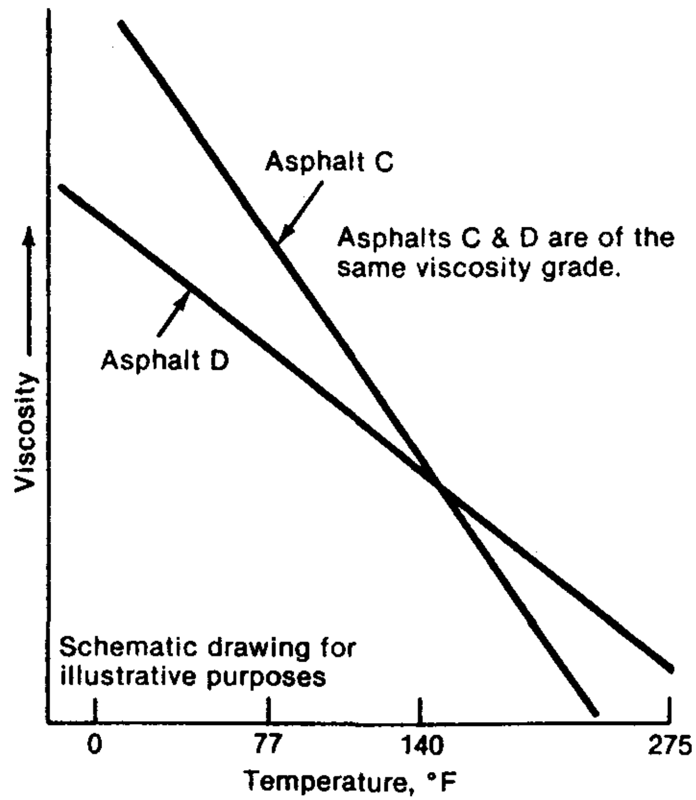


Figure 5 — Variation in viscosity of two viscosity graded asphalts at different temperatures.

Table . Asphalt Producer Codes

Refinery Code		Producer	Location/ City	State of Location
SDHPT*	TTI**			
0	3	American Petrofina Co.	Mt. Pleasant	TX
1	10	APCO	Cyril	OK
2		Vickers Petroleum Corp.	Ardmore	OK
3	15	Chevron	El Paso	TX
4	1	Odsoen Oil & Chem. Co.	Big Spring	TX
5	8	Diamond Shamrock O&G Co.	Sunray	TX
6	6	Exxon Co.	Baytown	TX
7	5	Gulf States Asph. Co.	Beaumont	TX
8	21	Gulf States Asph. Co.	Corpus Christi	TX
9	12	Gulf States Asph. Co.	Houston	TX
10	17	Kerr McGee Oil Industries	Wynnewood	OK
11		Okmulgee Refining Co.	Okmulgee	OK
12	11	Texaco Inc.	Port Neches	TX
13	22	Texas Emulsions Inc.	Austin	TX
14	23	Texas Emulsions Inc.	Port Neches	TX
15	24	Texas Fuel & Asph. Co.	LaCoste	TX
16	16	Trumbull Asph. Co. - H	Houston	TX
17	9	Trumbull Asph. - IR	Irving	TX
18		Nuway Emulsions	Admore	OK
19		Nuway Emulsions	Arlington	TX
20		Texas Emulsions	Corpus Christi	TX
21		Nuway Emulsions	Woodward	OK
22		Nuway Emulsions	Pleasanton	TX
23		Nuway Emulsions, Inc.	Garland	TX
24		Macmillan Ring Free Oil Co. Inc.	Norphlet	AR
25		Texas Fuel & Asph. Co.	Corpus Christi	TX
26		Dorchester Refining Co. (formerly American Petrofina)	Mt. Pleasant	TX
27		Tosce Corporation	Eldorado	AR
28		Oklahoma Refining Co. (formerly APCO)	Cyril	OK
29		Pitucote Products Co.	El Dorado	AR
30		Bitucote Products Co.	Lake Charles	LA

*Code used by Texas State Department of Highways and Public Transportation

**Code used by Texas Transportation Institute from 1957 to May 1981. After May 1981 Texas Transportation Institute has used SDHPT codes

Table 5. Typical Properties of AC-10 Asphalt Cements Used in Texas - Spring 1981

Refinery Code	Original					After Test				
	Penetration 77°F sec, dmm	Viscosity 140°F Stokes	Viscosity 275°F Stokes	Flash Point COC, °F	Specific Gravity	Viscosity 140°F Stokes	Viscosity Ratio	Penetration 77°F sec, dmm	Retained Penetration Percent	Ductility 77°F cm
2	86	1116	3.46	600	0.995					
4	91	895	2.32	600	1.029	2043	2.28	55	60	141
5	118	976	5.89	600	0.985	1524	1.36	84	71	141
6	99	1145	2.60	600	1.020	2018	1.76	63	64	141
8	91	986	2.40	600	1.021	1885	1.91	61	67	141
9	88	1102	2.60	600	1.023	2313	2.10	55	63	141
10	100	1005	3.24	600	1.003	2153	2.14	62	62	141
11	128	951	3.30	600	0.993	1678	1.76	90	70	141
12	123	1004	3.35	590	1.030	2106	2.10	80	65	141
15	107	1011	3.10	595	1.025	2542	2.51	63	59	141
16	105	886	2.37	600	1.028					
26	119	1007	3.40	600	1.023					

Table 6. Typical Properties of AC-20 Asphalt Cements Used in Texas - Spring 1981

Refinery Code	Original					After Test				
	Penetration 77°F sec, dmm	Viscosity 140°F Stokes	Viscosity 275°F Stokes	Flash Point COC °F	Specific Gravity	Viscosity 140°F Stokes	Viscosity Ratio	Penetration 77°F sec, dmm	Retained Penetration Percent	Ductility 77°F cm
2	63	1910	4.11	600	1.009					
3	75	1980	3.61	580	1.011	5108	2.58	50	67	141
4	60	1649	3.20	590	1.039	3771	2.29	38	63	141
5	80	1691	6.27	600	0.990	2842	1.68	58	73	141
6	67	1847	3.39	600	1.028	3683	1.99	44	66	141
9	60	1983	3.55	600	1.026	3320	1.67	42	70	141
10	57	2253	4.60	600	1.015	4878	2.17	40	70	141
12	83	1992	4.67	600	1.035	4302	2.16	52	63	141
15	80	2007	4.60	600	1.035	5253	2.62	49	61	141
16	63	1691	3.17	600	1.031	3829	2.26	38	60	141
17	58	2301	4.41	600	1.024	6104	2.65	35	60	141
24	95	2083	4.60	600	1.017	3757	1.80	69	73	141
26	87	1836	4.17	585	1.041					

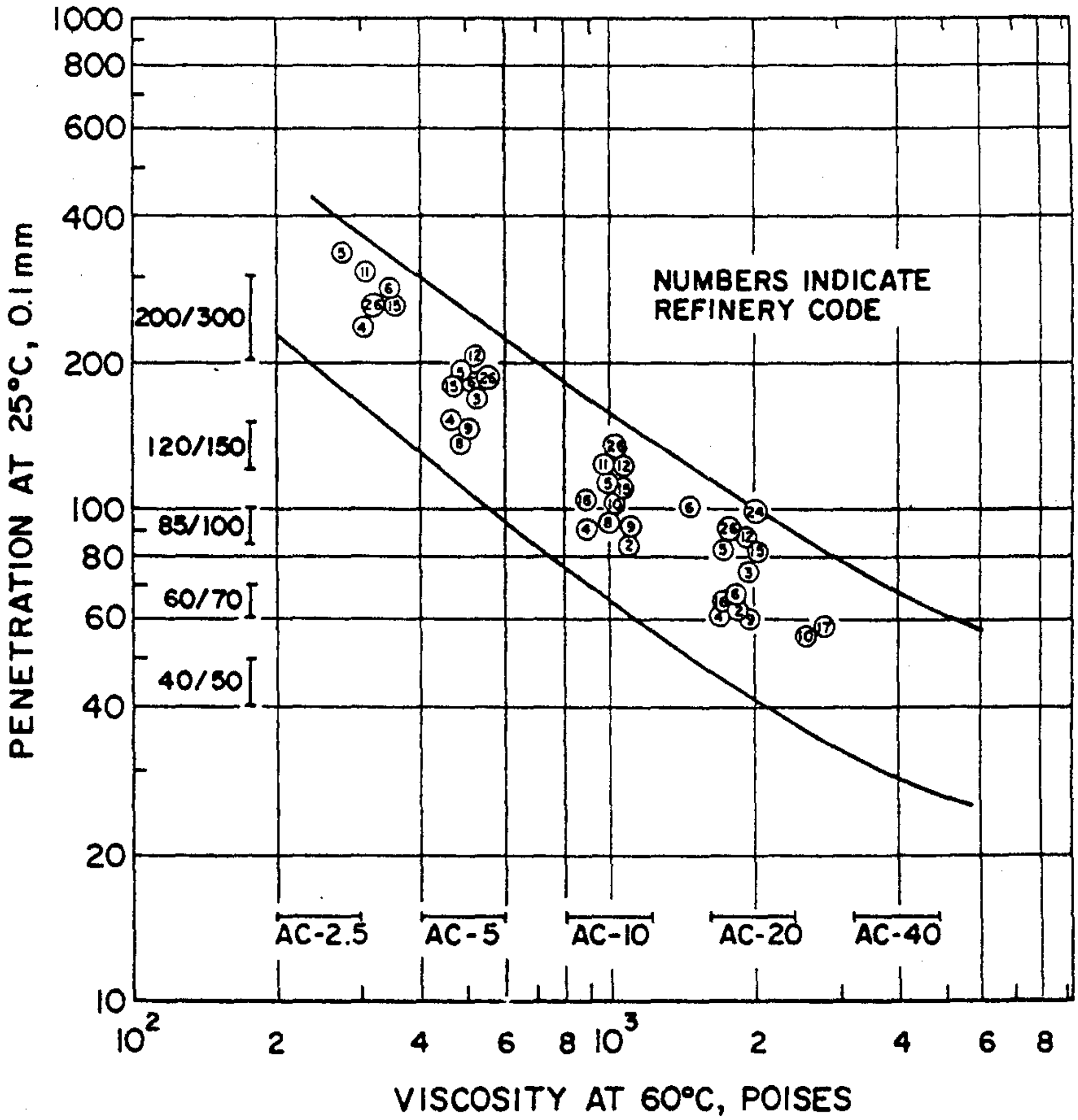


FIGURE 3. RELATIONSHIP BETWEEN VISCOSITY AT 60°C (140°F) AND PENETRATION AT 25°C (77°F) FOR ASPHALTS CEMENTS

(AFTER REFERENCE 14)

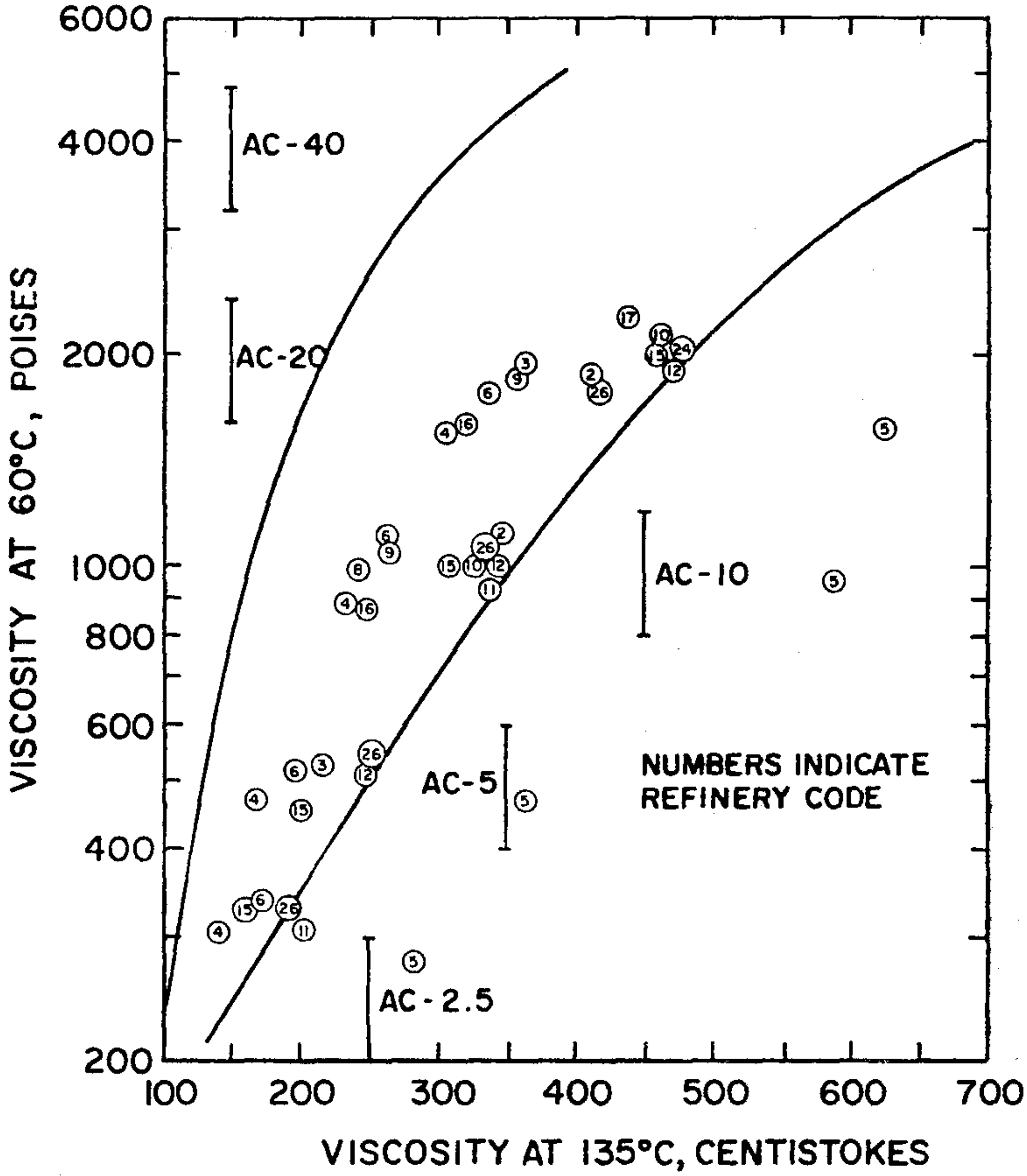


FIGURE 4. RELATIONSHIP BETWEEN VISCOSITY AT 60°C (140°F) AND 135°C (275°F) FOR ASPHALT CEMENTS

(AFTER REFERENCE 14)

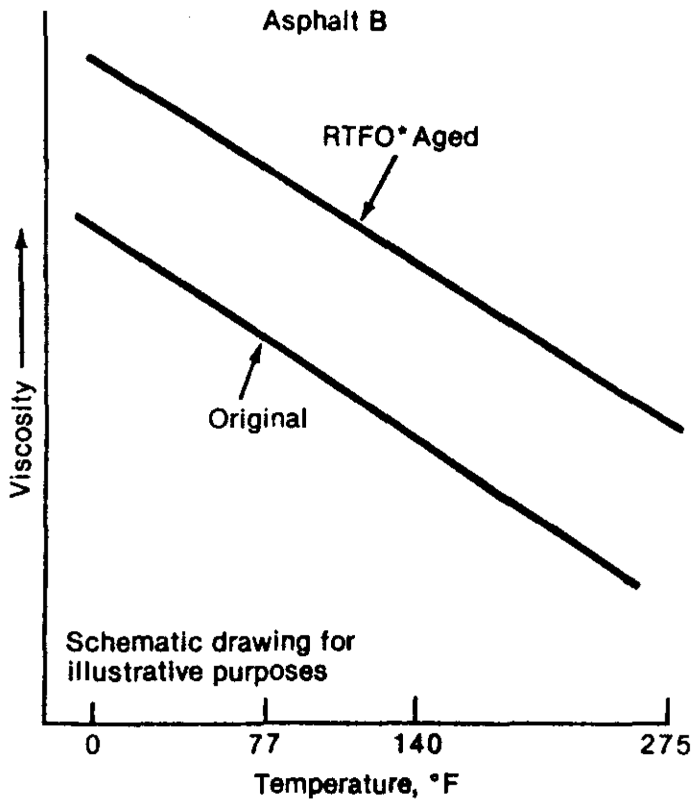


Figure 6 — After exposure to high temperature, asphalt becomes harder.

*RTFO — Rolling Thin Film Oven Test, used to simulate asphalt exposure in a pugmill.

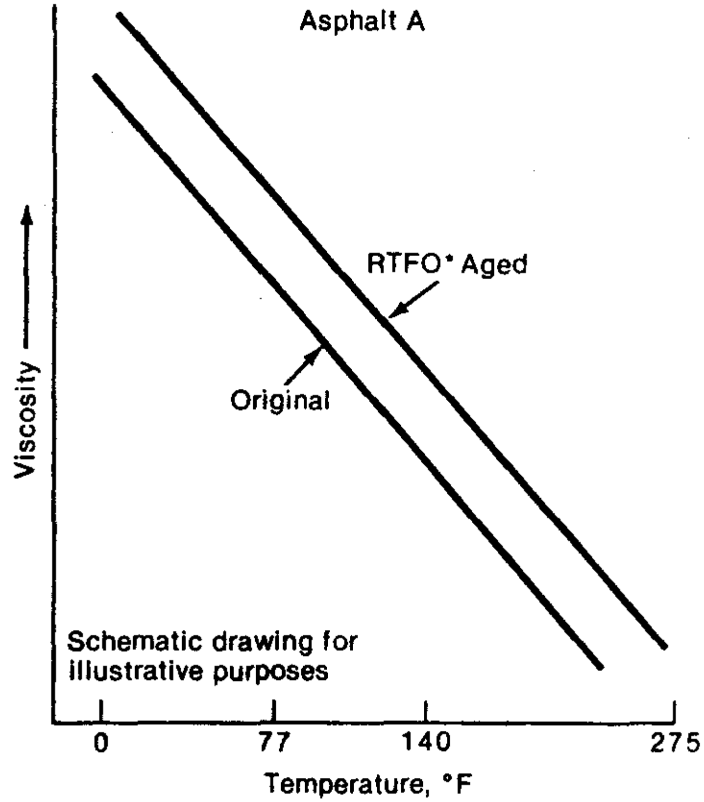


Figure 7 — All asphalts do not harden the same. Compare with Figure 6.

Note — Figures 6 and 7 (as do 4 and 5) show general relationships of the temperature and consistency of asphalts. These figures are not precise, but are schematic drawings for illustrative purposes.

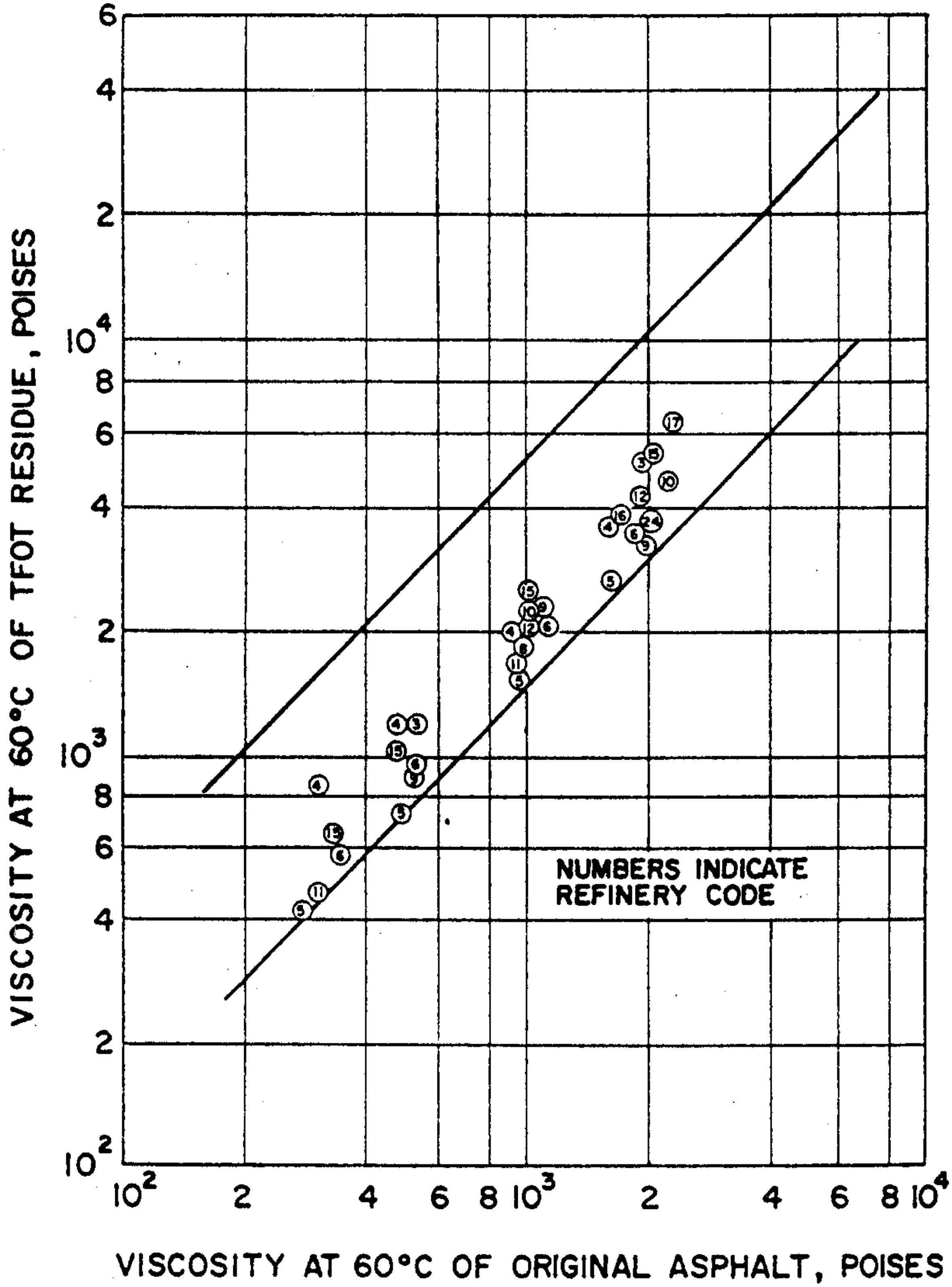


FIGURE 5. RELATIONSHIP BETWEEN VISCOSITY AT 60°C (140°F) FOR ORIGINAL AND HEATED ASPHALT CEMENTS

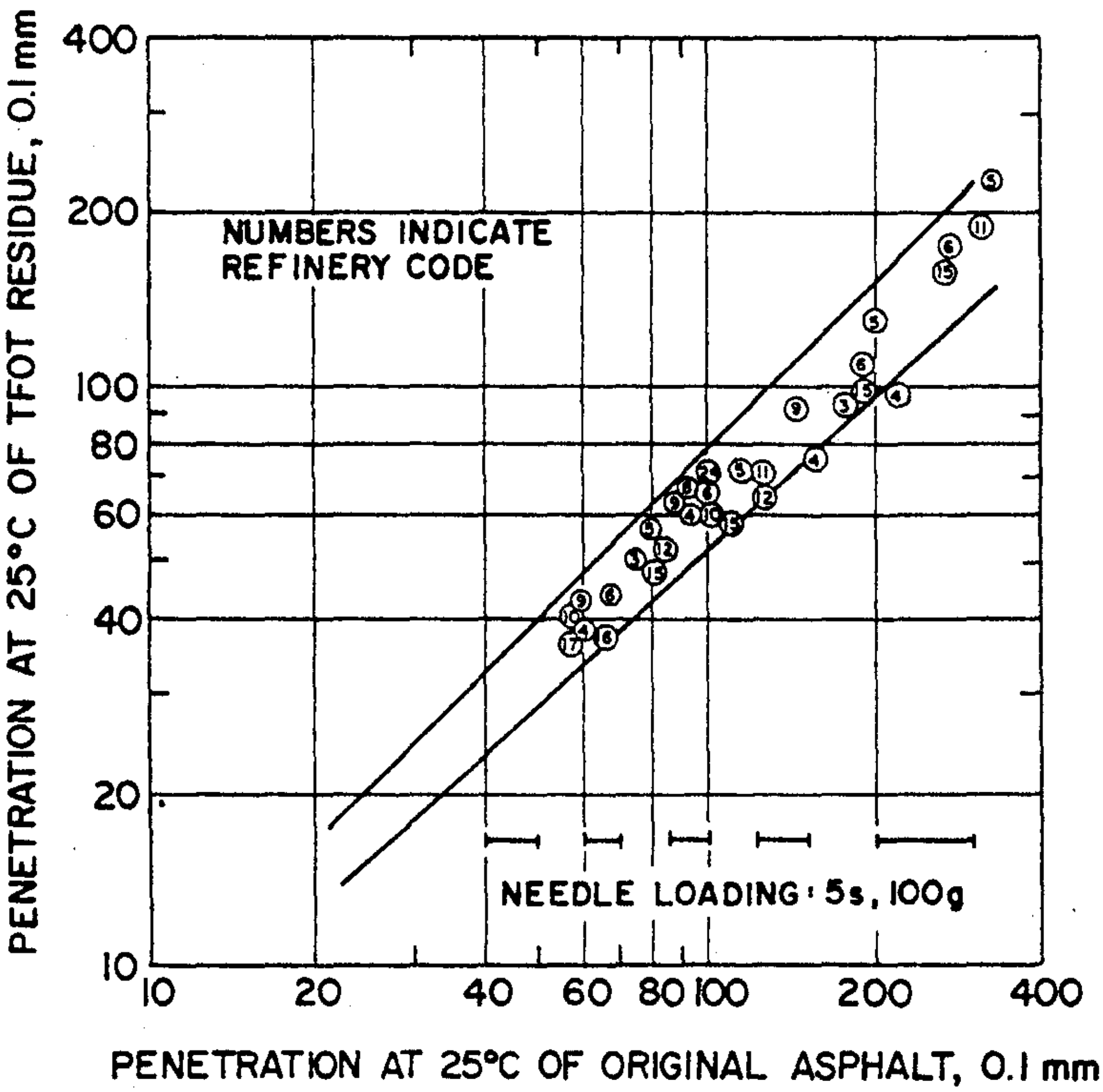


FIGURE 6. EFFECT OF TFOT HEATING ON PENETRATION AT 25°C (77°F) FOR ASPHALT CEMENTS

(AFTER REFERENCE 14)

