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16. Abstract

Five asphalt additives that are supposed to improve the stability and flexibility characteristics of asphalt concrete were installed in pavement test sections on Route 58 in Halifax County. Polymers, latex rubbers, and a diatomaceous deposit were used, and a control section was included that contained hydrated lime. The preliminary results of various field and laboratory tests are described. There were no major construction problems and all materials are performing satisfactorily.

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SI CONVERSION FACTORS

To Convert From	To	Multiply By
Length:		
in	cm	2.54
in	m	0.025 4
ft	m	0.304 8
yd	m	0.914 4
mi	km	1 . 609 344
Area:		
in^2	cm^2	6.451 600 E+00
ft^2	m^2	9.290 304 E-02
yd^2	m^2	8.361 274 E-01
mi^2	Hectares	2.589 988 E+02
acre (a)	Hectares	4.046 856 E-01
Volume:		
oz	m^3	2.957 353 E-05
pt	m^3	4.731 765 E-04
qt	m^3	9.463 529 E-04
gal	m^3	3.785 412 E-03
in^3	m^3	1.638 706 E-05
ft^3	m^3	2.831 685 E-02
yd^3	m^3	7.645 549 E-01

NOTE: $1m^3$ = 1,000 L

To Convert From	To	Multiply By
Volume per Unit Time:		
ft^3/min	m^3/sec	4.719 474 E-04
ft^3/s	m^3/sec	2.831 685 E-02
in^3/min	m^3/sec	2.731 177 E-07
yd^3/min	m^3/sec	1.274 258 E-02
gal/min	m^3/sec	6.309 020 E-05
Mass:		
oz	kg	2.834 952 E-02
dwt	kg	1.555 174 E-03
lb	kg	4.535 924 E-01
ton (2000 lb)	kg	9.071 847 E+02
Mass per Unit Volume:		
lb/yd^2	kg/m^2	4.394 185 E+01
lb/in^3	kg/m^3	2.767 990 E+04
lb/ft^3	kg/m^3	1.601 846 E+01
lb/yd^3	kg/m^3	5.932 764 E-01
Velocity: (Includes Speed)		
ft/s	m/s	3.048 000 E-01
mi/h	m/s	4.470 400 E-01
knot	m/s	5.144 444 E-01
mi/h	km/h	1.609 344 E+00
Force Per Unit Area:		
lbf/in^2 or psi	Pa	6.894 757 E+03
lbf/ft^2	Pa	4.788 026 E+01
Viscosity:		
cS_t	m^2/s	1.000 000 E-06
P	Pa·s	1.000 000 E-01

Temperature: $(°F-32)^5/9 = °C$

INSTALLATION REPORT

EVALUATION OF ASPHALT ADDITIVES

by

G. W. Maupin, Jr.
Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

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SUMMARY

Five asphalt additives that are supposed to improve the stability and flexibility characteristics of asphalt concrete were installed in pavement test sections on Route 58 in Halifax County. Polymers, latex rubbers, and a diatomaceous deposit were used, and a control section was included that contained hydrated lime. The preliminary results of various field and laboratory tests are described. There were no major construction problems and all materials are performing satisfactorily.

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INSTALLATION REPORT

EVALUATION OF ASPHALT ADDITIVES

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INTRODUCTION

The $50-million Strategic Highway Research Program has brought about the development of many asphalt modifiers and additives that are claimed to increase the service life of flexible pavements. Private companies are attempting to develop modifiers that will increase stability, yet maintain flexibility for the increased wheel loads and tire pressures that exist. Most companies have performed a substantial number of laboratory tests in the development process; however, it is usually left up to users to install test sections and obtain field performance data on a potential product.

The field evaluation described in this report was devised because the Virginia Department of Transportation was requested by numerous additive producers to evaluate their products in field installations. Several additives are being compared at a single location under identical conditions rather than at many locations under different conditions, as was commonly done in the past since it is very difficult to compare the performance of pavements if traffic, environment, and underlying materials are different.

PURPOSE AND SCOPE

The purpose of this investigation is to evaluate several additives that reportedly improve the deformation and flexibility characteristics of asphalt paving mixtures. The field performance of test sections will be monitored, and several laboratory tests will be used to evaluate the materials that were sampled during construction.

MATERIALS

Additives

The five additives listed in Table 1 were evaluated in test sections in this investigation; also, a control section was constructed using hydrated lime.

Table 1. Additives Used in Test Sections

Additive	Type	Supplier
Polybilt 100	Polymer	Exxon Chemical Co.
Styrelf 13	Polymer	Elf Aquitaine Asphalt
Downright HM 100L	Latex	Dow Chemical, U.S.A.
Ultrapave 70	Latex	Textile Rubber & Chemical Co.,Inc.
Celite 292	Diatomaceous Deposits	Manville Corp.

Polymers

Polybilt 100 is a translucent solid that can be blended with the asphalt cement or can be added directly into the pugmill in preweighed plastic bags as it was in this installation. It is claimed that it will reduce rutting while maintaining flexibility; also, it may improve the adhesion of the asphalt to the aggregate.

Styrelf is a polymerized asphalt cement that is used as the binder in asphalt concrete. It reportedly produces resistance to rutting, increases flexibility at low temperatures, alleviates stripping problems, and decreases age hardening.

Rubber Latexes

Downright HM-100L and Ultrapave 70 are styrene/butadiene rubber latexes. These materials are supposed to reduce shoving and rutting, increase flexibility, and increase the cohesion and adhesion of the asphalt-aggregate mixture. Some of the physical properties are listed in Table 2.

Table 2. Properties of Latexes

	Downright HM-100L	Ultrapave 70
Butadiene/Styrene monomer ratio	76/24	76/24
Solids Content, % by weight	69	69
Weight per gallon at 77°F, lbs.	7.9	7.9
Brookfield Viscosity, cps (Model RVT, #3 Spindle at 20 RPM)	700