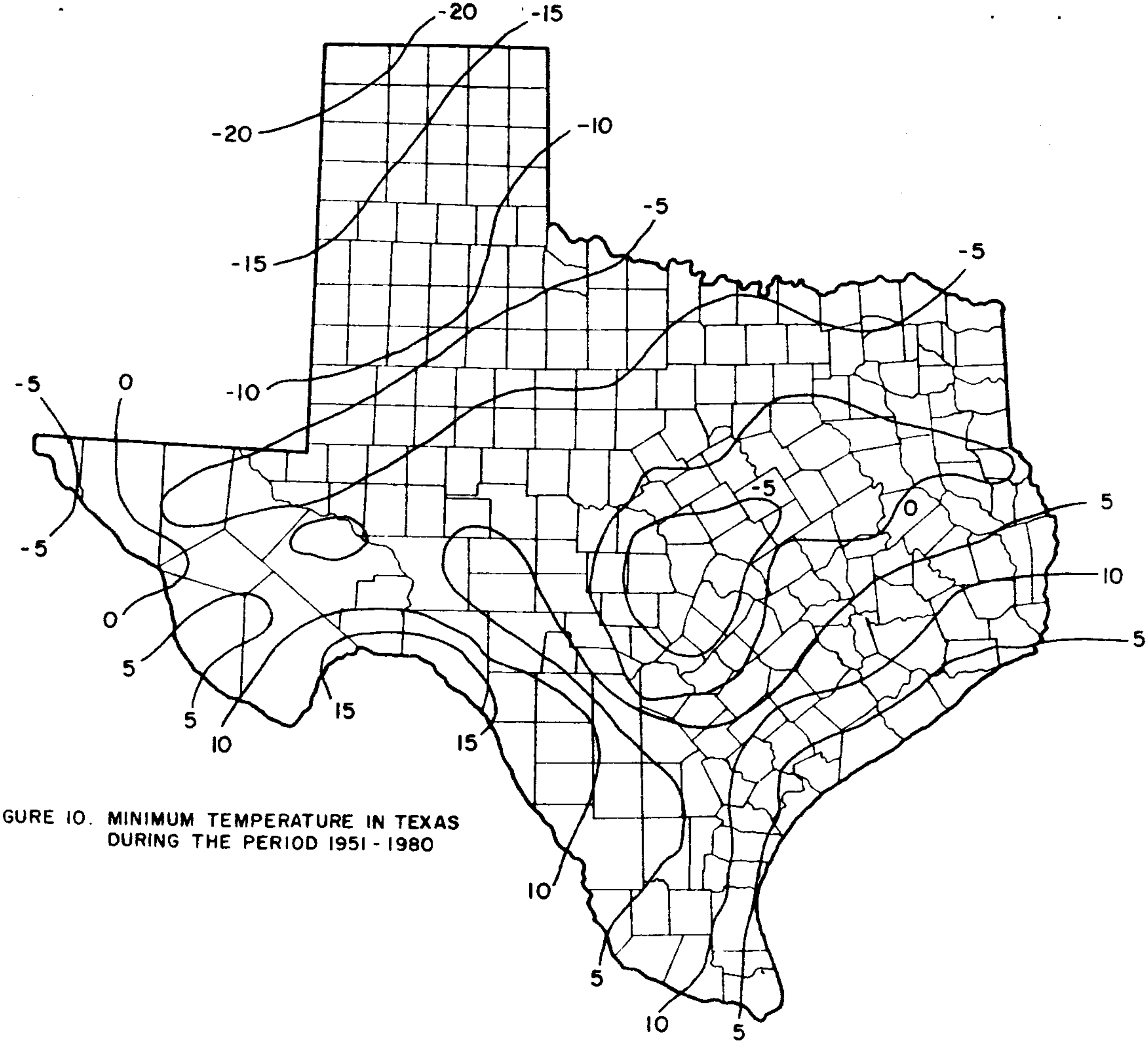


FIGURE 10. MINIMUM TEMPERATURE IN TEXAS DURING THE PERIOD 1951 - 1980

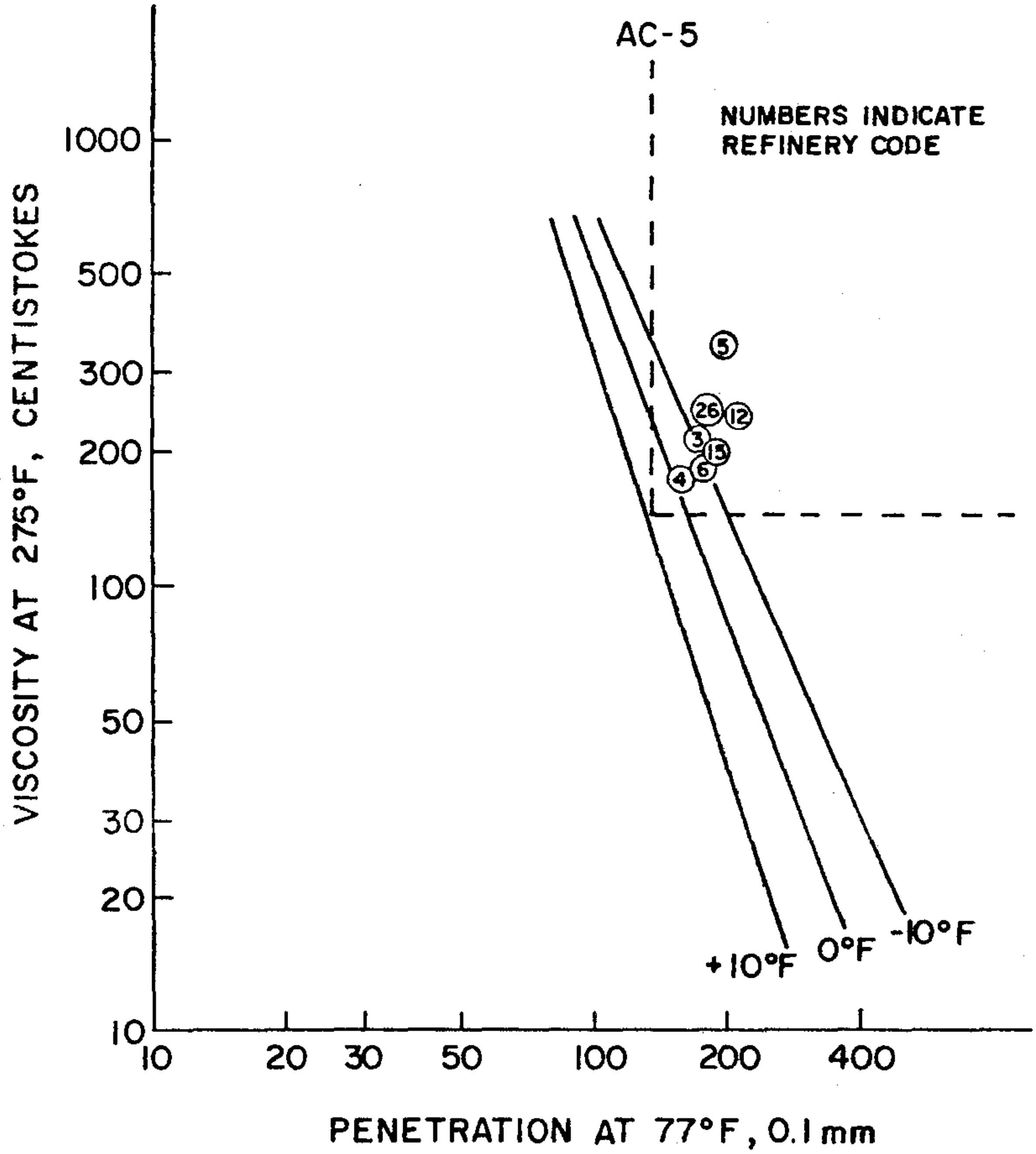


FIGURE 7. ALLOWABLE MINIMUM TEMPERATURE FOR AC-5 ASPHALTS

(AFTER REFERENCE 16)

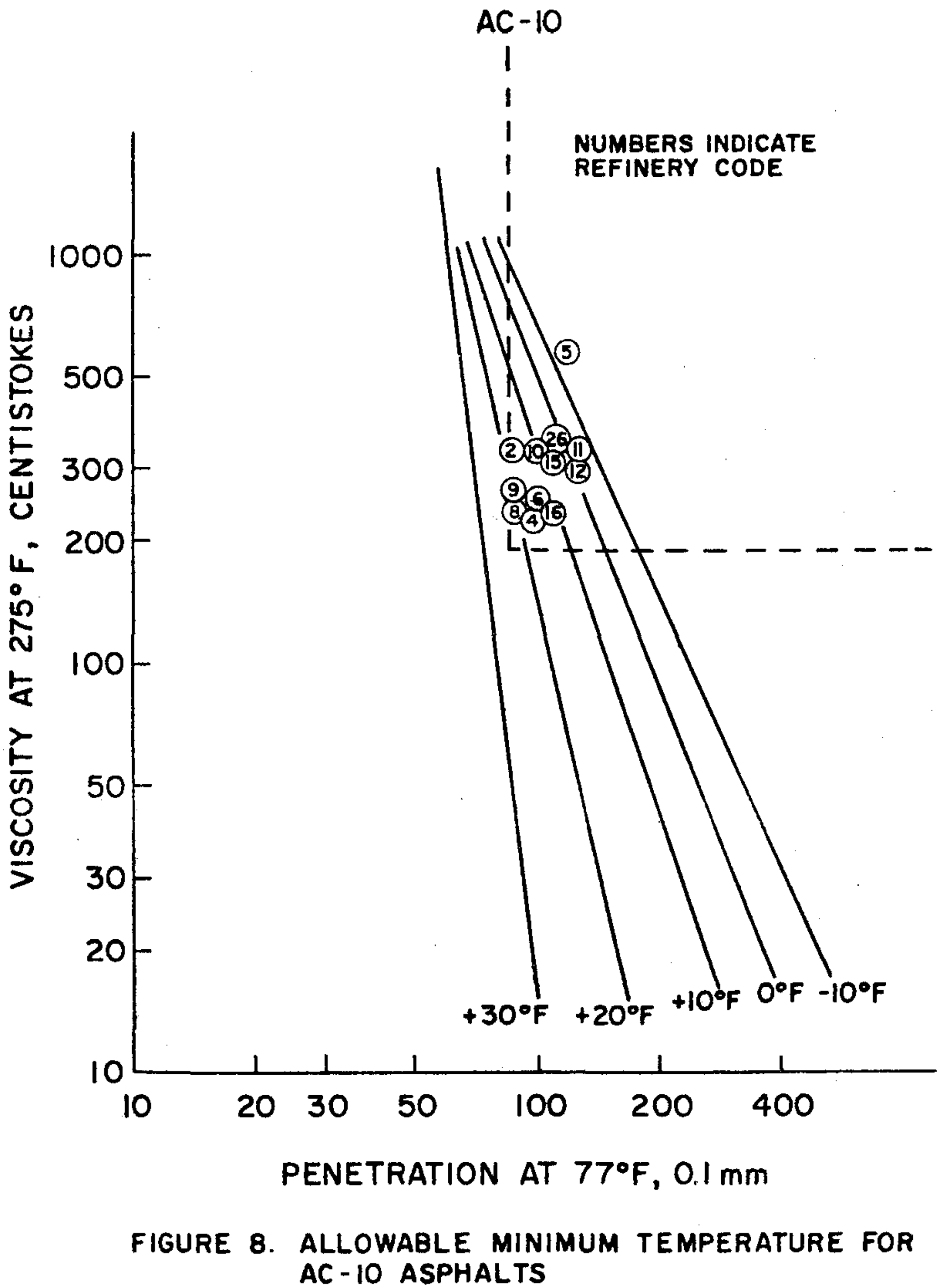


FIGURE 8. ALLOWABLE MINIMUM TEMPERATURE FOR AC-10 ASPHALTS

(AFTER REFERENCE 16)

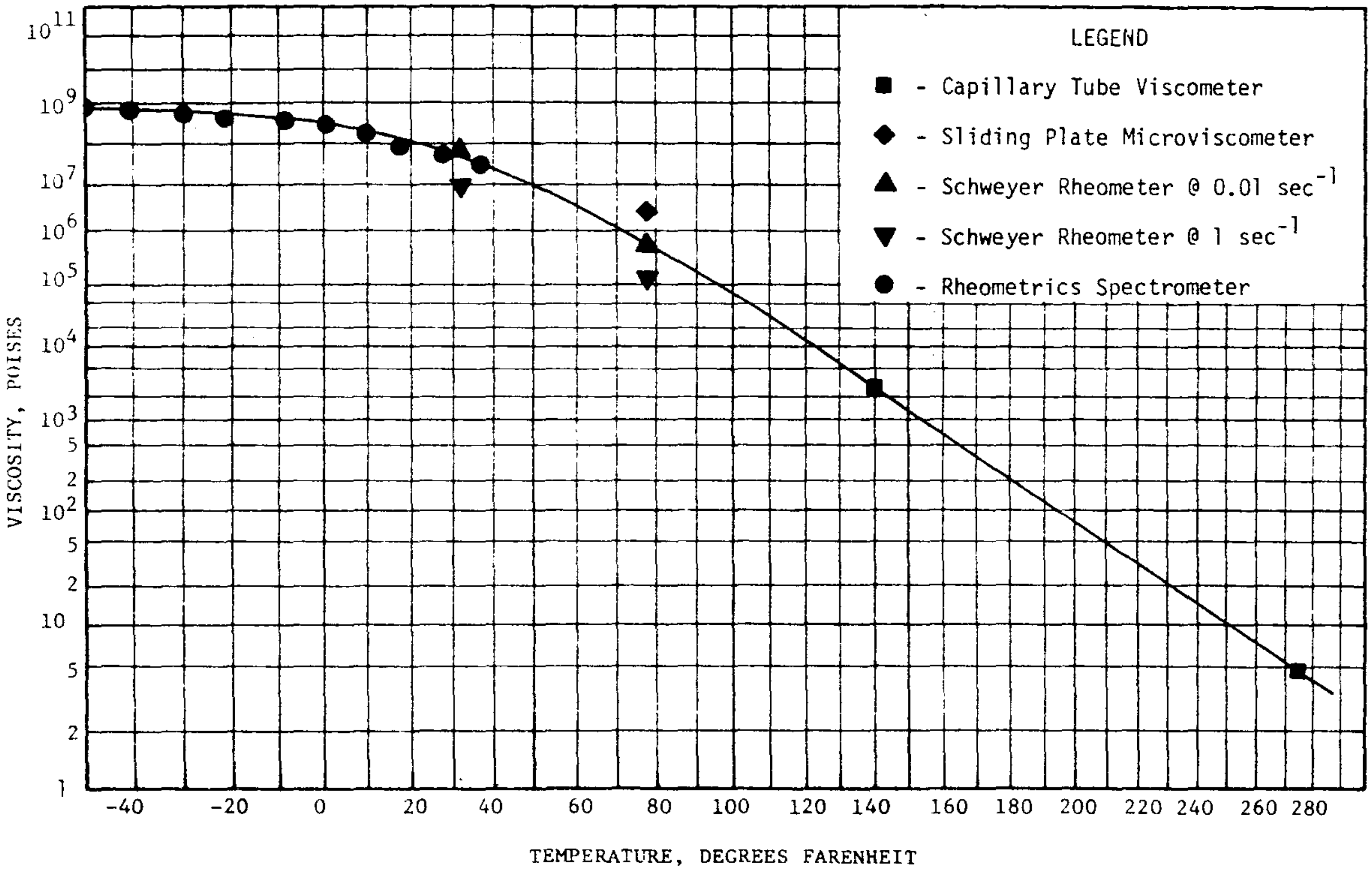


Figure E2. Viscosity as a Function of Temperature for Asphalt A2 (after TFOT).

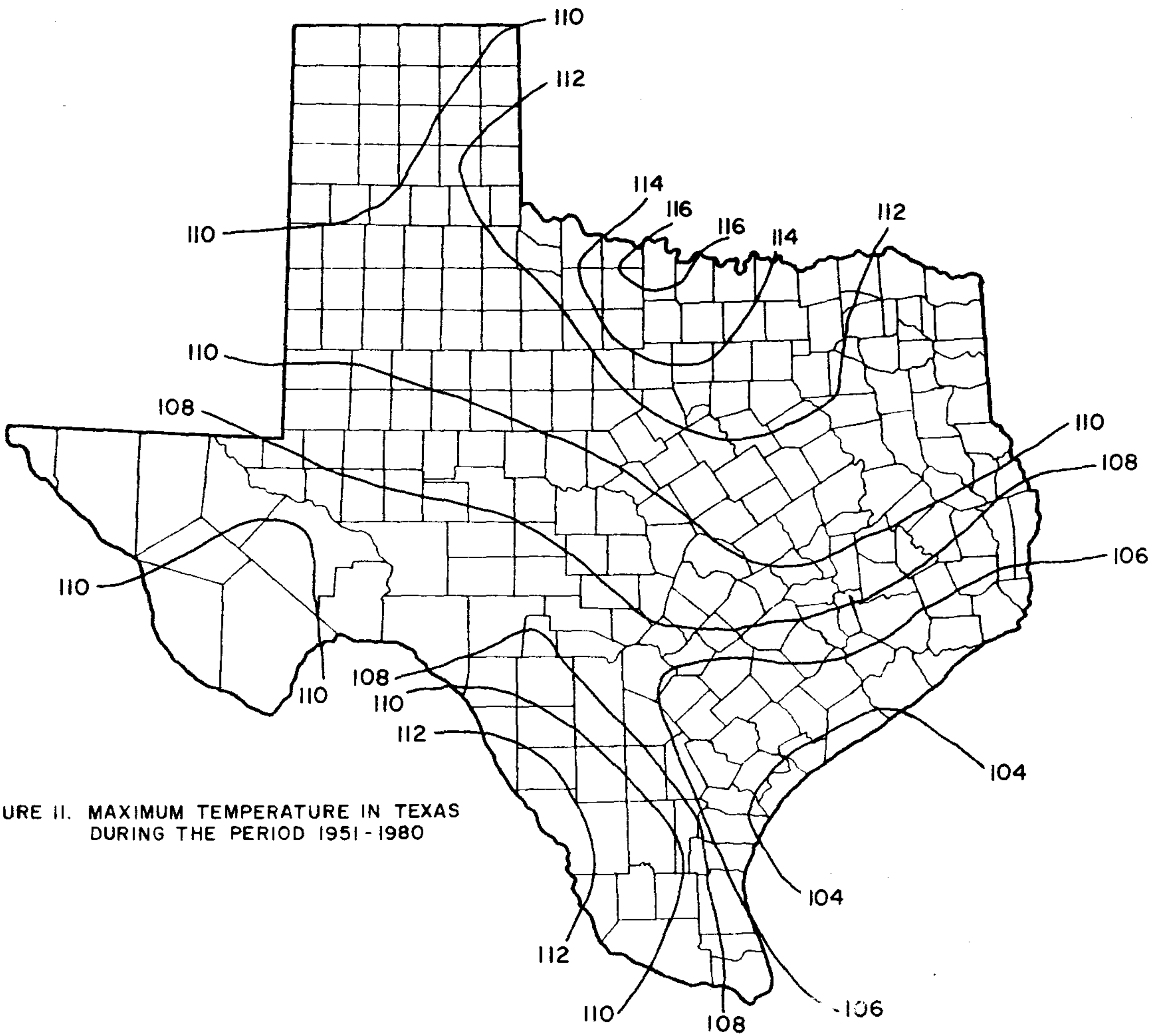


FIGURE 11. MAXIMUM TEMPERATURE IN TEXAS
DURING THE PERIOD 1951 - 1980

Table 13. General Recommendations for Asphalt Selection Based on Climatic Conditions.

	Type of Asphalt	Construction Season	Spring			Summer			Fall			Winter		
		Climatic Region (Fig. 12)	I	II	III	I	II	III	I	II	III	I	II	III
Asphalt Cements**	AC-5			X	X							X	X	X
	AC-10		X	X	X			X		X	X	X	X	X
Anionic Emulsions	EA-HVRS		X*	X*	X	X*	X*		X*	X*		X*	X*	X
	EA-HVRS-90		X*	X*	X	X*	X*	X	X	X	X	X	X	X
Cationic Emulsions	EA-CRS-2				X									X
	EA-CRS-2h		X	X	X			X	X	X	X	X	X	X
Cutbacks	RC-2		X	X	X	X	X	X	X			X		
	RC-250		X	X	X	X	X	X	X			X		
	RC-3		X	X	X	X	X	X	X			X		
	RC-4		X			X	X	X	X					
	RC-5		X			X	X	X	X					
	MC-800		X	X	X	X	X	X	X			X		
	MC-3000		X	X	X	X	X	X	X			X		

Spring - March, April, May

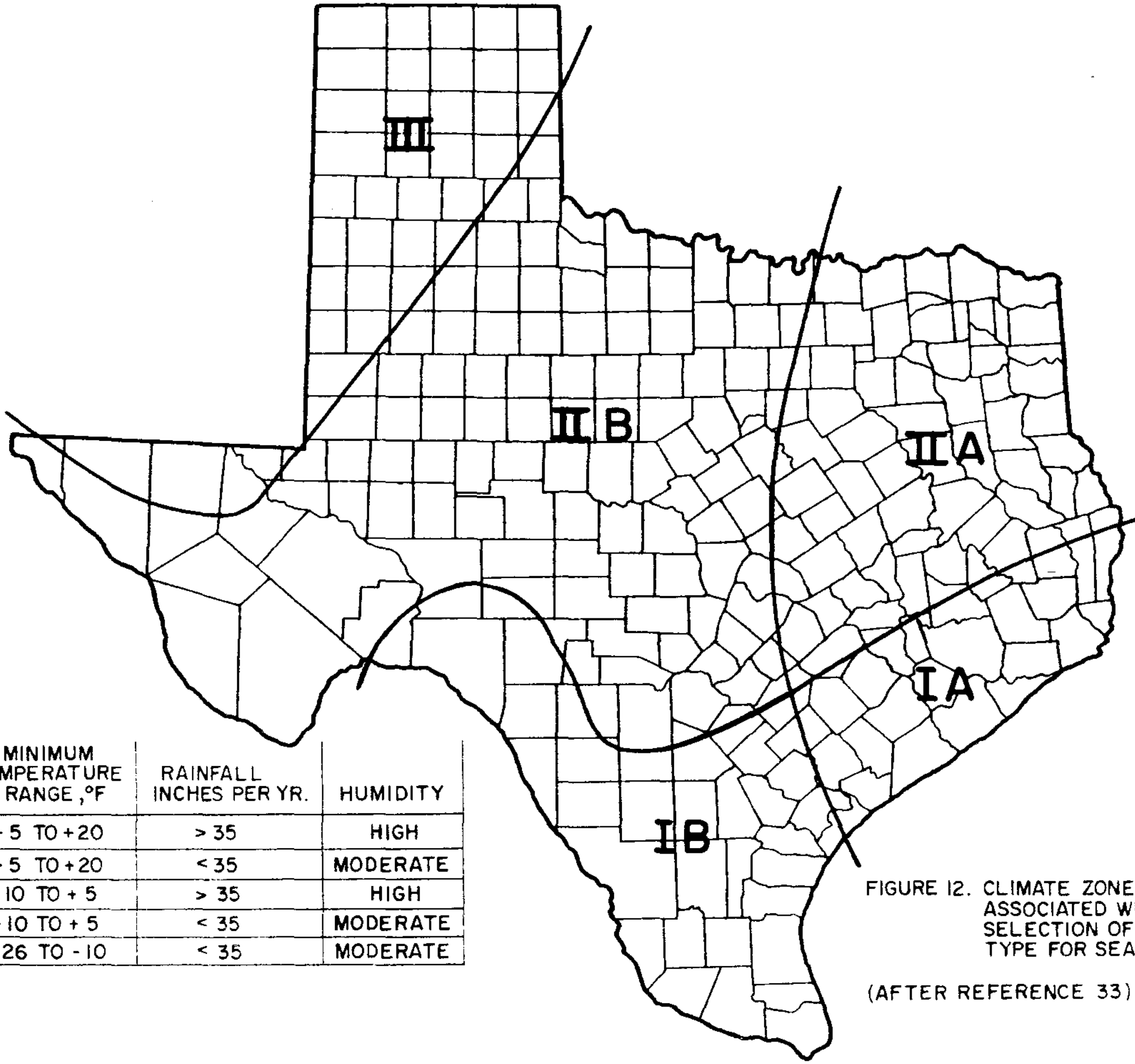
Summer - June, July, August

Fall - September, October

Winter - November, December, January, February

*Do not use in high humidity areas
**Use caution when using dusty rock.
X-Indicates that this grade of asphalt should not be used for defined applications.

(After reference 33)



ZONE	MINIMUM TEMPERATURE RANGE, °F	RAINFALL INCHES PER YR.	HUMIDITY
IA	+ 5 TO + 20	> 35	HIGH
IB	+ 5 TO + 20	< 35	MODERATE
IIA	- 10 TO + 5	> 35	HIGH
IIB	- 10 TO + 5	< 35	MODERATE
III	- 26 TO - 10	< 35	MODERATE

FIGURE 12. CLIMATE ZONES ASSOCIATED WITH SELECTION OF ASPHALT TYPE FOR SEAL COATS

(AFTER REFERENCE 33)

Table 12. Comparison of Asphalt Product Types Used For Surface Treatments and Seal Coats.

Asphalt Type	Advantages	Potential Problem Areas
Asphalt Cement	1. Few cure time problems: road surface will usually accept traffic without raveling when rolling is completed.	1. High spraying temperature required: a. May reduce durability of asphalt if overheated b. Introduces operator safety and discomfort problems. c. Demands careful control to obtain uniform asphalt distribution. d. Is influenced by atmospheric and road surface temperatures. 2. Sensitivity to aggregate surface moisture. 3. Aggregate must be spread and rolled soon after asphalt is distributed.
Asphalt Emulsion (Anionic)	1. Can be applied with little or no heat on distributor. 2. Water dilution can be used except for rapid setting emulsions.	1. Separation of asphalt and water on long storage or after freezing. 2. Asphalt stripping with high silica aggregates 3. Emulsion may run off if road surface temperature is too high. 4. Cure time problems: traffic control required until cure is completed. 5. Will separate if mixed with cationic emulsions.
Asphalt Emulsion (Cationic)	1. Can be applied with little or no heat on distributor. 2. Good adhesion with all aggregate types. 3. Good adhesion with moist aggregates. 4. Can be used in cool weather. 5. Resistant to wash-off if rain occurs soon after placement.	1. Separation of asphalt and water on long storage or after freezing. 2. Emulsion may run off if road surface temperature is too high. 3. Water dilution may cause premature break 4. Cure time problems: traffic control required until cure is completed. 5. Will break if mixed with anionic emulsions.
Cut-Back Asphalt	1. Convenient to use: Uniform distribution 2. Requires lower spraying temperature than asphalt cement. 3. Can be used in cool weather 4. Residue will not be brittle in cold weather.	1. Cure time problems. 2. Cut-back solvent creates air quality problems 3. Waste of energy in cut-back solvent. 4. Solvents have low flash and fire points thus workman safety problems. 5. Bleeding problems.

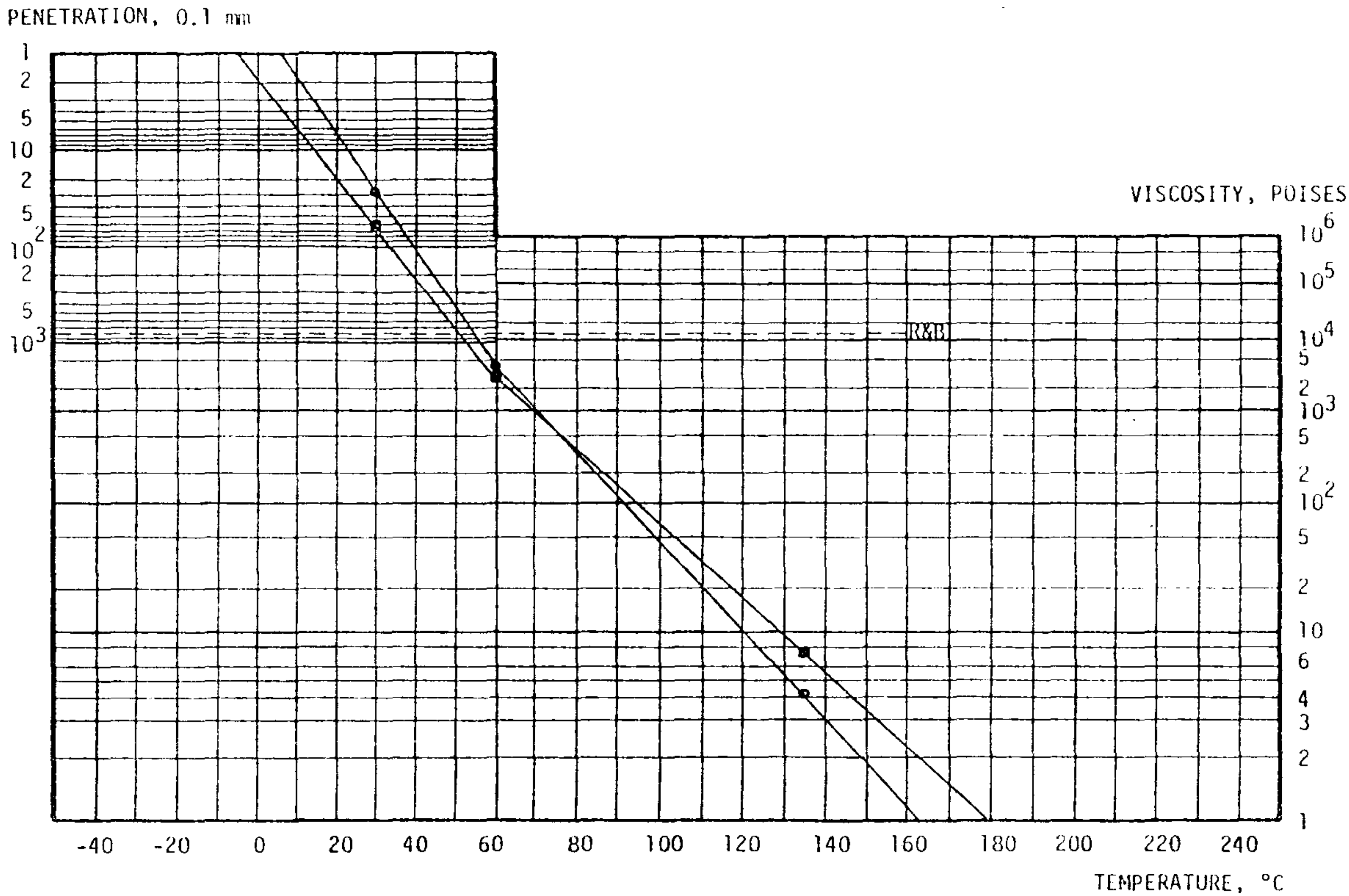


Figure 38. Range of Asphalt Properties After RTFOT for the Period 1974-1979(West Coast Refinery)

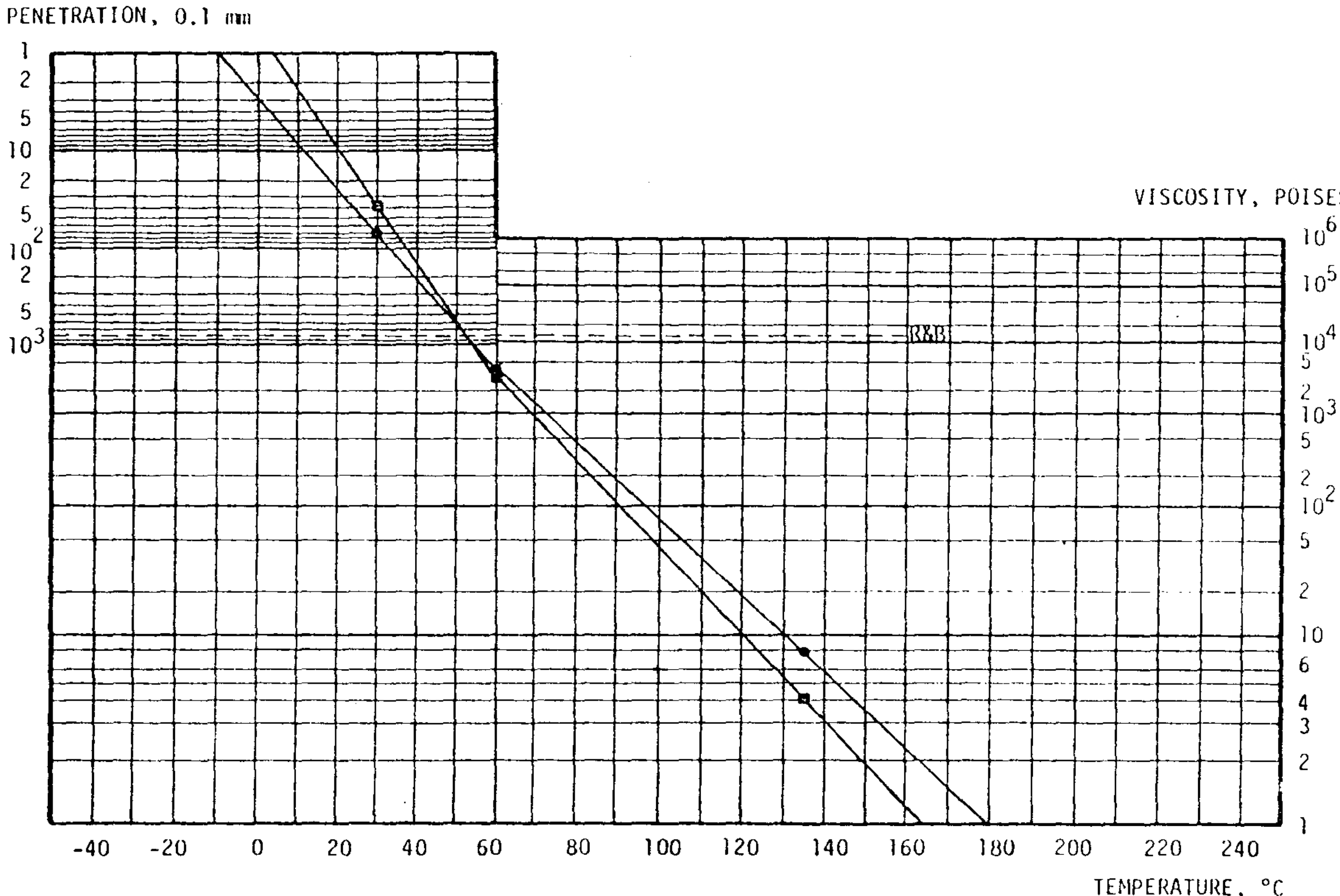


Figure 39. Range of Asphalt Properties After RTFOT for the Period April 10, 1977 and June 1, 1977

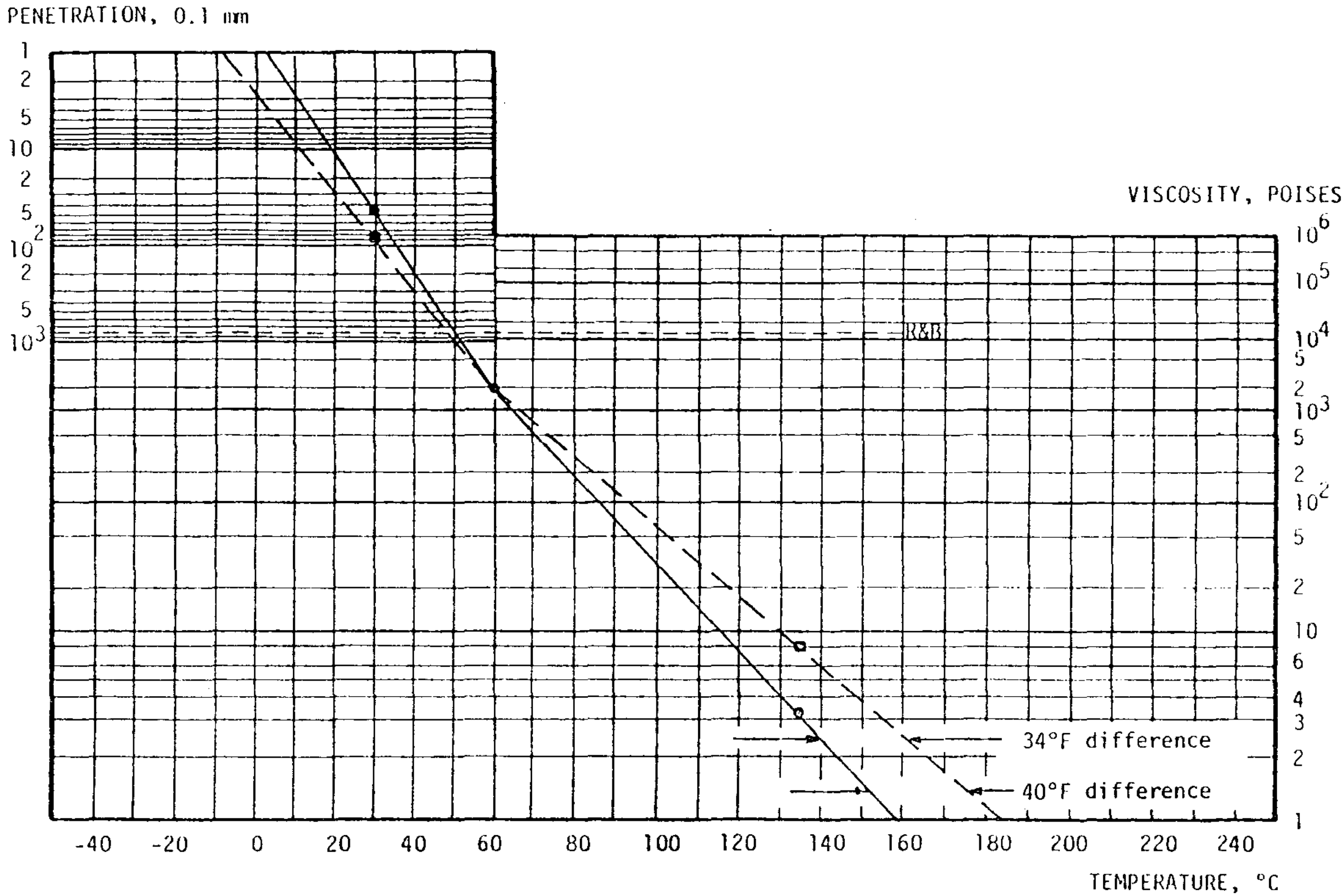


Figure 37. Range of AC-20 Properties in a Northwest Texas Market Area

IMPROVEMENTS OF ASPHALT CONCRETES IN TEXAS

* Binders
* Mixtures
* Specifications

POTENTIAL PAVEMENT MATERIALS

"NEW" PAVEMENT BINDERS

* Reduce dependence on petroleum products
* Large quantities of potential binders would become available
* Need to improve quality of binders
* Relative rapid increase in cost

POTENTIAL "NEW" PAVEMENT BINDERS

* Plasticized Sulphur (Sulphlex)
* Cement Kiln Dust
* Lime Kiln Dust
* Fly Ash
* Altered Asphalts

SULPHUR BINDER SYSTEMS

* Sulphur Extended Asphalt (SEA)
* Sand-Asphalt-Sulphur (SAS)
* Sulphlex

PLASTICIZED SULPHUR

* Sulphur	60-80%
* Plasticizers	20-40%

TYPICAL PLASTICIZERS

* Cyclodiene
* Dipentene
* Vinyl Toluene
* Coal Tar

SULPHUR ASPHALT

* Recorded experiments in 1800's
* Further investigations in 1930's
* Most recent efforts since 1973

PROJECTS IN TEXAS

* U.S. 69 North of Lukfin - September, 1975
* U.S. 77 - Kenedy County - April, 1977
* MH 153 between Bryan and College Station - June, 1978
* Loop 495 in Nacogdoches - August, 1980
* IH 10, Pecos County

WOOD LIGNINS

* Kraft lignin
* Lignin sulphonate

FILLERS

* Lime
* Carbon Black
* Stone Dust
* Baghouse Fines

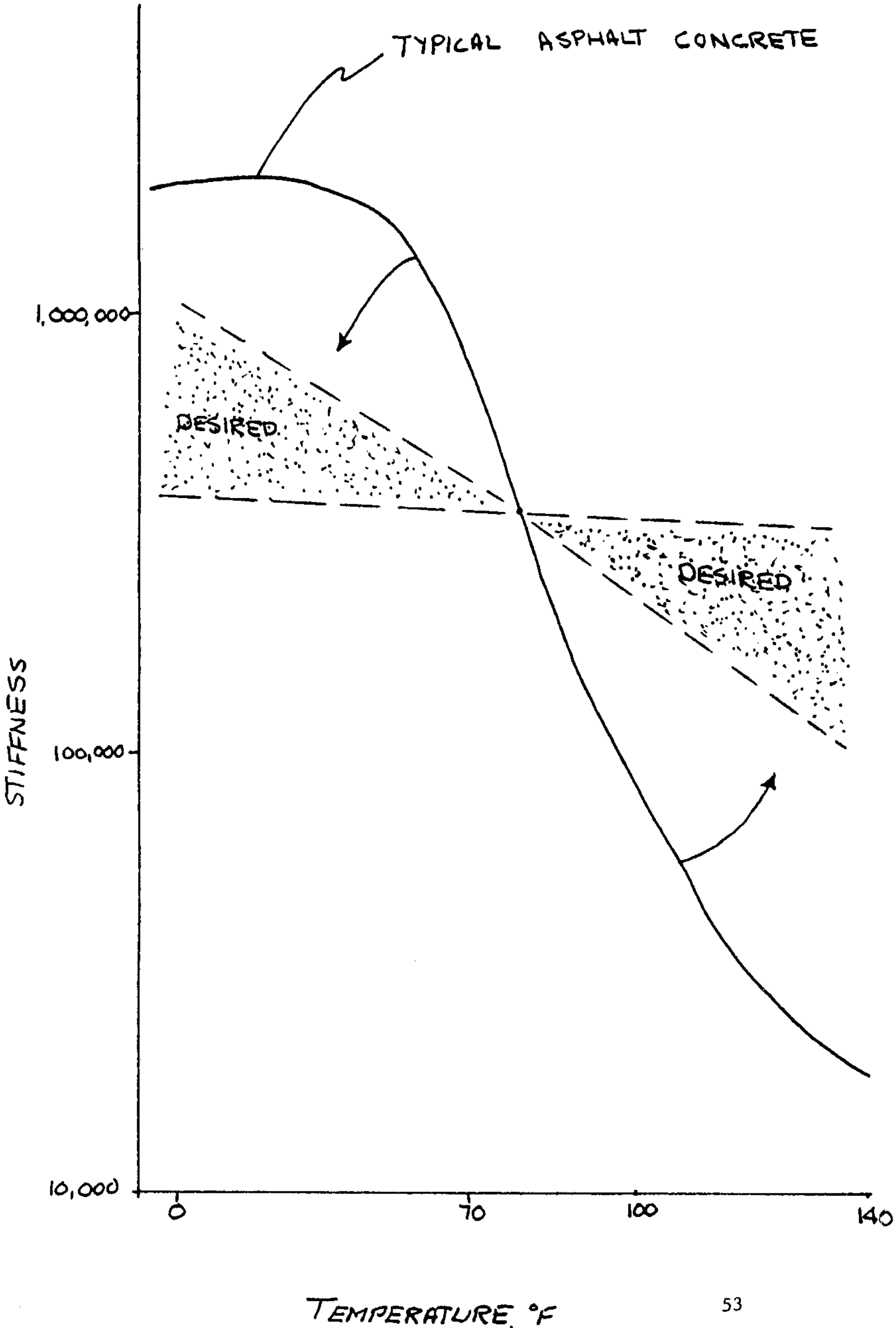
ALTERED ASPHALTS

* Sulphur Extended Asphalts
* Wood Lignins
* Foamed Asphalts
* Antioxidant Chemicals
* Antistrip Chemicals
* Temperature Susceptibility
* Fillers

ANTIOXIDANTS

* Dithiocarbamate salts

  zinc, antimony, lead, copper
* Sodium Hydroxide
* Silicone oil
* SBR rubber


TYPICAL ASPHALT CONCRETE
1,000,000
DESIRED
DESIRED
100,000
STIFFNESS
10,000
0
70
100
140
TEMPERATURE, °F

TEMPERATURE SUSCEPTIBILITY

* Chemcrete - organic salt
* Asphadur - 3M
* Asphalt-Rubber
* Rubber-Asphalt
* Blending Asphalts
* Blending Asphalt with Recycling Agent

WATER SUSCEPTIBILITY

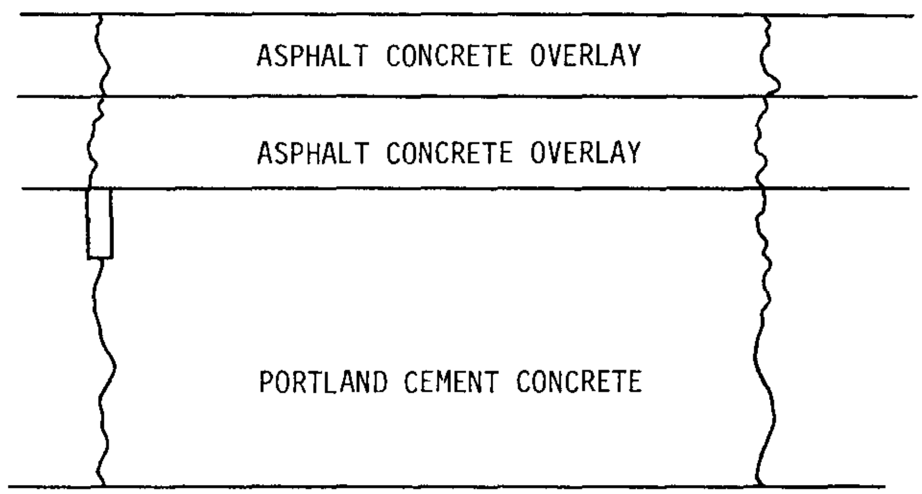
FIELD DISTRESS MOST COMMON

- HIGH MOISTURE SEASON
- HIGH TEMPERATURE
- HIGH TRAFFIC VOLUMES
- HEAVY TRAFFIC
- POOR DRAINAGE
- PERMEABLE SURFACE

SURFACE COURSE - ASPHALT CONCRETE

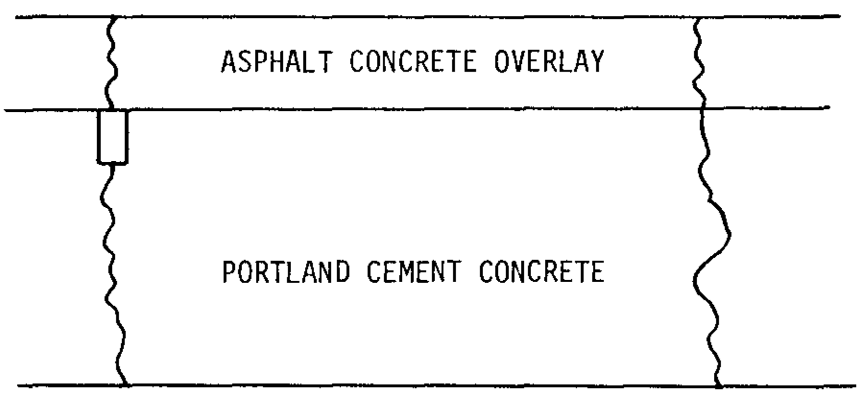
LEVELING COURSE - ASPHALT CONCRETE

AGGREGATE BASE


ASPHALT CONCRETE OVERLAY
ASPHALT CONCRETE OVERLAY
PORTLAND CEMENT CONCRETE

ASPHALT CONCRETE

BLACK BASE


ASPHALT CONCRETE OVERLAY
PORTLAND CEMENT CONCRETE

ANTISTRIP CHEMICALS

* Lime
* Lime slurry
* Chemical Additives to Asphalts
* Chemical Additives to Aggregates

RECOGNITION OF WATER SUSCEPTIBILITY PROBLEMS

- FIELD DISTRESS
  - Excess Asphalt on Surface (Flushing)
  - Rutting in Wheel Paths
  - Instability
- FIELD TESTS
  - Unable to Obtain Core
  - Brown Color Mixture
  - Mixture Can be Removed With Shovel Sometimes by Hand
  - Asphalt Will Stick to Hands
- LABORATORY TESTS
  - Loss of Strength After Exposure to Water
  - Gain of Strength Upon Drying

RECOGNITION IN LABORATORY

- VISUAL
- STRENGTH REDUCTION
    * Tensile Strength
    * Resilient Modulus
    * Hveem Stability

WATER SUSCEPTIBILITY TESTS AT TTI

- MODIFIED LOTTMAN PROCEDURE

  Vacuum Saturation - 30 Min.

  18 Freeze- Thaw Cycles (4 hrs. 0°F - 4 hrs. 120°F)

- MODIFIED CHEVRON

  Vacuum Saturation - 120 Min.

  7-Day Soak

POSSIBLE SOLUTIONS

- AFTER PROBLEM OCCURS IN PAVEMENT
- ALTER DESIGN
- RECOGNITION IN LABORATORY

FIELD DISTRESS

- SEAL SURFACE
  - Fog Seal
  - Slurry Seal
  - Chip Seal
  - Asphalt Concrete
  - Interlayer + Asphalt Concrete
- SEAL UNDERSIDE
- REMOVE AND REPLACE

ALTER DESIGN OF MIXTURE

- ASPHALT
  - Increase Content
  - Alter Asphalt (Anti-Strip Agents)
  - Change Asphalt
- AGGREGATE
  - Gradation
  - Surface Chemistry (Lime)
  - Change Aggregate
- MIXTURE
  - Air Void Content

ANTI-STRIP AGENTS

- DRY LIME (1.5%)
- LIME SLURRY (1.5%)
- COMMERCIALLY AVAILABLE ASPHALT ADDITIVES

  A = Pave Bond Special (Cincinnati Milacron)

  B = M-200 (Texas Emulsion)

  C = 82-S (Armak)

DESIGN OF PAVEMENT

- SEAL MIXTURE FROM WATER
    - Chip Seal
    - Fabric Interlayer
    - Asphalt-Rubber Interlayer
- ALLOW FOR STRENGTH REDUCTION

MIXTURE DESIGN

OVERALL OBJECTIVE OF MIXTURE DESIGN

To design a mixture which will perform satisfactorily in a pavement

STRESSES NEW PAVEMENTS

- Load Stresses
- Thermal Stresses
- Contraction Stresses

FACTORS AFFECTING STRESSES ARE

1. Stiffness of each layer

2. Thickness of each layer

3. Applied wheel load

4. Tire pressure

5. Coefficient of thermal expansion

6. Temperature

7. Pavement age

OTHER STRESS CONSIDERATIONS

Residual stresses

Load-induced stresses not directly under the wheel

SPECIFIC OBJECTIVES OF MIXTURE DESIGN

To determine an economical blend and gradation of aggregates and asphalt:

a. sufficient asphalt to ensure durability
b. sufficient mix stability strength, fatigue, etc.
c. sufficient voids for additional compaction --
   yet low enough to keep out air and water
d. sufficient workability for placement

PAVEMENT DISTRESSES

- Cracking
  - Thermal
  - Shrinkage
  - Fatigue
- Permanent Deformation
  - Rutting
  - Shoving
- Disintegration

TEXAS DISTRESS PROBLEMS

- Durability
  - Stripping
  - Softening
- Shoving
- Fatigue Cracking

DESIRABLE MIXTURE PROPERTIES

Strength

Stability

Flexibility

Stiffness

Fatigue Resistance

Durability

Skid Resistance

Workability

STRENGTH

Strength is primarily concerned with the ability of the mixture to withstand loads (stresses) and deformations (strains) without cracking. Primary concern should be with tensile stresses and strains since traffic and environment subject the pavement and mixture to tensile conditions.

Tensile Tests

- Cohesiometer
- Flexural (beams)
- Indirect tensile

STABILITY

Stability of an asphalt pavement is its ability to resist shoving and rutting under traffic loads. A stable pavement maintains its shape and smoothness under repeated loading; an unstable pavement develops ruts, washboard ripples or corrugations, shoves, etc.

Because establishing stability specifications for a pavement depends on the traffic expected to use the pavement, stability requirements can be established only after a thorough traffic analysis. Stability specifications should be high enough to handle traffic adequately, but not higher than required. Too high a stability value may produce a pavement that is too stiff and therefore less durable and less resistant to fatigue and thermal cracking than desired.

FLEXIBILITY

Flexibility is the ability of an asphalt mixture to adjust to gradual settlements and movements and to withstand load or environmentally-imposed deformations without cracking. Sometimes the need for flexibility conflicts with stability requirements, so that trade-offs have to be made.

Tests

No good tests to measure flexibility

STIFFNESS

Stiffness refers to the relationship between load (stress) and deformation (strain). A material with a high stiffness will not deform as much under load as a less stiff material. This property is closely related to stability and flexibility and is often considered to be the same as modulus of elasticity.

Stiffness Tests

Compression

Beams

Indirect Tension

$$E = \frac{\text{applied load (stress)}}{\text{deformation (strain)}}$$

$$S = \frac{\text{applied load (stress)}}{\text{deformation (strain) at some time}}$$

FATIGUE RESISTANCE

Fatigue resistance is the mixture's ability to resist repeated bending under wheel loads (traffic). As the percentage of air voids in the pavement increases, by either design or lack of compaction, pavement fatigue life (the length of time during which an in-service pavement is adequately fatigue-resistant) is drastically shortened. Likewise, a pavement containing asphalt that has aged and hardened significantly has reduced resistance to fatigue.

The thickness and strength characteristics of the pavement and the supporting power of the subgrade also have a great deal to do with determining pavement life and preventing load-associated cracking. Thick, well-supported pavements do not bend as much under loading as thin or poorly-supported pavements do. Therefore, they have longer fatigue lives.

Fatigue Tests

Beams (bending)

Indirect tensile

DURABILITY

The durability of an asphalt pavement is its ability to resist factors such as changes in the asphalt (polymerization and oxidation), disintegration of the aggregate, and stripping of the asphalt films from the aggregate. These factors can be the result of weather, traffic, or a combination of the two.

Durability Tests

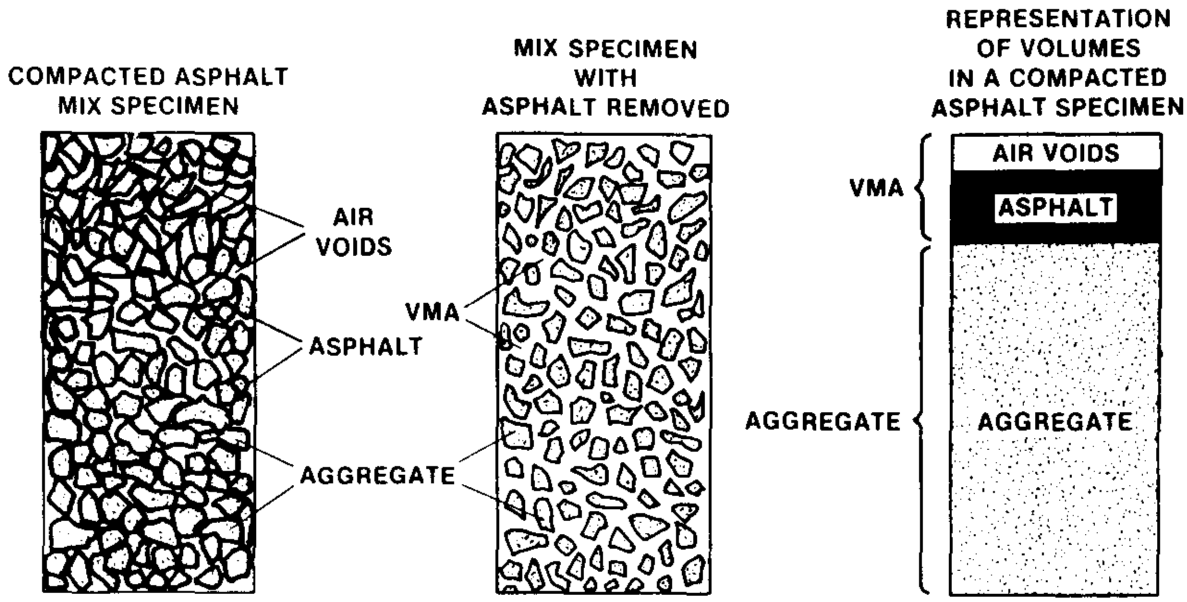
No good tests for mixtures except for moisture susceptibility

SKID RESISTANCE

Skid resistance is the ability of an asphalt surface mixture to minimize skidding or slipping of vehicle tires, particularly when wet. For good skid resistance, tire tread must be able to maintain contact with the aggregate particles. Mixtures that tend to rut and bleed present serious skid resistance problems.

WORKABILITY

Workability describes the ease with which a paving mixture can be placed and compacted. Mixtures with good workability are easy to place and compact; those with poor workability are difficult to place and compact. Workability can often be improved by changing mix design parameters such as aggregate type or gradation. Mix workability is related to pavement stability and density; however, there are no set test procedures whereby problems with workability can be positively identified in the laboratory.



NOTE: The volume of absorbed asphalt is not shown.

MINIMUM PERCENT VOIDS IN MINERAL AGGREGATE (VMA)

U.S.A. Standard Sieve Designation*	Nominal Maximum Particle Size ‡ in.*	Minimum Voids in Mineral Aggregate, Percent
1.18 mm (No. 16)	0.0469	23.5
2.36 mm (No. 8)	0.093	21
4.75 mm (No. 4)	0.187	18
9.5 mm (3/8 in.)	0.375	16
12.5 mm (1/2 in.)	0.500	15
19.0 mm (3/4 in.)	0.750	14
25.0 mm (1 in.)	1.0	13
37.5 mm (1 1/2 in.)	1.5	12
50 mm (2 in.)	2.0	11.5
63 mm (2 1/2 in.)	2.5	11

*Standard Specification for Wire Cloth Sieves for Testing Purposes, AASHTO Designation M 92.
‡For processed aggregate, the nominal maximum particle size is the largest sieve size listed in the applicable specification upon which any material is permitted to be retained.

Asphalt

- amount
- viscosity
- temperature susceptibility

Aggregate

- amount
- type
- natural vs. crushed
- surface texture
- gradation

Air Voids

- 3-5% for surface courses
- 3-8% for base courses

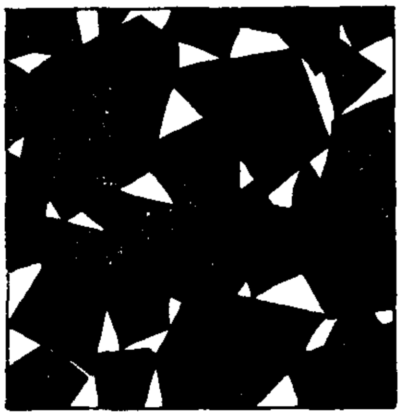
VMA

Minimum 11 - 23%

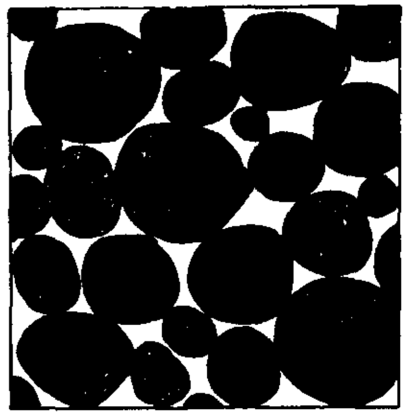
Depends on maximum size

FIELD STABILITY

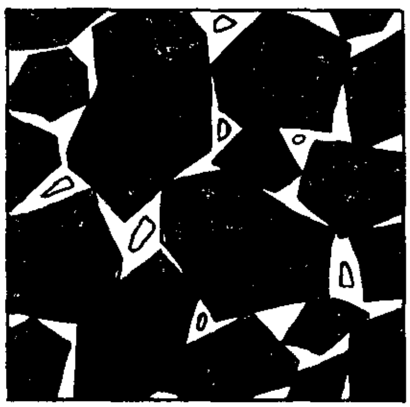
Dependent on aggregate interlock and cohesion due to binder.



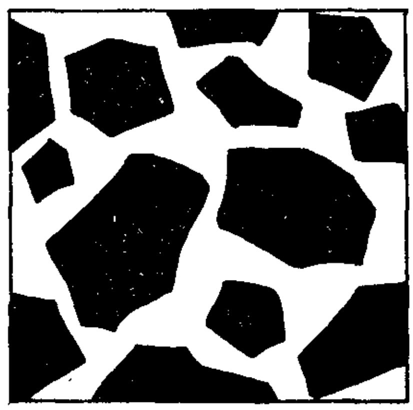
Angular Aggregate
Compacted Mass



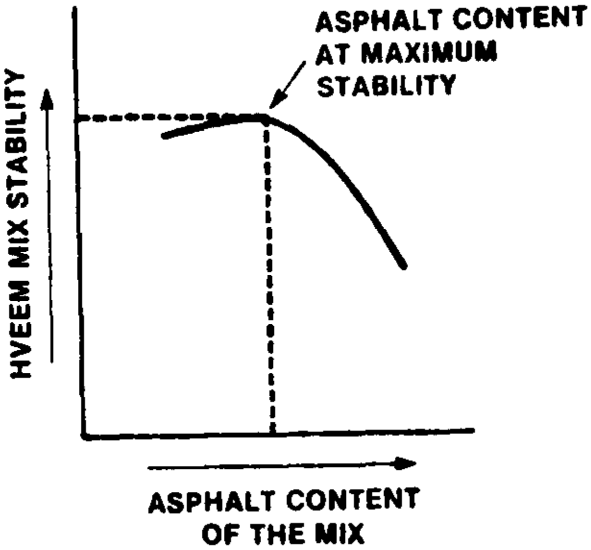
Rounded Aggregate
Compacted Mass



Angular Aggregate
With Asphalt



Angular Aggregate
With Excess Asphalt



CAUSES AND EFFECTS OF PAVEMENT INSTABILITY

LOW STABILITY

Causes	Effects
Excess asphalt in mix	Washboarding, rutting, and flushing or bleeding
Excess medium size sand in mixture	Tenderness during rolling and for period after construction, difficulty in compacting
Rounded aggregate, little or no crushed surfaces	Rutting and channeling

HVEEM DESIGN

Determines asphalt content at 3% air voids

Measures stability at 97% of theoretical density

Hveem stability test measures aggregate interlock

INDIRECT TENSILE TEST

Measures cohesion and tensile strength

COHESION

Depends on viscosity (stiffness) and mineral filler content

FILLERS IMPROVE

Cohesion through increased apparent viscosity and binder stiffness and waterproofing

Many Texas mixture designs have a deficit of minus #200 material (filler)

RECOMMENDED MAXIMUM FILLER CONTENT

$$\frac{W_a/1.0}{W_f/G_f} = 1.5$$

W_a = weight of asphalt

W_f = weight of filler

G_f = specific gravity of filler

FILLERS

Lime

Carbon Black

Stone Dust

Baghouse Fines

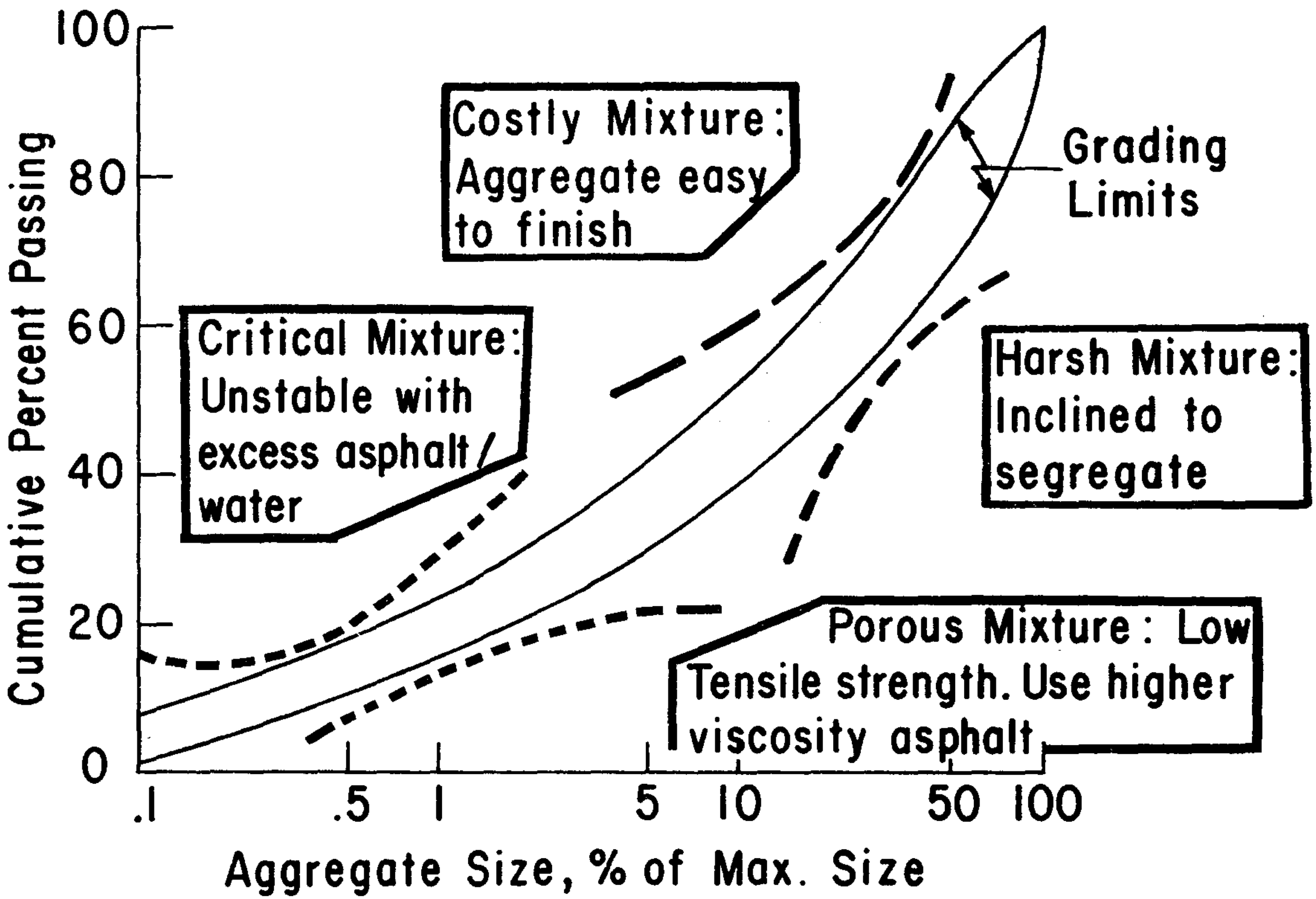
Many Texas mixture designs have a deficit of material between the minus #40 and plus #80 material (a hump in the gradation curve).

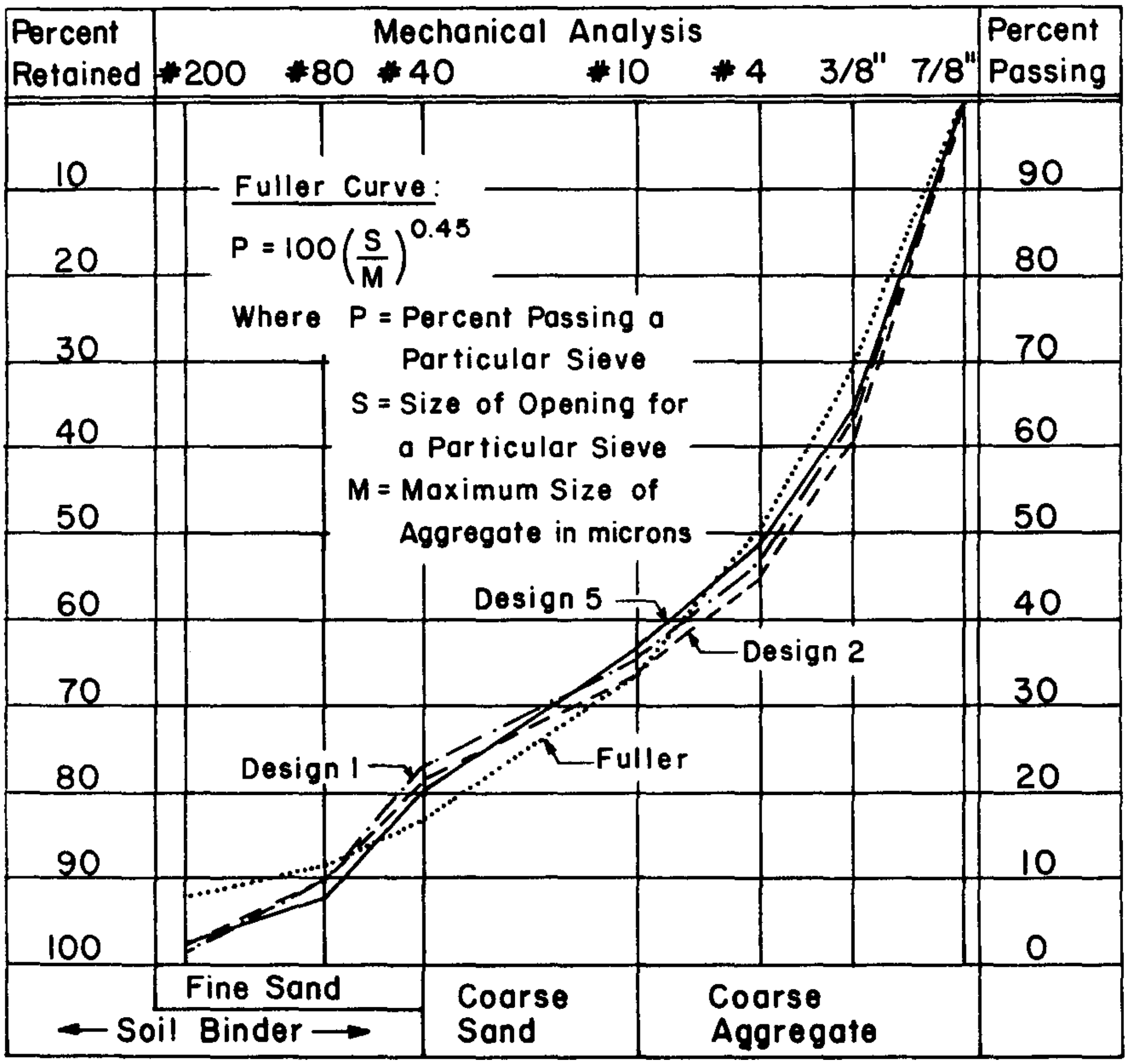
Specifications for aggregate gradations need to be evaluated

Nos. 40 to 80 sieves

% fines

Distribution of aggregate sizes


Costly Mixture: Aggregate easy to finish
Critical Mixture: Unstable with excess asphalt/water
Grading Limits
Harsh Mixture: Inclined to segregate
Porous Mixture: Low Tensile strength. Use higher viscosity asphalt
Cumulative Percent Passing
100
80
60
40
20
0
.1
.5
1
5
10
50
100
Aggregate Size, % of Max. Size



Example of typical gradation curve

Asphalt content tolerance of $\pm$ 0.5% needs to be evaluated

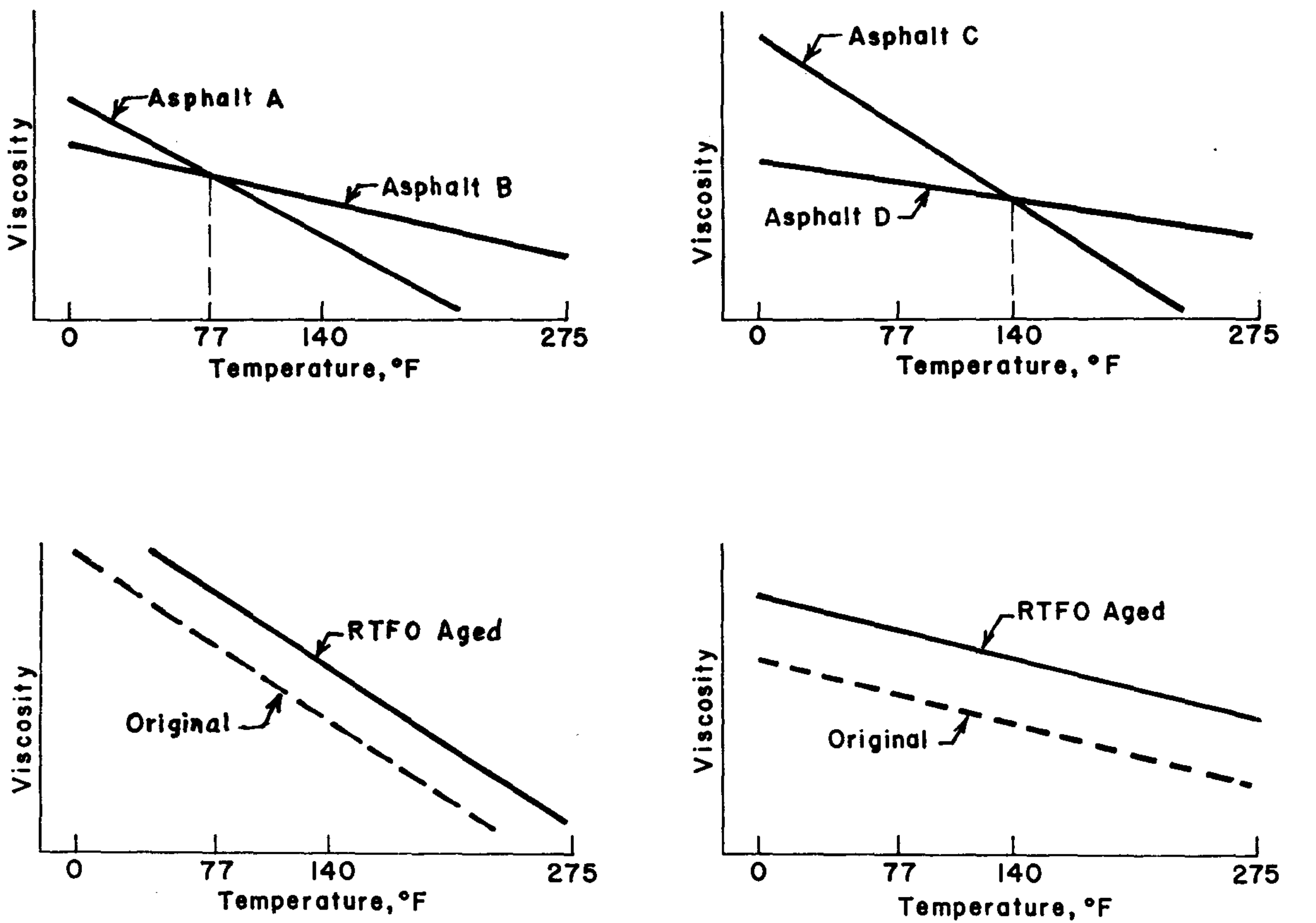
Increase required Hveem stability value to 35 or 40

Asphalt viscosity should be evaluated relative to its effect on stability and strength

Effect of plant temperature needs to be evaluated

Temperatures

Laboratory		
	Mixing	275°F
	Compaction	250°F
Field		Varies widely and typically does not correspond to lab values


Asphalt A
Asphalt B
Viscosity
0
77
140
275
Temperature, °F
Asphalt C
Asphalt D
Viscosity
0
77
140
275
Temperature, °F
RTFO Aged
Original
Viscosity
0
77
140
275
Temperature, °F
RTFO Aged
Original
Viscosity
0
77
140
275
Temperature, °F

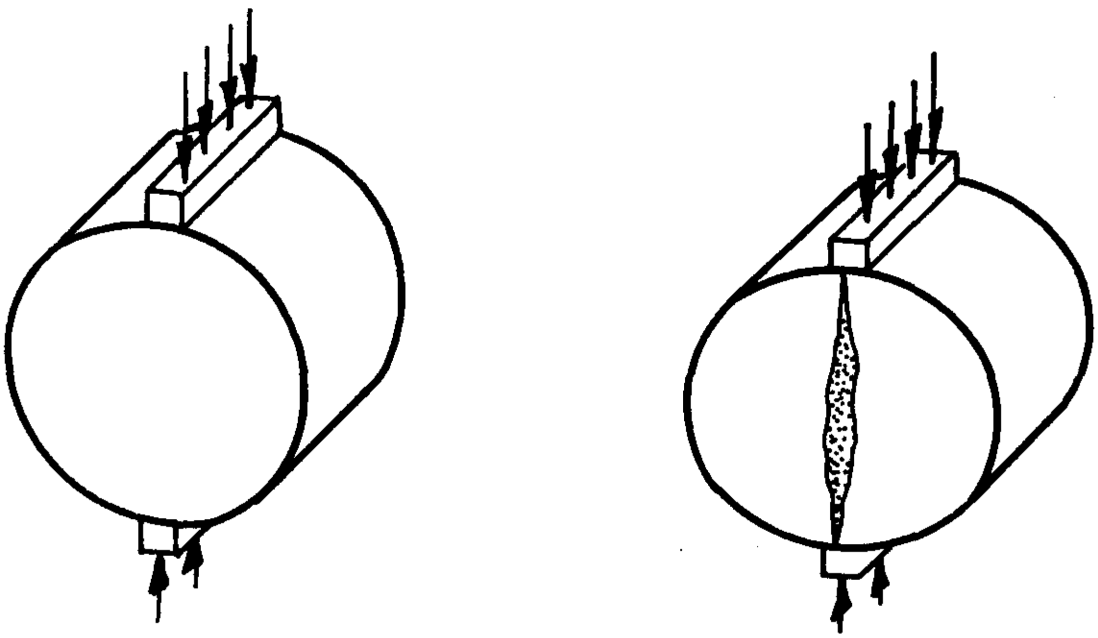
METHODS FOR INCREASING STABILITY

- Optimum asphalt content
- Dense, well-graded aggregate
- Angular particles
- Rough surface texture
- Mineral filler
- High viscosity asphalts
- Oxidized asphalts

STRENGTH

- Tensile Tests
  - Cohesiometer
  - Flexural
  - Indirect tensile

TENSILE TEST LOADING ARRANGEMENT

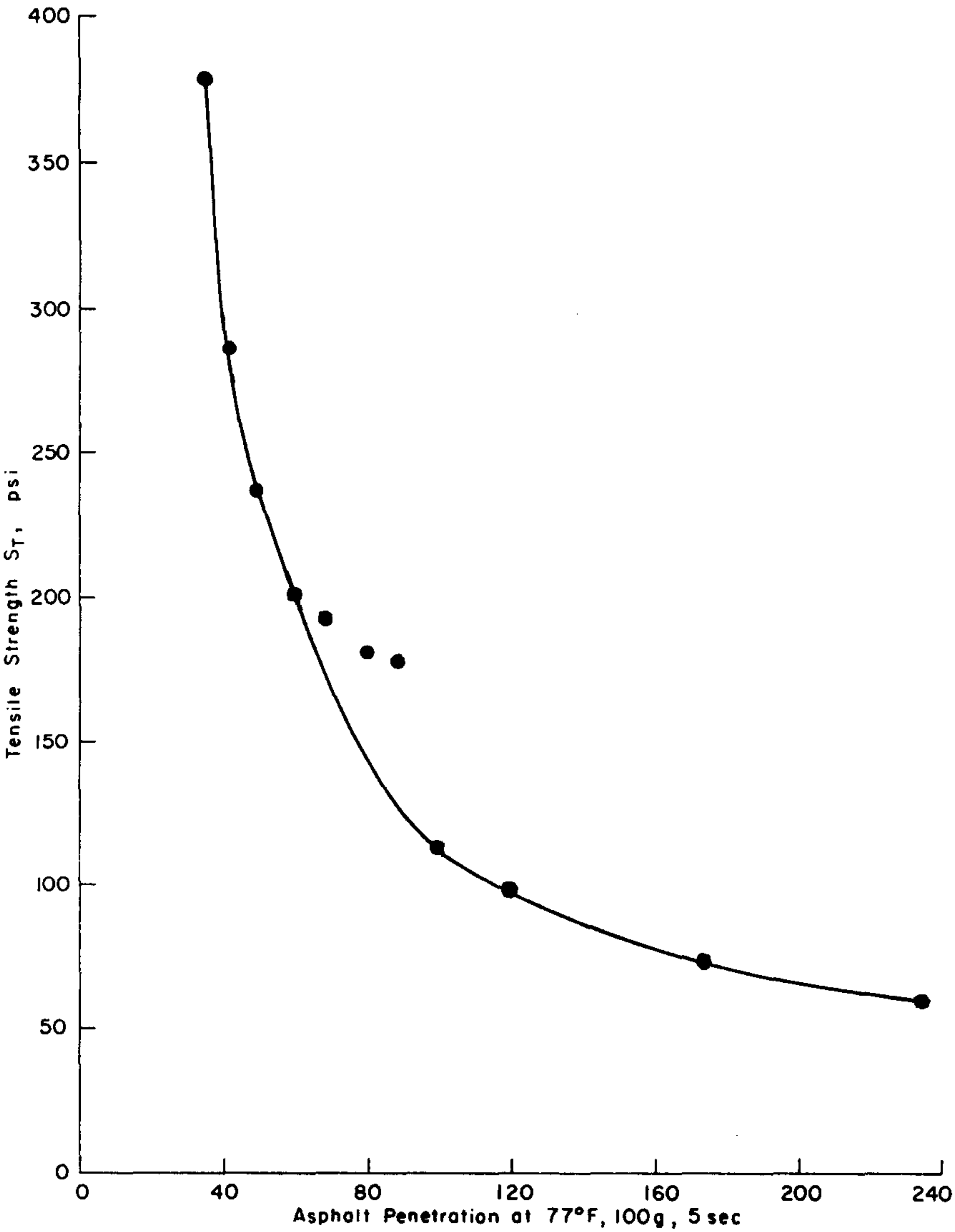


Indirect tensile test can be conducted using the large gyratory press

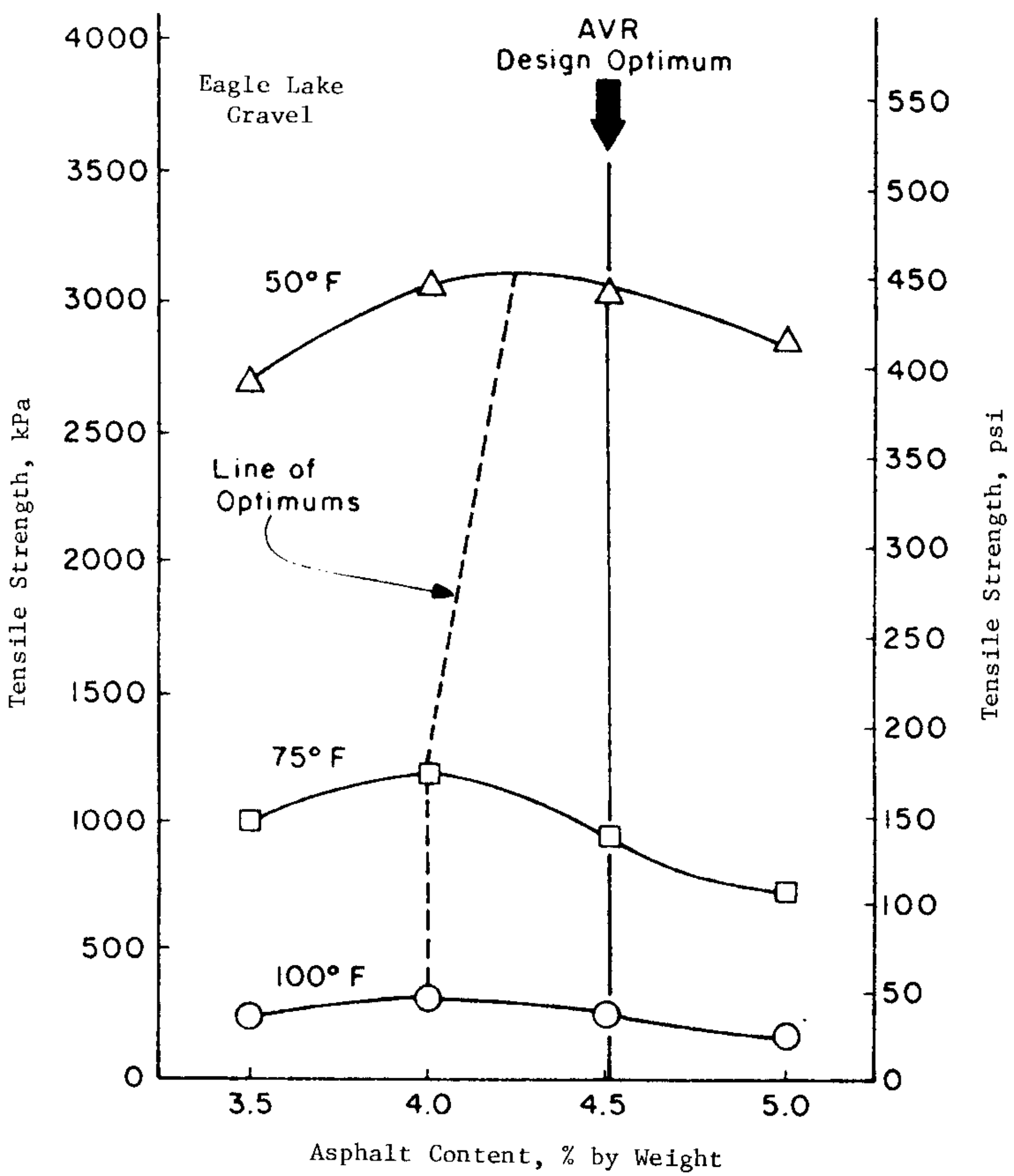
References:

Anagnos, J. N., and T. W. Kennedy, "Practical Method of Conducting the Indirect Tensile Test," Research Report 98-10, Center for Highway Research, The University of Texas at Austin, Austin, Texas, August 1972.

Kennedy, T. W., F. L. Roberts, and J. N. Anagnos, "Method for Conducting the Static and Repeated-Load Indirect Tensile Test," Research Report 183-14, Center for Transportation Research, The University of Texas at Austin, Austin, Texas (in progress).



400
350
300
250
200
150
100
50
0
Tensile Strength S_T, psi
0
40
80
120
160
200
240
Asphalt Penetration at 77°F, 100g, 5 sec


AVR
Design Optimum
Eagle Lake
Gravel
50° F
75° F
100° F
Line of
Optimums
Tensile Strength, kPa
Tensile Strength, psi
Asphalt Content, % by Weight
4000
3500
3000
2500
2000
1500
1000
500
0
550
500
450
400
350
300
250
200
150
100
50
0
3.5
4.0
4.5
5.0

FATIGUE TESTS

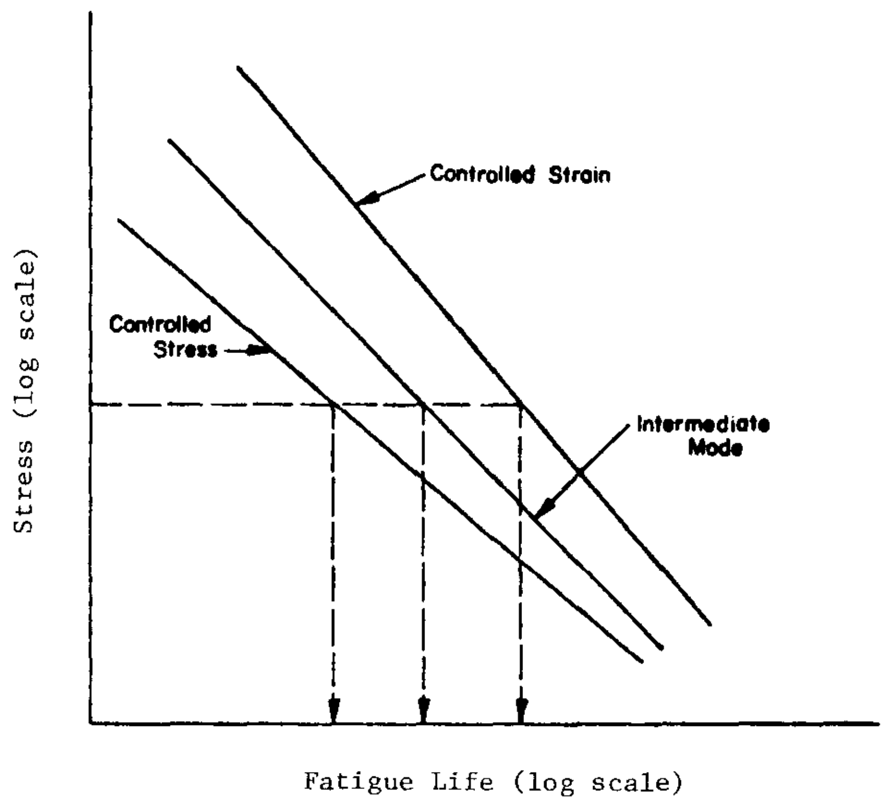
Flexural (bending)

Indirect Tensile

Fatigue Loadings

Controlled (constant) stress or load

Controlled (constant) strain or deformation



Controlled stress loading simulates stresses in thick asphalt concrete pavements

Controlled strain loading simulates stresses in thin asphalt concrete pavements

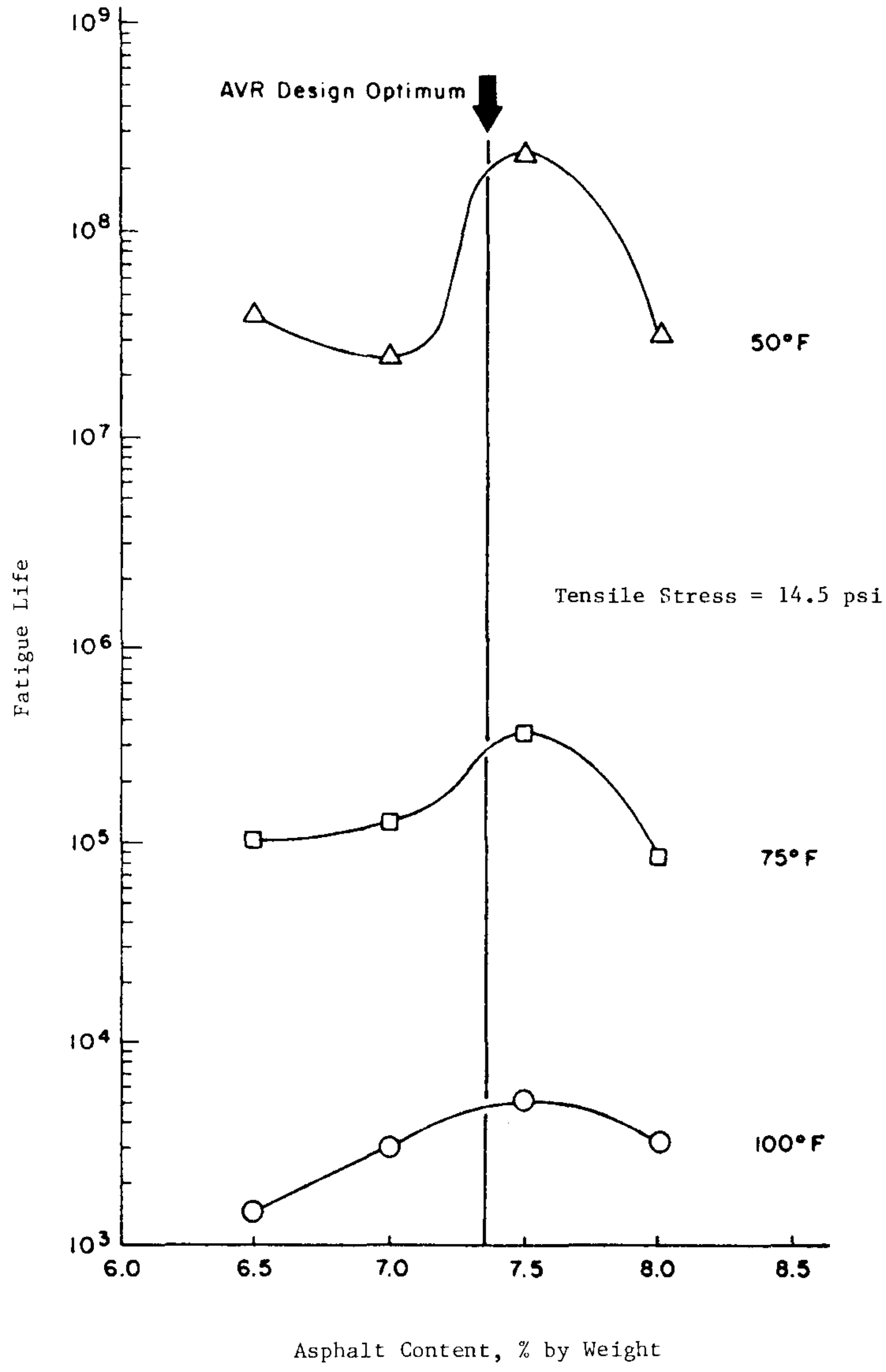
FATIGUE RESISTANCE

% Asphalt

% Air Voids

Gradation

Stiffness


AVR Design Optimum
Fatigue Life
10^9
10^8
10^7
10^6
10^5
10^4
10^3
50°F
Tensile Stress = 14.5 psi
75°F
100°F
6.0
6.5
7.0
7.5
8.0
8.5
Asphalt Content, % by Weight

FACTORS AFFECTING THE STIFFNESS AND FATIGUE BEHAVIOR OF ASPHALT CONCRETE MIXTURES

Factor	Change in Factor	Effect of Change in Factor		
		On Stiffness	On Fatigue Life in Controlled-Stress Mode of Test	On Fatigue Life in Controlled-Strain Mode of Test
Asphalt penetration	Decrease	Increase	Increase	Decrease
Asphalt content	Increase	Increase[a]	Increase[a]	Increase[b]
Aggregate type	Increase roughness and angularity	Increase	Increase	Decrease
Aggregate gradation	Open to dense gradation	Increase	Increase	Decrease[d]
Air void content	Decrease	Increase	Increase	Increase[d]
Temperature	Decrease	Increase[c]	Increase	Decrease

[a]Reaches optimum at level above that required by stability considerations.

[b]No significant amount of data; conflicting conditions of increase in stiffness and reduction of strain in asphalt make this speculative.

[c]Approaches upper limit at temperature below freezing.

[d]No significant amount of data.

POOR FATIGUE RESISTANCE

Causes	Effects
Low asphalt content	Fatigue cracking
High design voids	Early aging of asphalt followed by fatigue cracking
Lack of compaction	Early aging of asphalt followed by fatigue cracking
Inadequate pavement thickness	Excessive bending followed by fatigue cracking

DURABILITY

Problems

- Asphalt polymerization and oxidation
- Aggregate disintegration
- Stripping of asphalt from aggregate

POOR DURABILITY

Causes	Effects
Low asphalt content	Dryness or ravelling
High void content through design or lack of compaction	Early hardening of asphalt followed by cracking or disintegration
Water susceptible (hydrophillic) aggregate in mixtures	Films of asphalt strip from aggregate leaving an abraded, ravelled, or mushy pavement

STRIPPING

Loss of adhesion between the asphalt cement and the aggregate surface is primarily due to the action of water.

Other contributing factors are aggregate surface coatings, smooth aggregate surface texture, and raveling.

RAVELING

Progressive disintegration of an asphalt mixture layer from the surface downward by dislodgement of aggregate particles caused insufficient asphalt, hardening of asphalt, wet or dirty aggregate, smooth aggregate texture, and/or surface stripping.

METHODS FOR REDUCING MOISTURE DAMAGE

- Eliminate moisture
  - compaction
  - sealing
  - drainage
- Eliminate use of moisture susceptibility aggregates
- Treat aggregates
  - liquid antistripping agents
  - lime

MOISTURE SUSCEPTIBILITY TESTS

Static Indirect Tensile Test

Repeated-Load Indirect Tensile Test

Texas Freeze-Thaw Pedestal Test

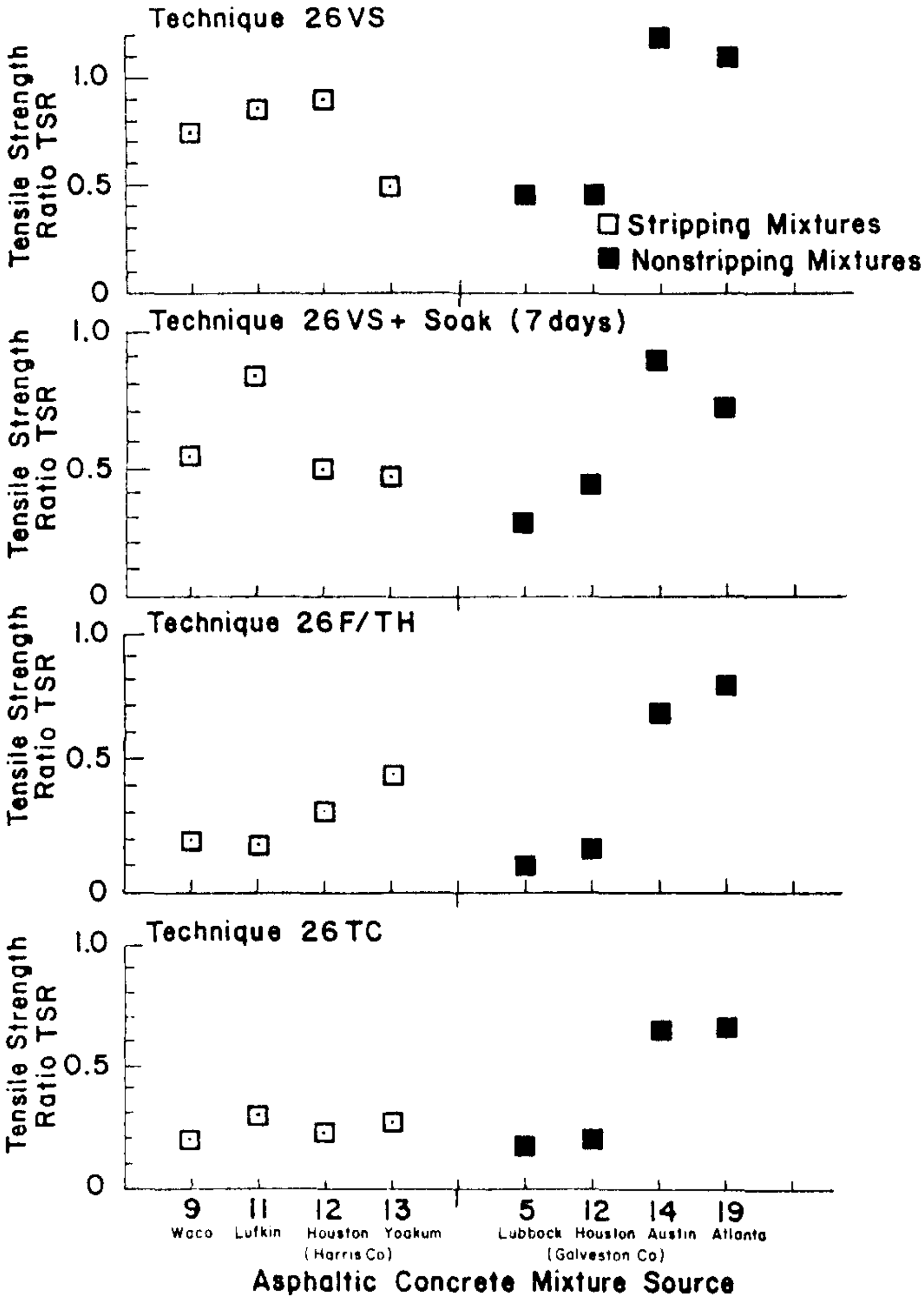
Boiling Test

WET-DRY TESTS

INDIRECT TENSILE TEST ON WET AND DRY SPECIMENS

In the indirect tensile test a cylindrical specimen is subjected to compressive loads distributed along two opposite generators that create a relatively uniform tensile stress perpendicular to and along the diametrical plane, which contains the applied load, that leads to a splitting failure. Estimates of the tensile strength, modulus of elasticity, and Poisson's ratio can be calculated from the applied load and corresponding vertical and horizontal deformations.

All specimens are tested in indirect tension, and the moisture susceptibility is determined by the ratio of tensile strength in a wet condition to that in a dry condition. Wet specimens are prepared by subjecting 4-in.-diameter specimens to various amounts of mercury pressure in water, releasing the vacuum, and the water forcing by atmospheric pressure into the voids available in the mixtures. After vacuum saturation, some specimens were placed in a plastic bag along with a small amount of water, and then subjected to various thermal cycles. All wet specimens are submerged in a pretest water bath before testing.



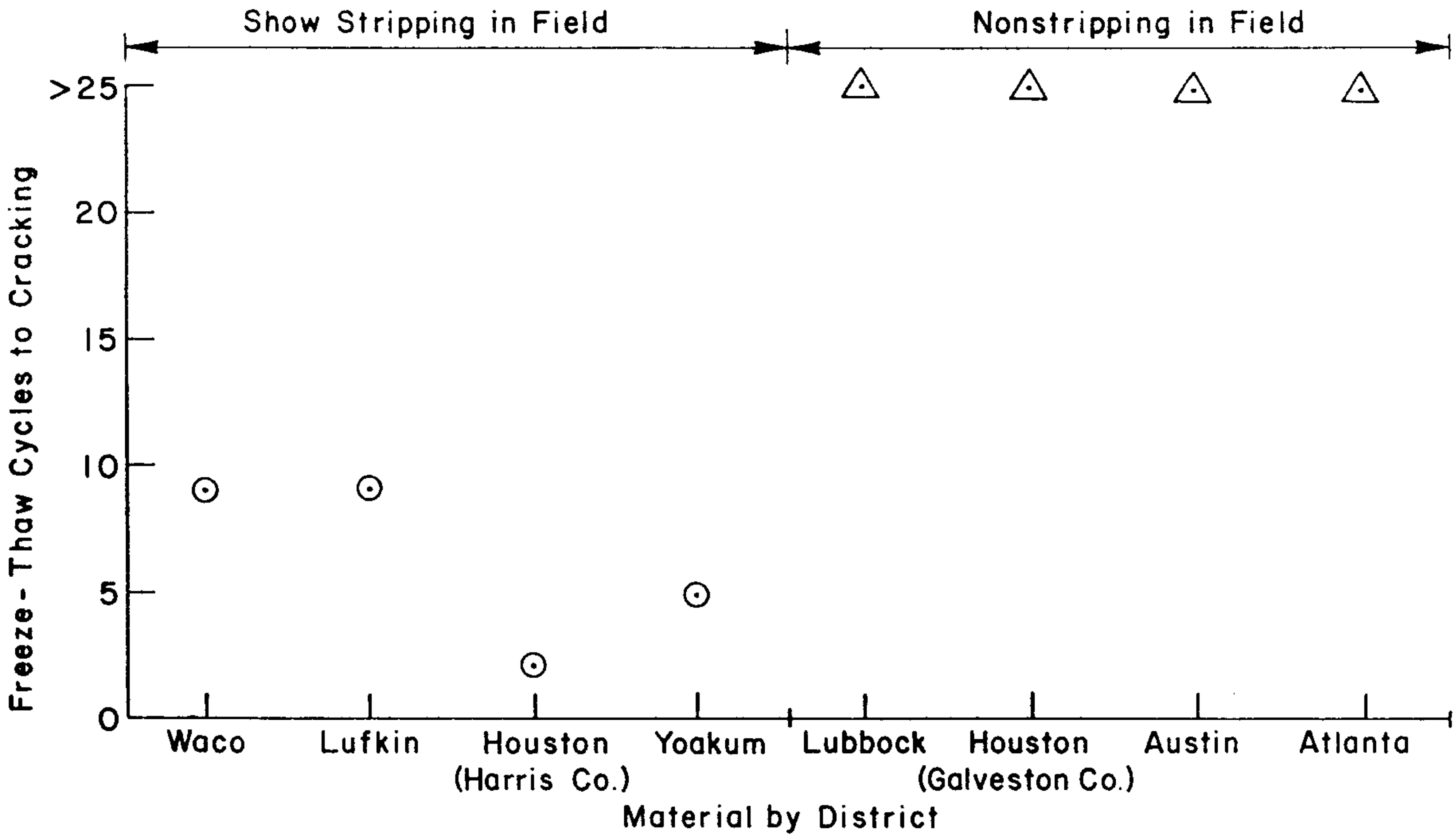
Technique 26VS
Tensile Strength Ratio TSR
1.0
0.5
0
Stripping Mixtures
Nonstripping Mixtures
Technique 26VS + Soak (7days)
Technique 26F/TH
Technique 26TC
9
Waco
11
Lufkin
12
Houston
(Harris Co)
13
Yoakum
5
Lubbock
12
Houston
(Galveston Co)
14
Austin
19
Atlanta
Asphaltic Concrete Mixture Source

Generally recommended cutoff value for TSR is between 0.70 and 0.75. Mixtures with TSR values below this value are considered to be stripping-prone.

TEXAS FREEZE-THAW PEDESTAL TEST

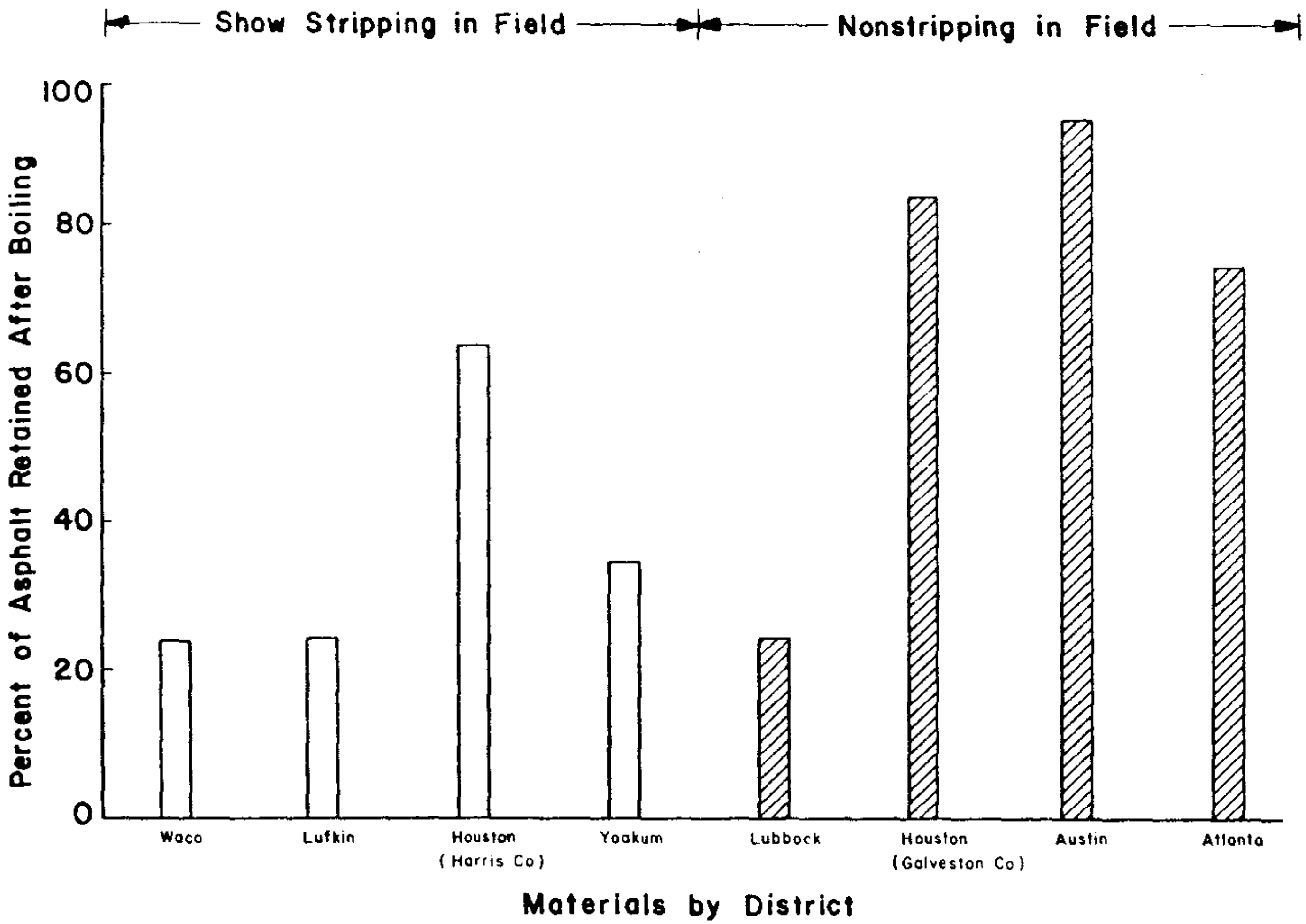
This test determines the number of freeze-thaw cycles required to induce cracking on the surface of a specimen. This test procedure involves subjecting miniature asphalt-aggregate briquets to repeated freeze-thaw cycles in water. The briquets are highly permeable to allow easy penetration of water and are designed to minimize mechanical interlocking of the aggregate particles by using a uniform aggregate size. Thus, the briquet properties are largely determined by the asphalt-aggregate bond. The moisture susceptibility of an asphalt concrete mixture is evaluated by determining the freeze-thaw cycles required to crack a briquet seated on a beveled pedestal.

Research Report 253-3, "Texas Freeze-Thaw Pedestal Test for Evaluating the Moisture Susceptibility of Asphalt Mixtures"


Show Stripping in Field
Nonstripping in Field
>25
20
15
10
5
0
Freeze - Thaw Cycles to Cracking
Waco
Lufkin
Houston (Harris Co.)
Yoakum
Lubbock
Houston (Galveston Co.)
Austin
Atlanta
Material by District

TEXAS BOILING TEST

In this test a visual observation is made of the extent of stripping of the asphalt from aggregate surfaces after the mixture has been subjected to the action of water at elevated temperatures for a specified time. Many agencies have used different versions of the boiling test to evaluate the potential stripping of asphalt mixtures. To perform this test the cool, loose asphalt mixture, either plant or laboratory mixed, is boiled in distilled water for 10 minutes. After boiling the water is drained, the contents emptied on paper, and the extent of stripping is visually rated. The method can also be used to evaluate the effectiveness of candidate antistripping additives in asphalt-aggregate mixtures.


Show Stripping in Field
Nonstripping in Field
Percent of Asphalt Retained After Boiling
100
80
60
40
20
0
Waco
Lufkin
Houston
(Harris Co)
Yoakum
Lubbock
Houston
(Galveston Co)
Austin
Atlanta
Materials by District

ANTISTRIPPING AGENTS SUMMARY

1. All antistripping agents should be tested with the proposed asphalt and aggregate

    - Freeze-Thaw Pedestal
    - Texas Boiling
    - Wet-Dry Indirect Tensile

2. Liquid antistripping agents are relatively ineffective but work with some aggregate-asphalt combinations

3. Lime is generally effective as an antistripping agent

GENERAL OBSERVATIONS ON LIME

Reaction involves asphalt and not aggregate.

Carbonation makes the lime ineffective, thus prolonged exposure of the lime or the treated aggregate is detrimental.

Slurry holds the lime on the aggregate, thus allowing asphalt at the interface to be treated.

METHODS OF APPLYING LIME

1. Lime slurry is best method of application (especially for drum mixers).
2. Dry lime is effective if it can be kept on the aggregate surface.
3. Mixing dry lime directly in asphalt cement not recommended.

SKID RESISTANCE

Skid resistance is the ability of an asphalt surface mixture to minimize skidding or slipping of vehicle tires, particularly when wet. For good skid resistance, tire tread must be able to maintain contact with the aggregate particles. Mixtures that tend to rut and bleed present serious skid resistance problems.

WORKABILITY

Workability describes the ease with which a paving mixture can be placed and compacted. Mixtures with good workability are easy to place and compact; those with poor workability are difficult to place and compact. Workability can often be improved by changing mix design parameters such as aggregate type or gradation. Mix workability is related to pavement stability and density; however, there are no set test procedures whereby problems with workability can be positively identified in the laboratory.

WORKABILITY

Aggregate Factors

- gradation
- surface texture
- shape
- maximum size

Asphalt Factors

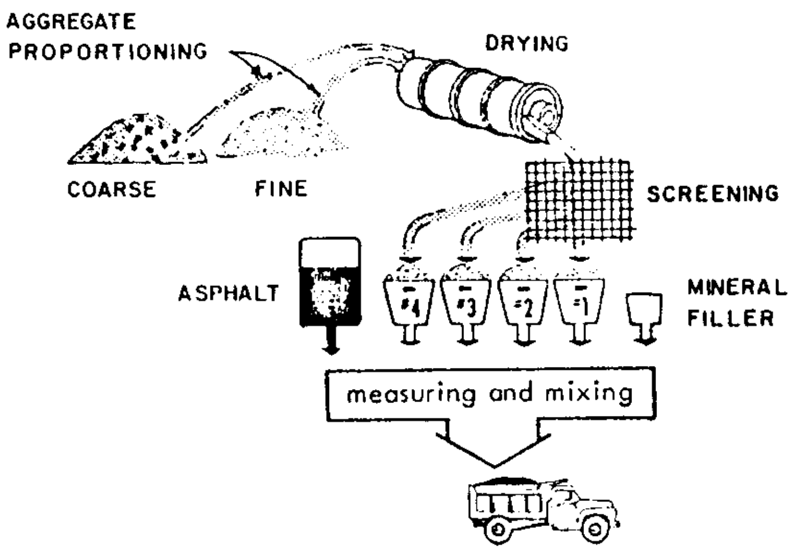
- laydown and compaction temperature
- viscosity
- % asphalt

PLANTS

TYPES OF PLANTS

* Batch
* Continuous
* Drum

1-103 The same sequence is illustrated here; the different placements of the parts will broaden your overview of the plant's structure.



A. Proportioned amounts of ________ and ________ aggregates are fed into the dryer.

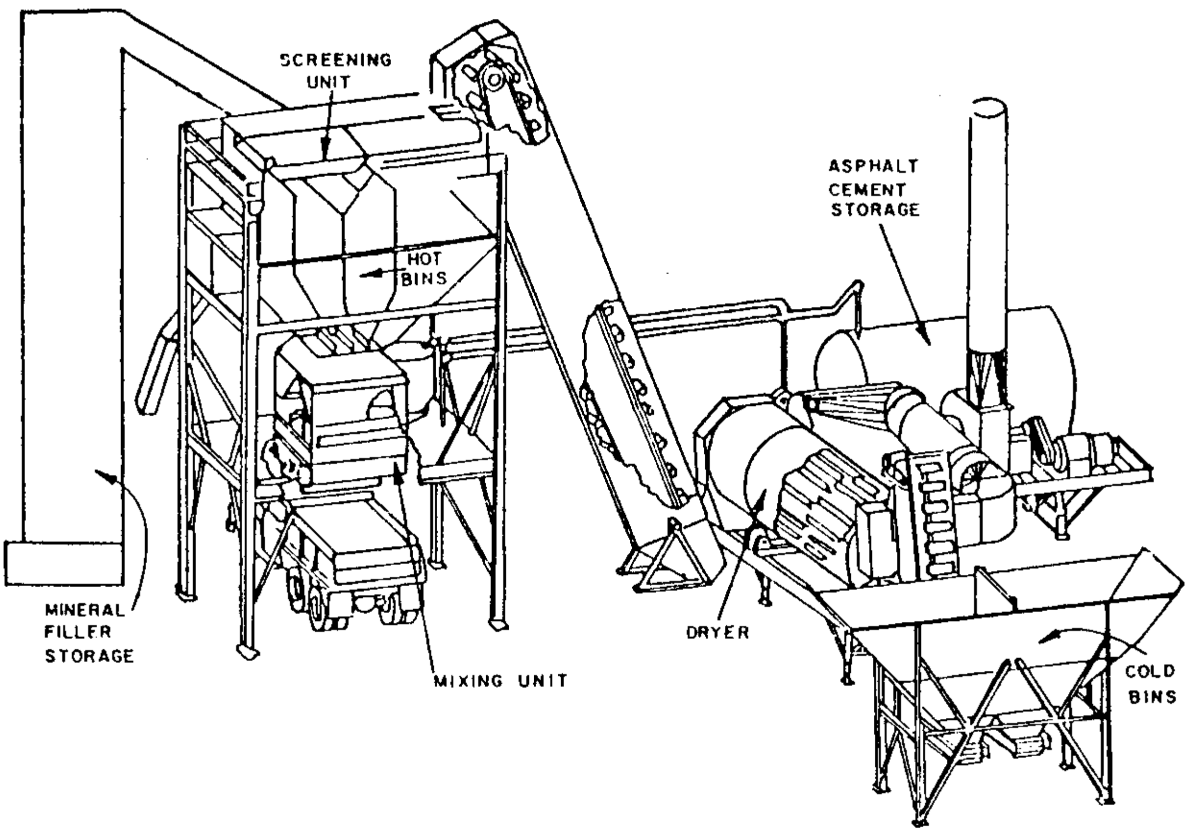
B. The aggregates are shown stored in ________ (number) hot bins after screening.

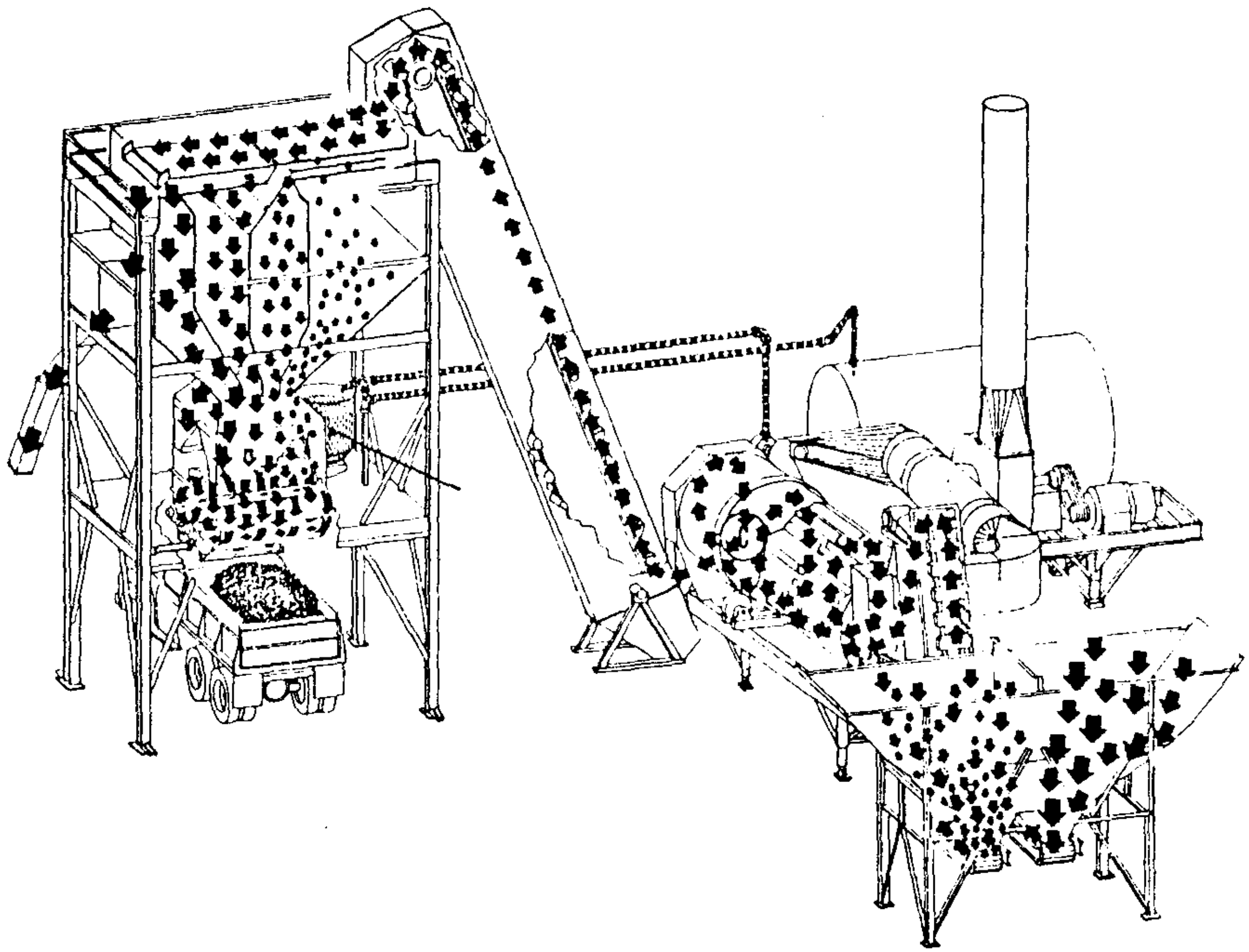
C. Measured amounts from each hot bin are mixed with ________ and ________.

BASIC ELEMENTS OF BATCH PLANT

* Aggregate Stockpiling
* Asphalt Storage
* Cold Aggregate Bins
* Cold Aggregate Feeders
* Dryer
* Hot Screens
* Hot Bins
* Batching
* Mixing Unit
* Hot Storage

1-104 Now you can follow the same basic steps in a sketch of a hot mix plant.





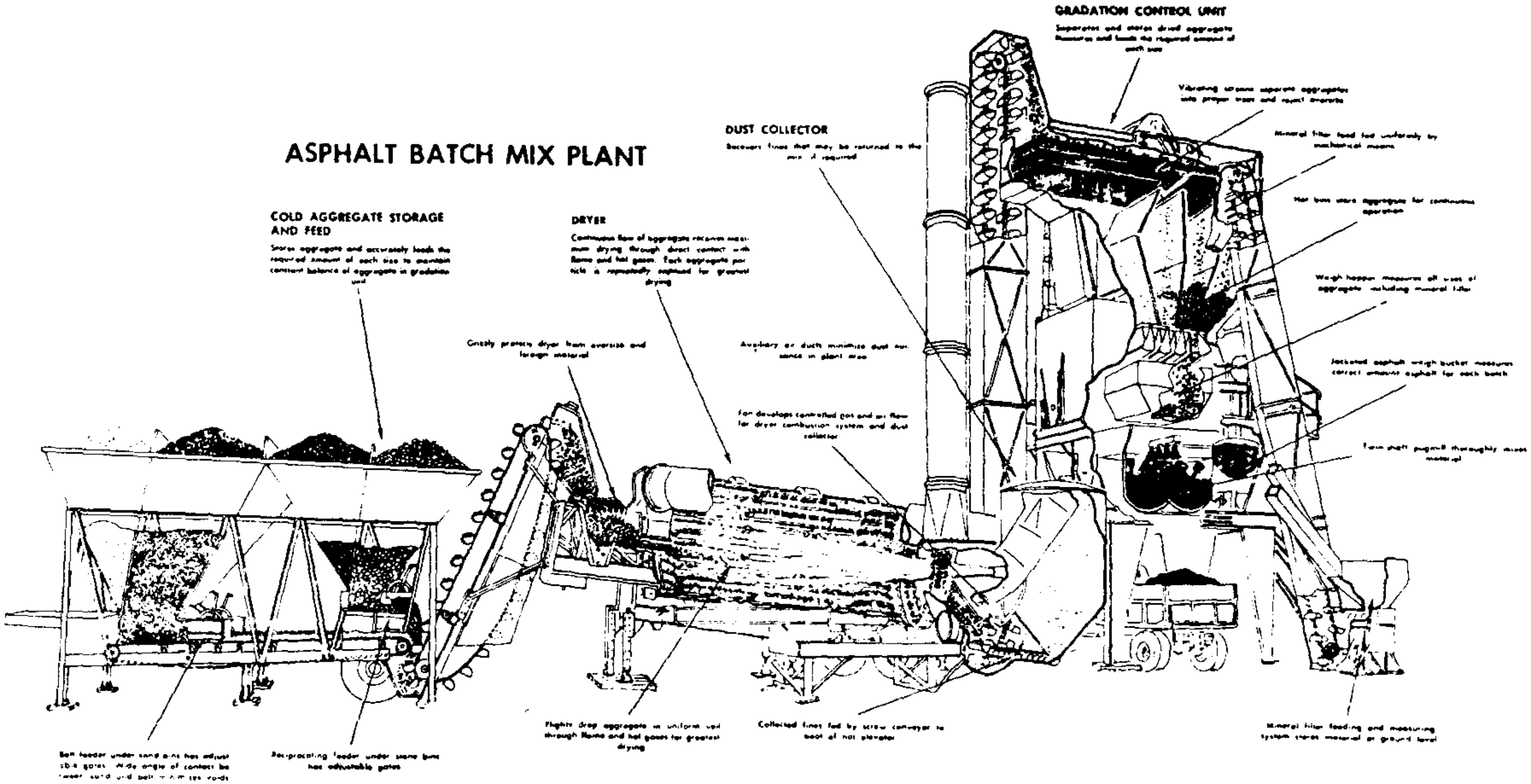


Figure 44. Asphalt batch mix plant (52).

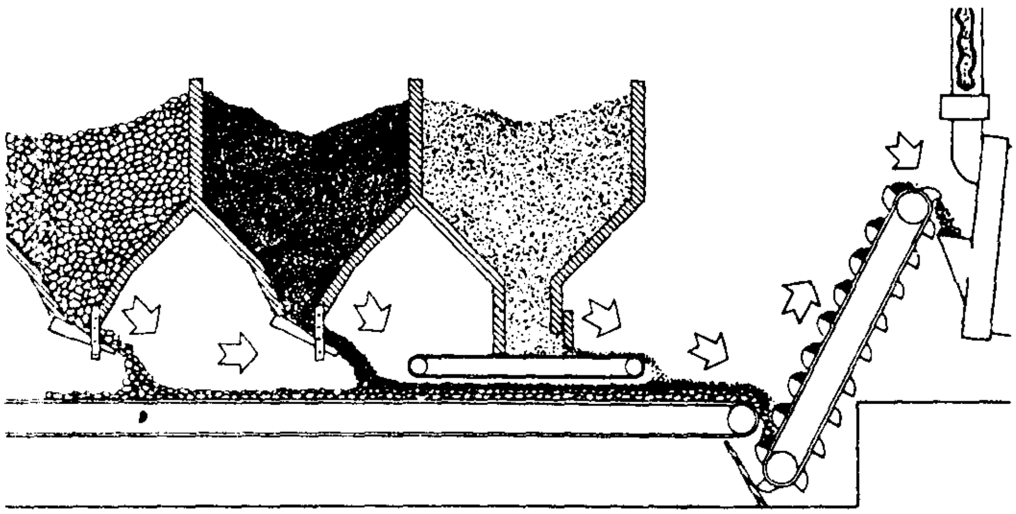


Figure 6. Three-bin cold feeder and belt

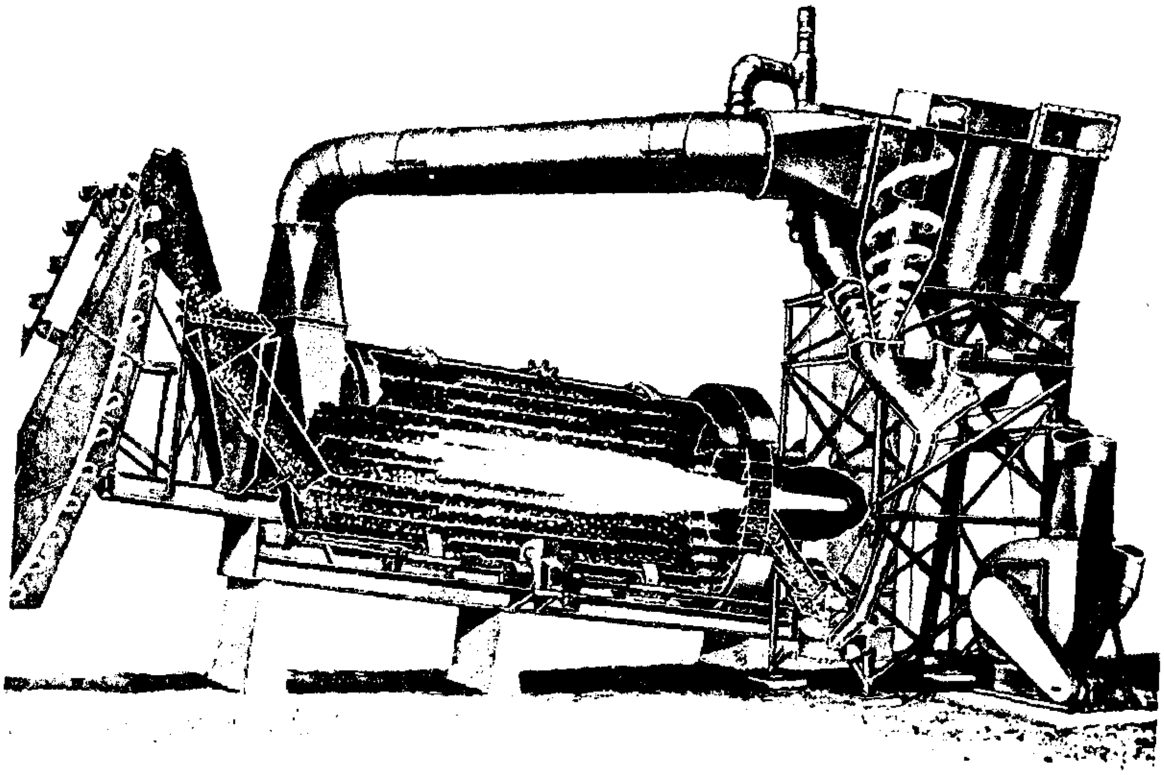


Figure 11. Dryer used in a central mixing plant
(Courtesy Barber-Greene Co.)

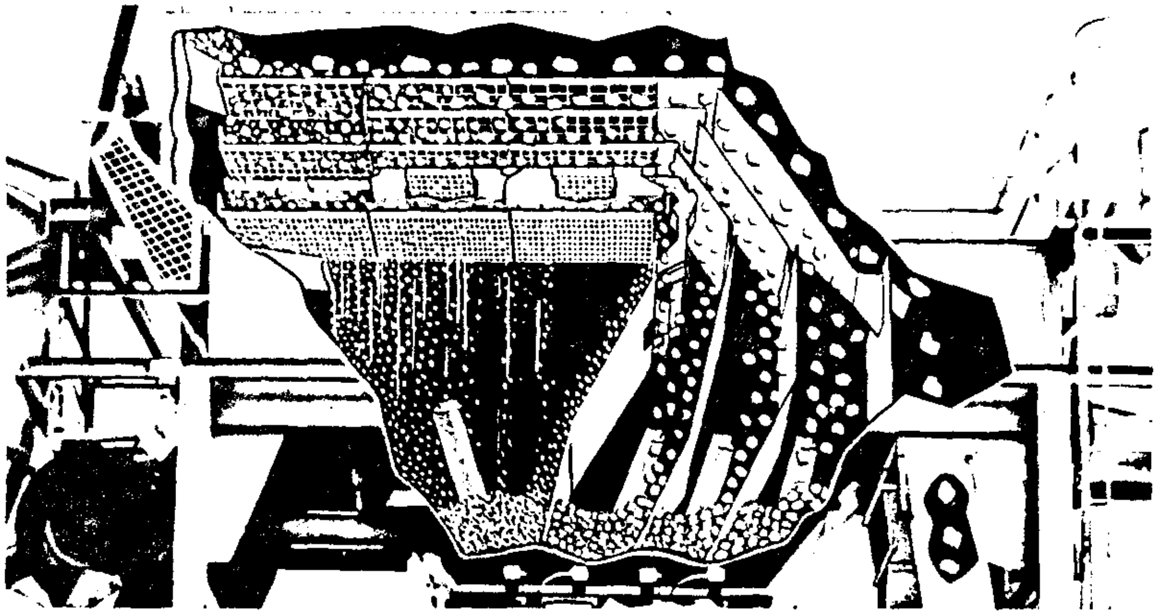
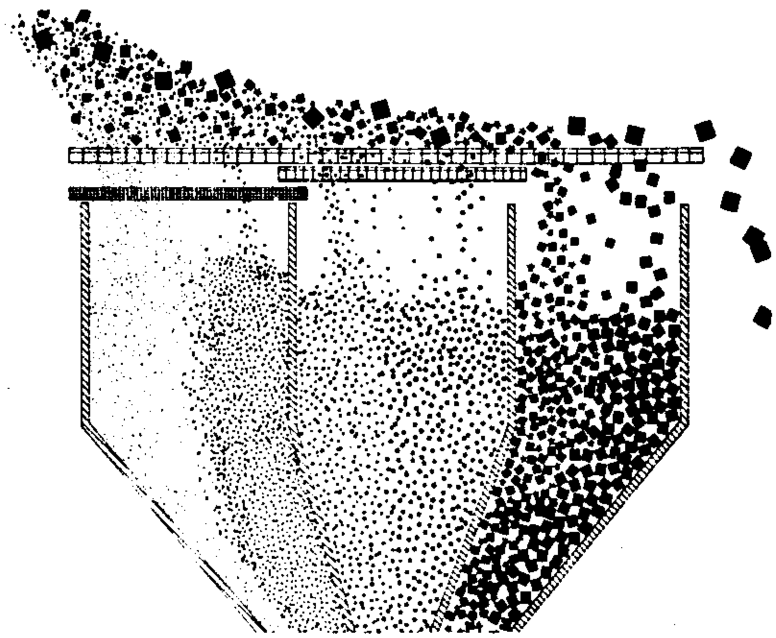


Figure 12. Cutaway view showing details of flow of material through screens and bins

(Courtesy Iowa Manufacturing Company)

Figure 6. Segregation of materials in the hot bins



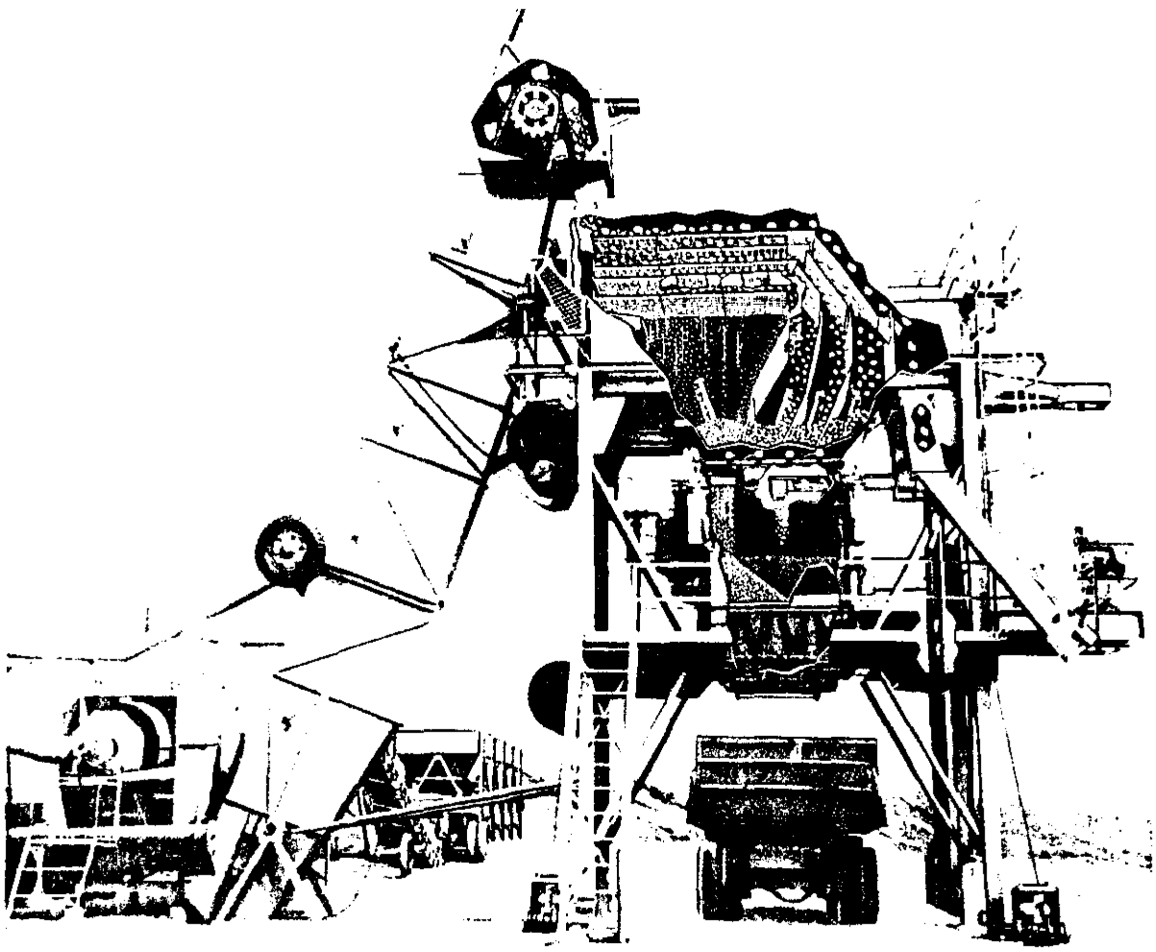


Figure 14. Cutaway drawing of asphalt batch-mix plant
(Courtesy Iowa Manufacturing Company)

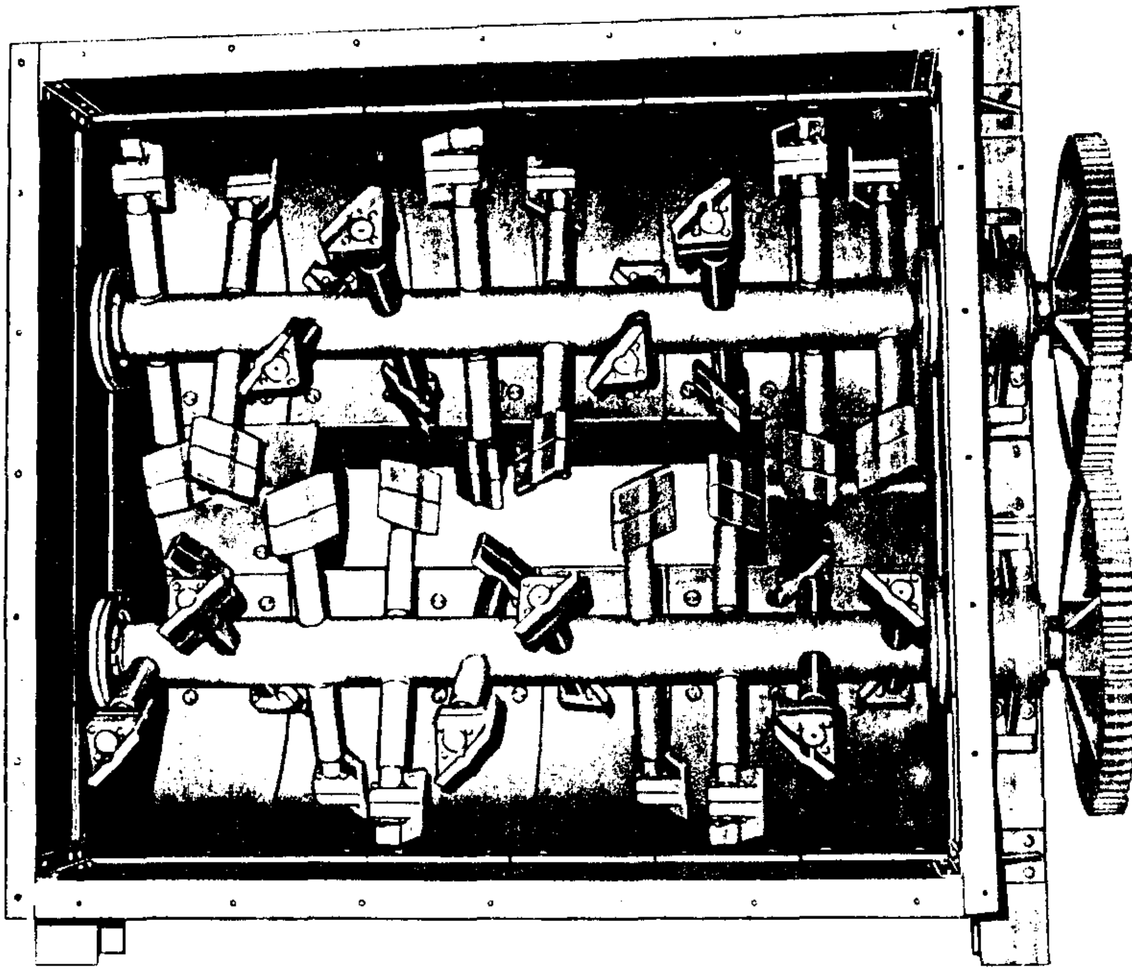


Figure 15. Pugmill mixer for a batch plant

(Courtesy Iowa Manufacturing Company)

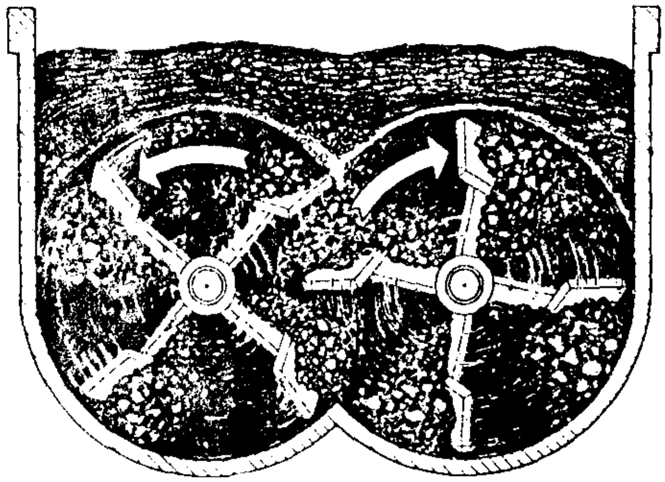


Figure 2. Overfilled pugmill

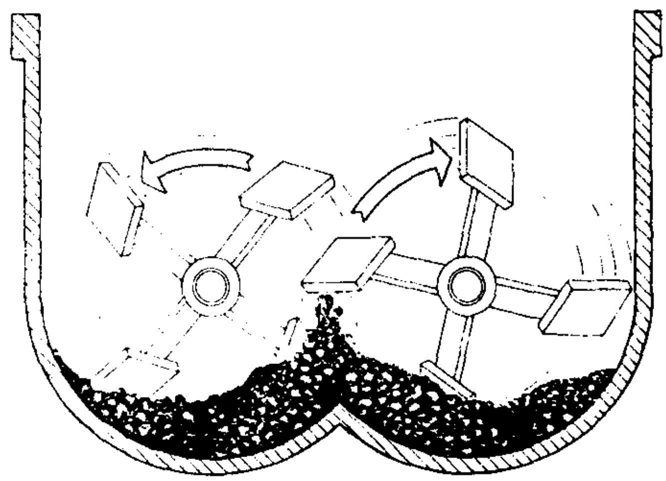


Figure 3. Underfilled pugmill

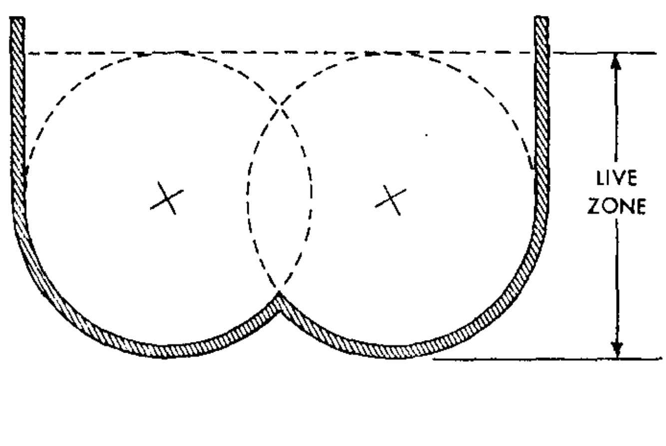


Figure 4. Pugmill "live zone"

BASIC ELEMENTS OF DRUM MIXER PLANT

* Aggregate Stockpiling
* Asphalt Storage
* Cold Aggregate Bins
* Cold Aggregate Feeders
* Drum Dryer and Mixer
* Hot Storage

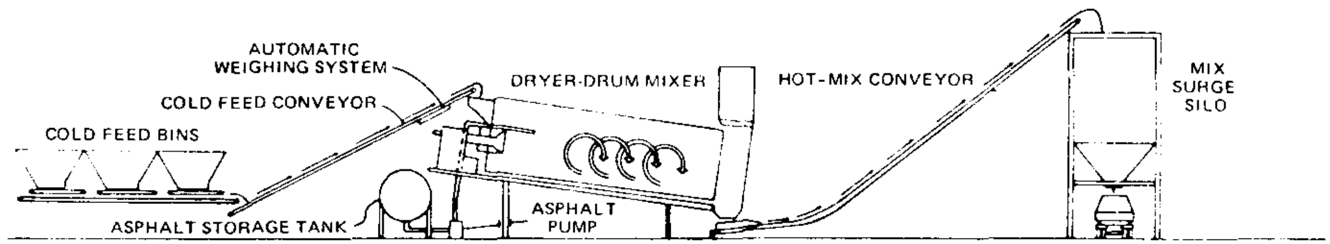


Figure III-26–Asphalt dryer drum mix plant

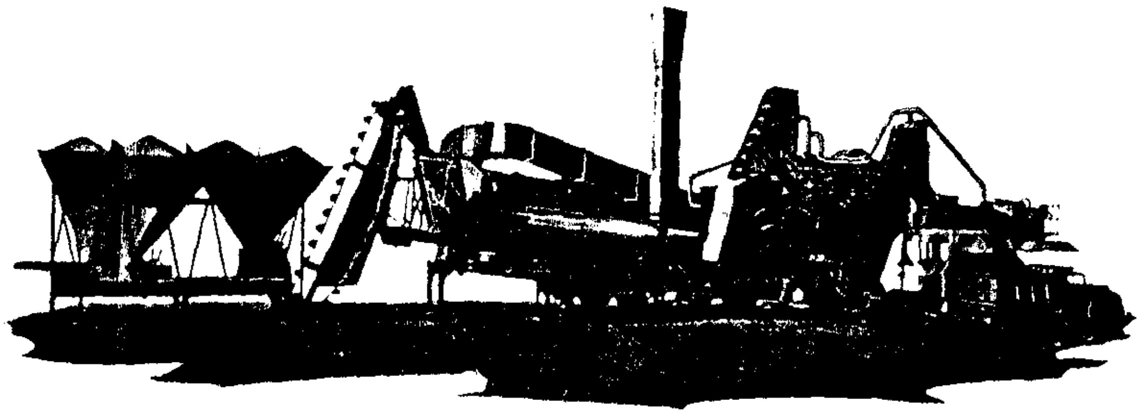


Figure 5. Diagram of continuous-type process
(Courtesy Barber-Greene Co.)

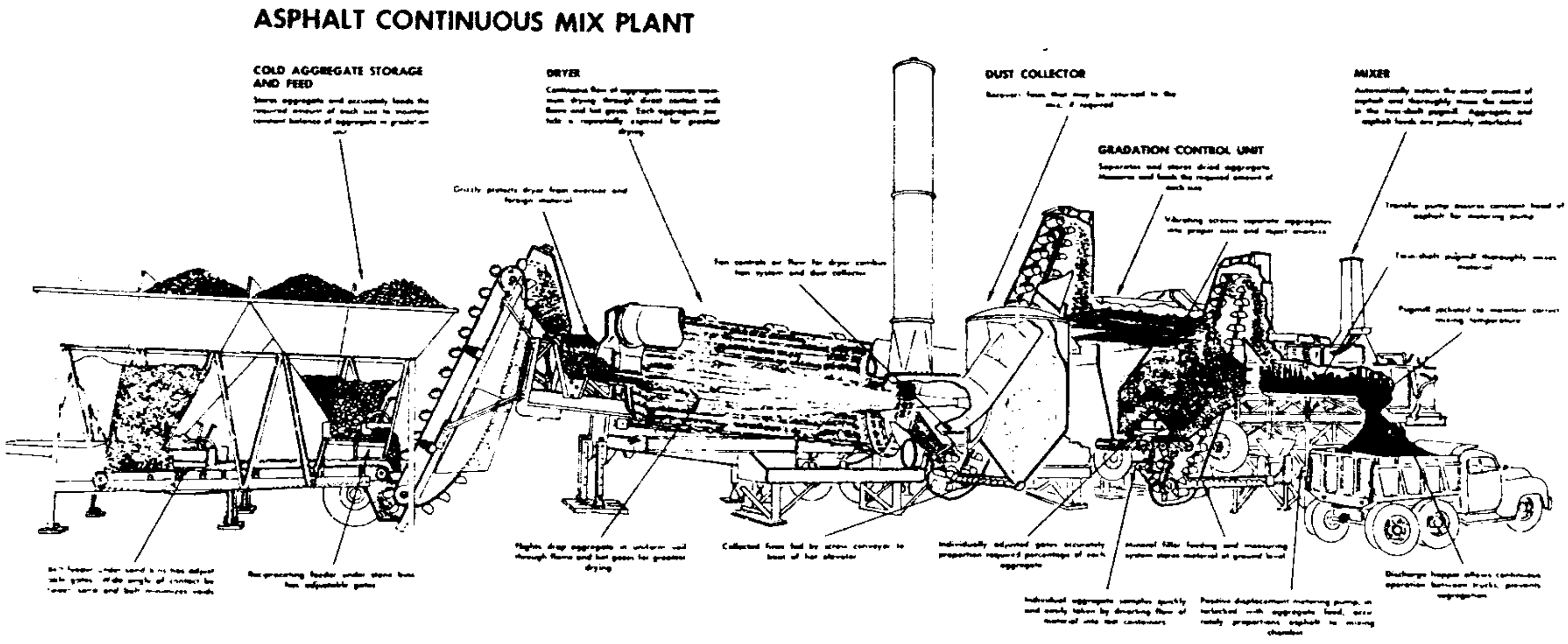


Figure 43. Asphalt continuous mix plant (52).

OPERATING AND INSPECTION OF ASPHALT PLANTS

* Materials Handling and Storage
* Cold Aggregate Feeding
* Drying and Heating
* Screening and Grading
* Temperatures
* Balanced Flow of Materials

RECOMMENDED ASPHALT VISCOSITIES FOR MIXING

Type of Mix	Viscosity	
	Kinematic, cs	Saybolt-Furol, sec.
dense-graded	150-300	75-150
open-graded	300+	150+

ASPHALTIC CONCRETE PAVEMENTS

THIS IS A GUIDE FOR NORMAL SAMPLING AND TESTING. WHEN NECESSARY FOR QUALITY CONTROL, ADDITIONAL SAMPLING AND TESTING WILL BE REQUIRED.

MATERIAL or PRODUCT		TEST FOR	TEST NUMBER	JOB CONTROL TESTS: LOCATION or TIME of SAMPLING	JOB CONTROL TESTS: FREQUENCY of SAMPLING	RECORD TESTS: LOCATION or TIME of SAMPLING	RECORD TESTS: FREQUENCY of SAMPLING (E)	REMARKS
MINERAL AGGREGATES (PRIOR TO MIXING)	COARSE AGGREGATE	Gradation	Tex-200-F (Dry)	During Delivery to Plant or From Stockpile	Each 6,000 Tons or Fraction Thereof (D)	Same as Job Control	Each 60,000 Tons or Fraction Thereof (A) (D)	Tests To Be Made for Each Stockpile
	COARSE AGGREGATE	Deleterious Material and Decantation	Tex-217-F	As Designated by District Engineer or as Specified	Each 6,000 Tons or Fraction Thereof (D)	Same as Job Control	Each 60,000 Tons or Fraction Thereof (A) (D)	
	COARSE AGGREGATE	Plasticity Index	Tex-106-E	As Designated by District Engineer or as Specified	Each 6,000 Tons or Fraction Thereof (When Necessary)	Same as Job Control	Each 60,000 Tons or Fraction Thereof (When Necessary) (A)	
	FINE AGGREGATE	Gradation	Tex-200-F (Dry)	During Delivery to Plant or From Stockpile	Each 6,000 Tons or Fraction Thereof (D)	Same as Job Control	Each 60,000 Tons or Fraction Thereof (A) (D)	Tests To Be Made for Each Stockpile
	FINE AGGREGATE	Plasticity Index	Tex-106-E	During Delivery to Plant or From Stockpile	Each 6,000 Tons or Fraction Thereof (D)	Same as Job Control	Each 60,000 Tons or Fraction Thereof (A) (D)	
	MINERAL FILLER	Gradation	Tex-200-F (Dry)	During Delivery to Plant or From Stockpile	Each 6,000 Tons or Fraction Thereof	Same as Job Control	Each 60,000 Tons or Fraction Thereof (A)	
	COMBINED AGGREGATES	Gradation	Tex-200-F (Dry)	Hot Bins or Feeder Belt	4 For Each Day's Production **	Same as Job Control	Each 30,000 Tons or Fraction Thereof (A) (D)	** Reduce the Required Number of Tests Proportionately When Plant Produces Fractional Part of Day
	COMBINED AGGREGATES	Sand Equivalent	Tex-203-F	Hot Bins or Feeder Belt	1 For Each 10 Days' Production			Mineral Filler Not To Be Included
	COMBINED AGGREGATES							
ASPHALTS, OILS & EMULSIONS		Compliance With Item 300 "Asphalts, Oils and Emulsions"	Tex-500-C, Etc.	Sampled, Tested, and Approved by D-9				
COMPLETE MIXTURE	HOT MIX ACP & HOT MIX-COLD LAID ACP	Laboratory Density	Tex-207-F	Plant or Road	1 For Each Day's Production	Same as Job Control	1 For Each 10 Days' Production or Fraction Thereof (A)	
	HOT MIX ACP & HOT MIX-COLD LAID ACP	Stability	Tex-208-F	Plant or Road	1 For Each Day's Production	Same as Job Control	1 For Each 10 Days' Production or Fraction Thereof (A)	
	HOT MIX ACP & HOT MIX-COLD LAID ACP	Extraction	Tex-210-F	Plant or Road	1 For Each Day's Production	Same as Job Control	1 For Each 10 Days' Production or Fraction Thereof (A)	
	HOT MIX ACP & HOT MIX-COLD LAID ACP	In Place Density (When Required by Specifications)	Tex-207-F	Completed Course	1 For Each Day's Production	Same as Job Control	1 For Each 10 Days' Production or Fraction Thereof	
	HOT MIX ACP & HOT MIX-COLD LAID ACP	Cohesiometer (When Required by Specifications)	Tex-214-F	Plant or Road	1 For Each Day's Production	Same as Job Control	1 For Each 10 Days' Production or Fraction Thereof (A)	
	HOT MIX ACP & HOT MIX-COLD LAID ACP	Moisture Content	Tex-212-F	Plant or Road	1 For Each Day's Production *	Same as Job Control	1 For Each 10 Days' Production or Fraction Thereof (A)	* Sampled, Tested, and Approved at Source When D-9 Provides Inspection at Plant
	HOT MIX ACP & HOT MIX-COLD LAID ACP	Hydrocarbon Volatile Content	Tex-213-F	Plant or Road	1 For Each Day's Production *	Same as Job Control	1 For Each 10 Days' Production or Fraction Thereof (A)	* Sampled, Tested, and Approved at Source When D-9 Provides Inspection at Plant
	COLD MIX LRA PAVEMENT	Compliance With Item 330 "Cold-Mix Limestone Rock Asphalt"	Tex-217-F Etc.	Sampled, Tested, and Approved by D-9				
		Dimensions		Completed Pavement	As Necessary For Control		1 Total Depth Per Travel-Way Per 2 Miles or Fraction Thereof (B) (C)	

(A) Not Required When D-9 Provides Inspection at Plant.

(B) Travel-Way Is Defined As Total Width of a Travel Facility That Is Not Separated from Other Parallel Travel Facilities by a Median, Ditch, Etc.

(C) Not Required for Level-ups and Overlays.

(D) When Synthetic Aggregate Is Used in Lieu of Natural Aggregate Reduce the Quantity Under "Frequency of Sampling" by 50%.

Example: Natural Aggregate 6,000 Tons = Synthetic Aggregate 3,000 Tons.

(E) Record Tests are not Required for a Contract Quantity Resulting in Less Than 3 Job Control Tests.

TABLE V

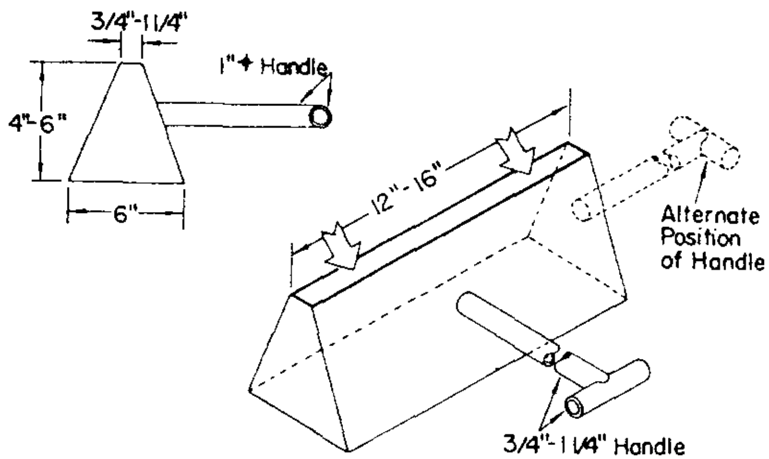


Figure 7. Asphalt plant aggregate sampling device

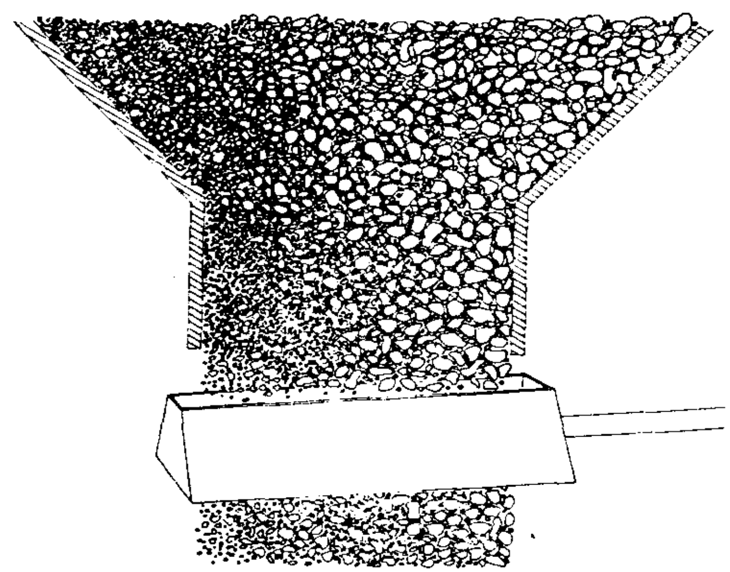


Figure 8. Correct use of sampling device

TABLE 1 POSSIBLE CAUSES OF MIX DEFICIENCIES IN HOT PLANT-MIX PAVING MIXTURES

Aggregates Too Wet	Inadequate Bunker Separation	Aggregate Feed Gates Not Properly Set	Over-rated Dryer Capacity	Dryer set too steep	Improper Dryer Operation	Temp. Indicator Out of Adjustment	Aggregate Temperatures Too High	Worn Out Screens	Faulty Screen Operation	Bin Overflows Not Functioning	Leaky Bins	Segregation of Aggregates in Bins	Carryover in Bins Due to Overloading Screens	Aggregate Scales Out of Adjustment	Improper Weighing	Feed of Mineral Filler Not Uniform	Insufficient Aggregates in Hot Bins	Improper Weighing Sequence	Insufficient Asphalt	Too Much Asphalt	Faulty Distribution of Asphalt to Aggregates	Asphalt Scales Out of Adjustment	Asphalt Meter Out of Adjustment	Undersize or Oversize Batch	Mixing time not proper	Improperly Set or Worn Paddles	Faulty Dump Gate	Asphalt and Aggregate Feed Not Synchronized	Occasional Dust Shakedown in Bins	Irregular Plant Operation	Faulty Sampling	Types of Deficiencies That May Be Encountered in Producing Hot Plant-Mix Paving Mixtures
		A												B	B				A	A	A	B	C	B	B	A		C			A	Asphalt Content Does Not Check Job Mix Formula
	A	A						A	A	A	A	A	A	B	B	A	A							B		A	A	C	A		A	Aggregate Gradation Does Not Check Job Mix Formula
	A	A							A	A	A	A	A	B	B	A	A							B	B			C	A		A	Excessive Fines in Mix
A			A	A	A	A	A																							A		Uniform Temperatures Difficult to Maintain
											B			B	B									B								Truck Weights Do Not Check Batch Weights
														B	B					A	A	B	C	B		A		C				Free Asphalt on Mix in Truck
																		B									B					Free Dust on Mix in Truck
A			A	A	A	A													A		A	B	C	B	B	A		C		A		Large Aggregates Uncoated
									A	A	A	A	A	B	B	A	A	B			A	B	C		B	A	B	C	A	A		Mixture in Truck Not Uniform
																		B			A			B	B	A				A		Mixture in Truck Fat on One Side
					A															A	A	B	C	B				C		A		Mixture Flattens in Truck
		A			A	A	A																							A		Mixture Burned
A			A	A	A	A			A										A			B	C	B				C		A		Mixture Too Brown or Gray
														B	B	A	A			A	A	B	C	B				C		A		Mixture Too Fat
					A	A	A																							A		Mixture Smokes in Truck
A			A	A	A	A																								A		Mixture Steams in Truck
					A	A	A												A										A	A		Mixture Appears Dull in Truck

—Applies to Batch and Continuous Type Plants. B—Applies to Batch Plants only. C—Applies to Continuous Plants only.

I. <u>PLANT INSPECTOR'S CHECK LIST</u>. For the convenience of the Engineer and the Inspector, some of the more important details of inspection in production of the hot mix asphaltic concrete are listed below:

1. Determine that the testing tools and equipment are on hand and in good condition. Make sure you understand all the tests.

2. Inspect all components of the mixing plant, and make sure that all deficiencies are corrected <u>before</u> mixing is begun.

3. Check all scales for accuracy periodically, and determine correct adjustment to zero daily.

4. See that the stockpiled aggregates are kept separate, and that no intermingling occurs at the cold feeders.

5. Check the temperature of the heated aggregate frequently.

6. Watch for evidence of incomplete combustion of the burner fuel, as evidenced by dark smoke from the plant exhaust and coating on the aggregate.

7. Check the temperature of the asphalt frequently.

8. Establish the scale settings for the batch weights, and station the Weight Inspector at or near the batching scales so that he can observe the weighing of the aggregates and asphalt.

9. Daily check the screens, bins, and overflow chutes for proper operation.

10. Check an occasional batch to see that it is mixed the required length of time.

11. Make frequent visual inspections of the mix leaving the plant for evidence of non-uniformity or incomplete mixing.

12. Check the temperature of the mix frequently.

13. Inspect the truck beds before loading; see that the truck beds are free of congealed chunks of mix and excess diesel oil.

14. Check occasionally with the Road Inspector concerning workability and uniformity of the mix at the paving machine.

15. Take samples of the mixture for extraction test and for molding the Hveem stability specimens. Sample the aggregates from the hot bins and perform the combined sieve analysis.

16. Maintain an accurate and complete record of all the test results, the number of batches mixed, the quantity of the asphalt used, and other pertinent data.

COMPACTION

DENSITY - the unit weight of the asphalt mixture.

Density increases with

- Greater compactive effort
- Higher asphalt content
- Increased mineral filler content
- Higher aggregate specific gravity

COMPACTION is the process of densification of a mixture by mechanical means, i.e., the asphalt and aggregate are compressed into a smaller volume.

PURPOSE OF COMPACTION

Improve the engineering properties and performance characteristics of the asphalt mixture

- Increases stability
- Reduces air voids
- Increases density
- Smooths surface

METHODS OF ACHIEVING COMPACTION

Construction Rolling

Traffic

Construction Rolling

- Compaction by static weight
- Compaction by kneading action
- Compaction by vibrating rollers

FACTORS AFFECTING COMPACTION

Aggregate Factors

Surface Texture

Soundness

Porosity (absorptive aggregates)

Gradation

Asphalt Factors

Viscosity (Grade)

Temperature at compaction

Amount

IMPORTANT EQUIPMENT FACTORS

Compaction Pressure

Roller Speed

Vibration Frequency

Vibration Amplitude

Amplitude is based on lift thickness and support conditions

- Use low amplitude on thin lifts
- Use high amplitude on thick lifts

Frequency is the number of impacts per minute

2000 - 3000 vibrations per minute typical

AMPLITUDE is the peak to peak vertical movement of the drum.

SUGGESTED RECOMMENDATIONS:

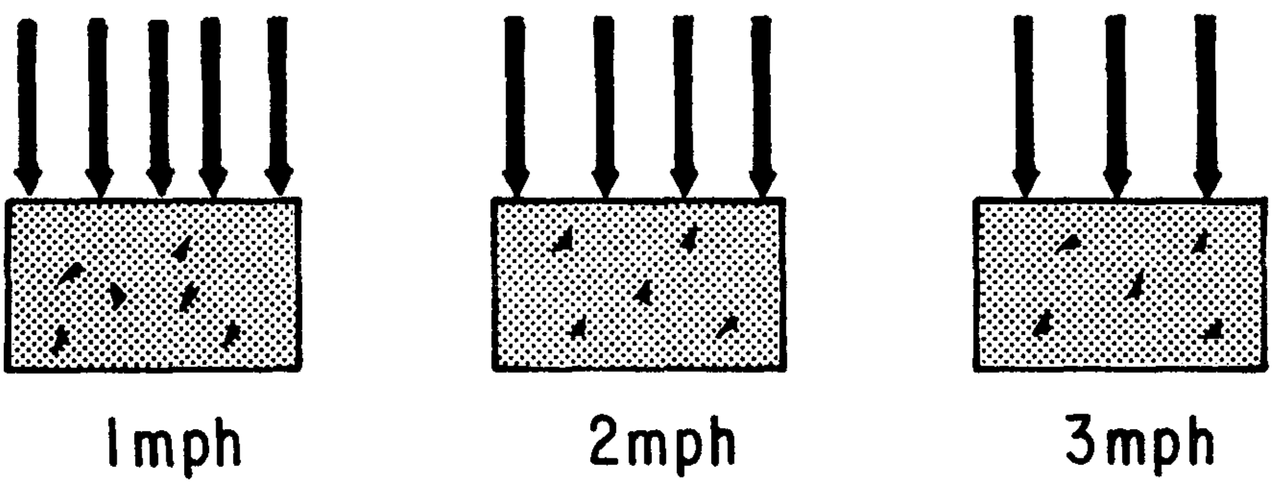
Thin Lifts ($t < 1$ in.) - use low amplitude

Medium Lifts (1 in. $< t <$ 2 in.) - use medium amplitude

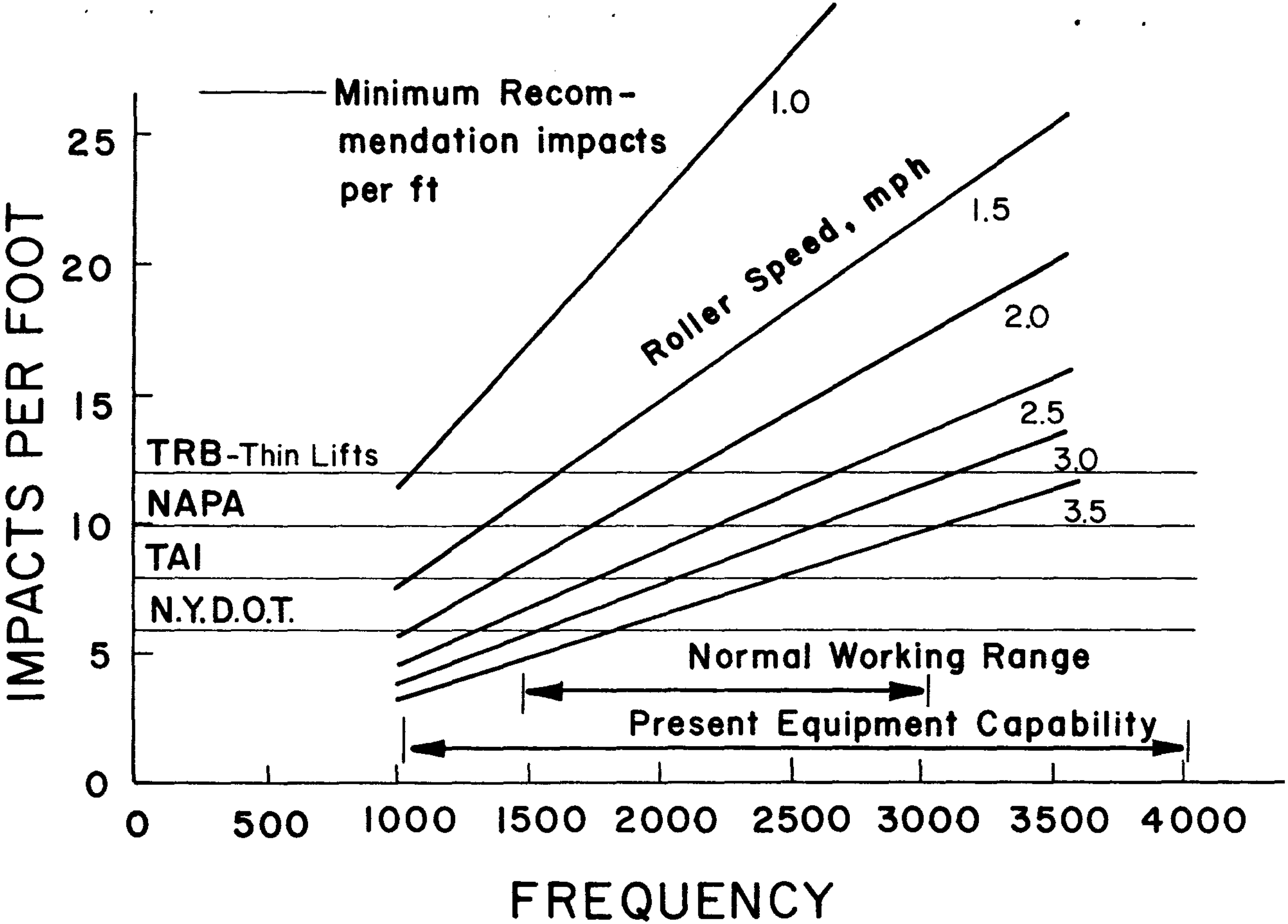
Thick Lifts ($t > 2$ in.) - use high amplitude

Roller speed is used to define impact spacing.

Impact spacing is the distance traveled between impacts.



$$\text{Impact Spacing} = \frac{\text{Roller Speed (ft./min.)}}{\text{Vibrating Frequency (rev./min.)}}$$


Minimum Recom-
mendation impacts
per ft
Roller Speed, mph
1.0
1.5
2.0
2.5
3.0
3.5
TRB-Thin Lifts
NAPA
TAI
N.Y.D.O.T.
Normal Working Range
Present Equipment Capability
IMPACTS PER FOOT
0
5
10
15
20
25
0
500
1000
1500
2000
2500
3000
3500
4000
FREQUENCY

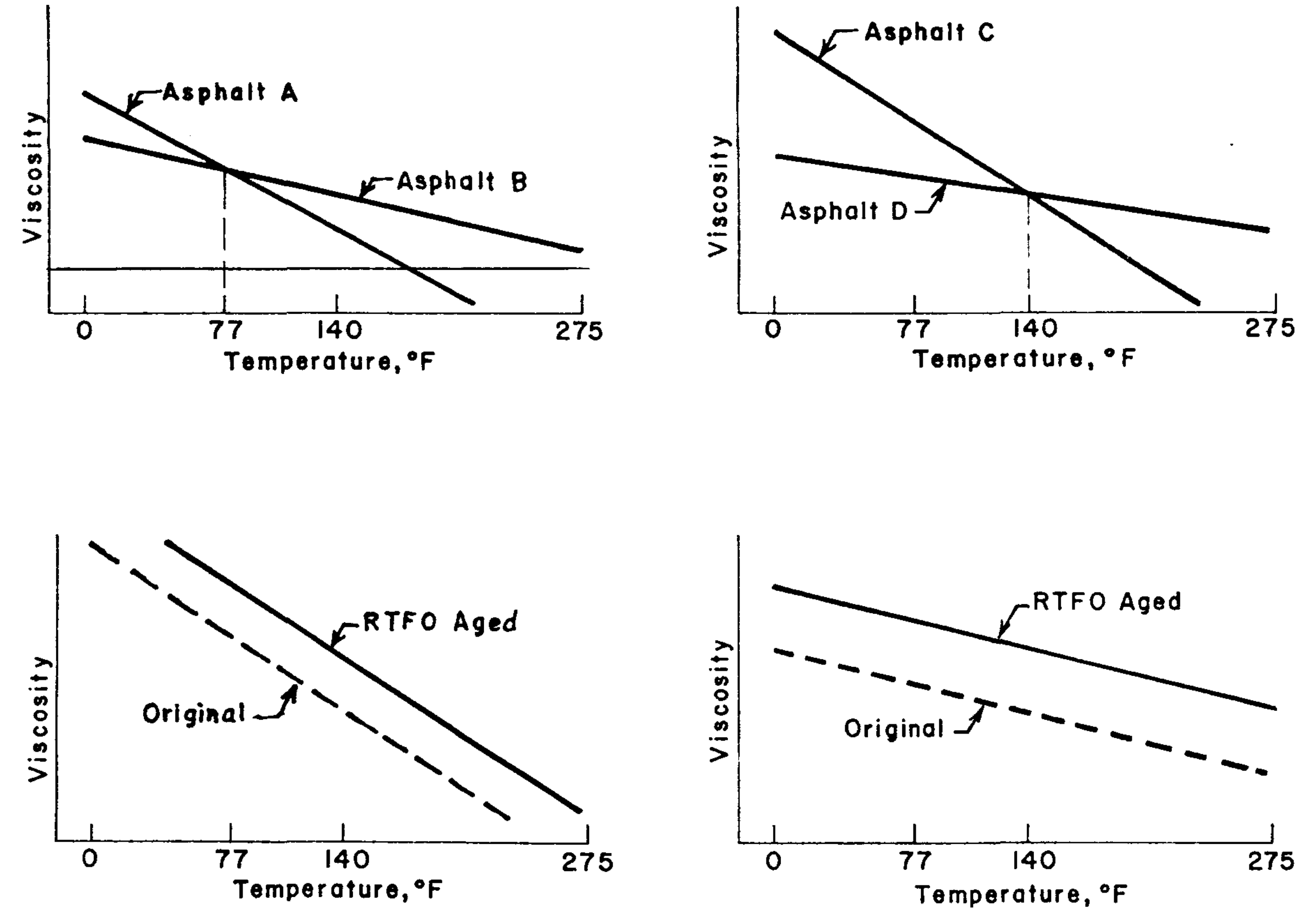
TEMPERATURE INFLUENCES

WORKABILITY

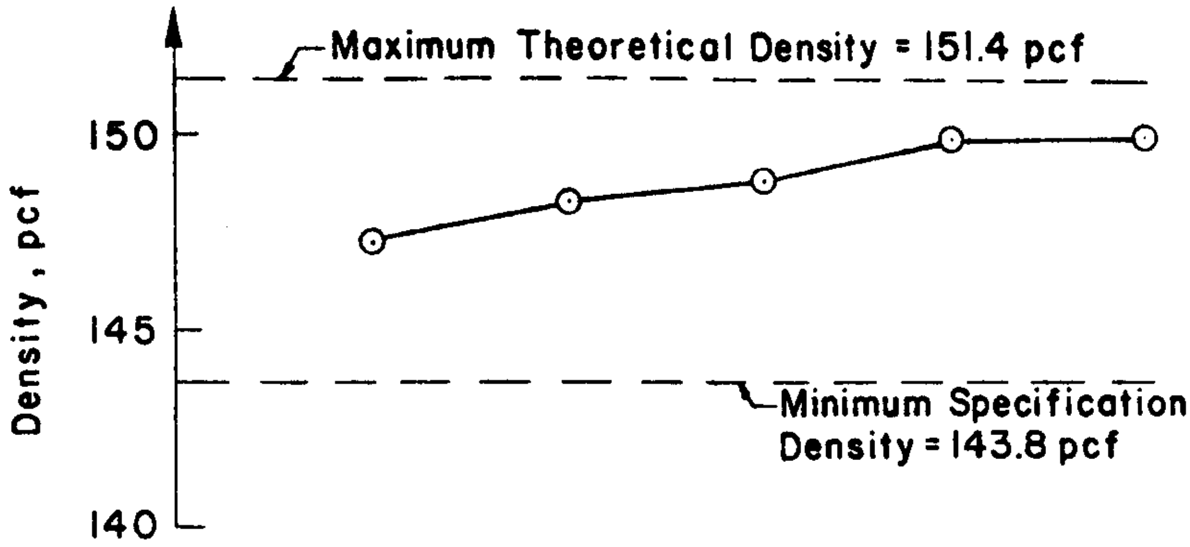
Allows <u>less</u> rolling time

↑	↑	↑
Thin lifts	Cloudy, windy day	Low temp.
Thick lifts	Sunny day	High temp.
↓	↓	↓

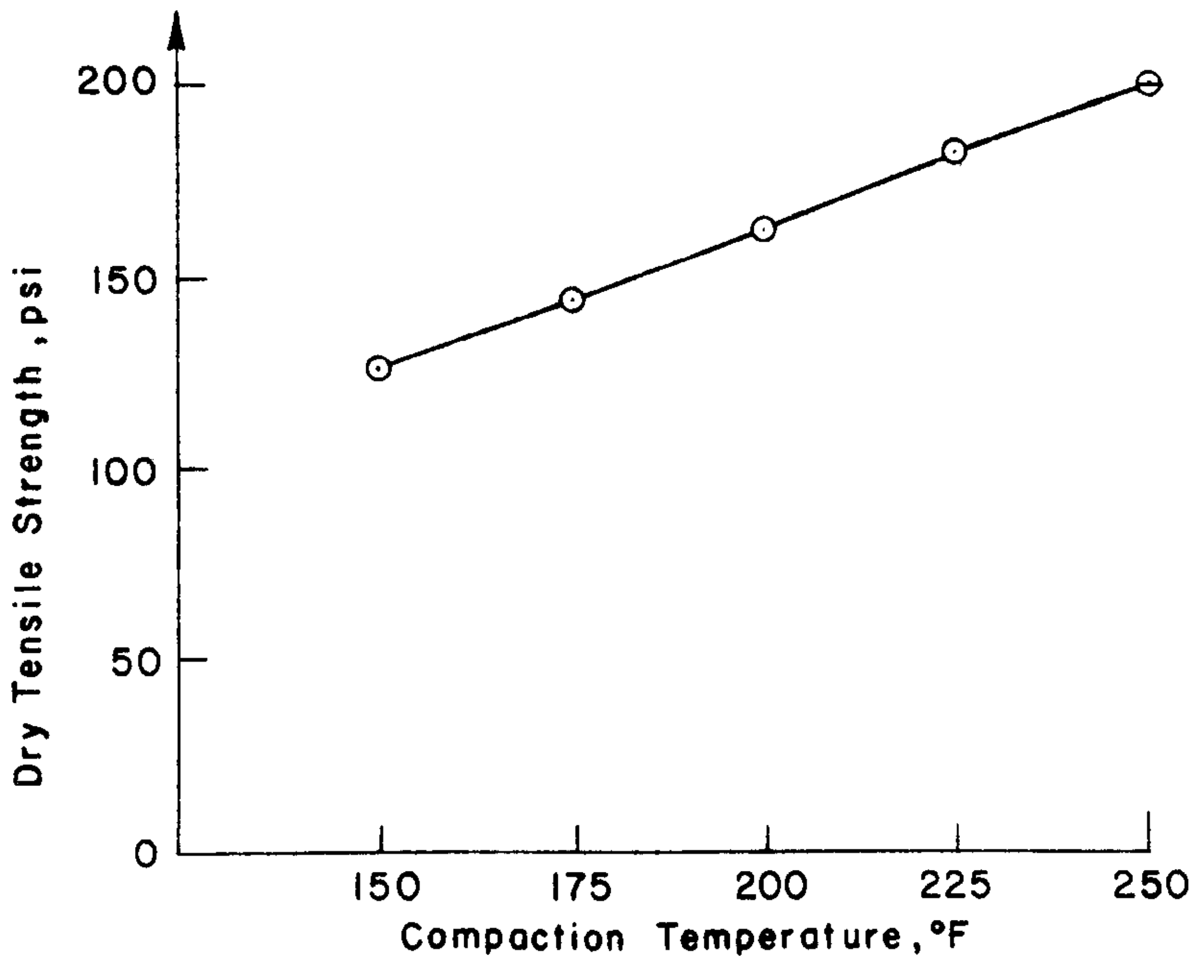
Allows <u>more</u> rolling time


Asphalt A
Asphalt B
Viscosity
0
77
140
275
Temperature, °F
Asphalt C
Asphalt D
Viscosity
0
77
140
275
Temperature, °F
RTFO Aged
Original
Viscosity
0
77
140
275
Temperature, °F
RTFO Aged
Original
Viscosity
0
77
140
275
Temperature, °F

MIXTURE TEMPERATURES OFTEN TOO LOW
FOR COMPACTION



STANDARD DHT COMPACTION



CESSATION REQUIREMENTS

Base Temp.	Recommended Minimum Laydown Temperature					
	1/2"	3/4"	1"	1-1/2"	2"	3" and Greater
20-32	—	—	—	—	—	285[1]
+32-40	—	—	—	305	295	280
+40-50	—	—	310	300	285	275
+50-60	—	310	300	295	280	270
+60-70	310	300	290	285	275	265
+70-80	300	290	285	280	270	265
+80-90	290	280	275	270	265	260
+90	280	275	270	265	260	255
Rolling time, min.	4	6	8	12	15	15

[1] Increase by 15° when placement is on base or subbase containing frozen moisture.

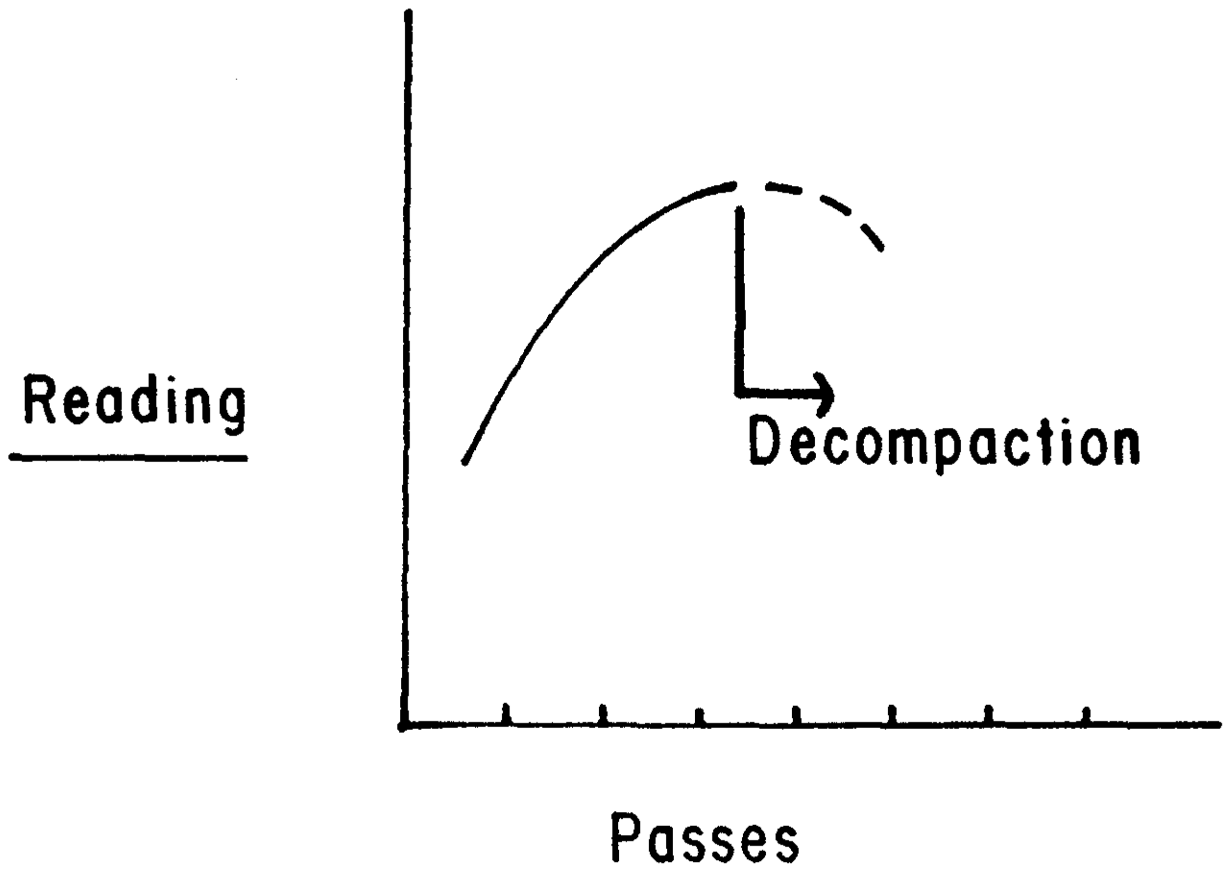
ROLLING PATTERNS

A single pattern cannot be designed.

Pattern should be developed on a test strip.

Use nuclear gage for monitoring test strip densification.

Determine core density after construction.



GUIDELINES ROLLING PATTERNS

General Rule - apply the heaviest load or energy level possible at the highest temperature possible without overstressing the mixture

Roll as close to the paver as possible

FIRST PASS

- Vibratory mode
- Combination mode
- Static mode

SUBSEQUENT COMPACTION PASSES

Compact in vibratory mode

FINISH ROLLING

Use static mode

Vibrate only while moving.

EDGE ROLLING

ROLLING THIN LIFTS

Start at outer edge with 2 to 4-inch overhang

ROLLING THICK LIFTS

Start 12 to 15 inches from outside edge

JOINT ROLLING

Seldom produces uniform joint density

Second lane usually has higher density

TYPES

- Full width paving - no joint
- Echelon paving - hot joint

JOINT ROLLING PROCEDURE

Roll joints directly behind paver

Static Rollers - First pass: overlap 6 in. onto hot side

Vibratory Rollers - First pass: overlap 6 in. onto cold side

or

First pass completely on hot side
but 3 in. away from cold side

OBJECTIVE

COMPACTION CONTROL

To aid in achieving desired density (engineering properties)
and void content

MINIMUM SPECIFICATION

Average density should be equal to or greater than 97 percent of maximum laboratory density with no individual determination less than 95 percent.

Voids in the mineral aggregate (VMA) should be:

MAX. AGGREGATE SIZE, INCHES	MINIMUM VMA, %
1-1/2	12
1	13
3/4	14
1/2	15
3/8	16

Air voids should be

3-5% for surfaces

3-8% for bases

Need to establish a minimum compaction temperature

- density
- engineering properties

MAJOR CHANGES

Skid Resistant Aggregates

Master Gradings

Design

Stability

Equipment

Stockpiling

In-Place Density

SKID RESISTANT AGGREGATES

1. Incorporate Provisions of Administrative Order for Polish Value for Coarse Aggregates.
2. Differential wear when required by Plan Note.

MASTER GRADINGS

1. Based on 100% Aggregate.
2. Required %, No. 10 - No. 40 Sieve
3. Required % Passing No. 200
4. Tolerances apply to extraction test except Minus 200 and % Asphalt.

DESIGN

1. Master Grading Applicable to Design by Weight or Volume.

   Volume Design required of Bulk Specific Gravity varies more than 0.300.

2. Option for Contract to provide design.

STABILITY

Increase to 35

EQUIPMENT

1. Drum-Mixer Requirements
2. Contractor's Responsibility

STOCKPILING

1. Basically same for Weigh Batch and Continuous Mixing Plants

2. Drum-Mix Plants
   Maximum tolerance of $\pm$ 8 percentage points.

IN PLACE DENSITY

1. Required for all mixtures.
2. Cores, pavement sections, nuclear

PROJECT 285

Asphalt Concrete Mixture Design
and Specification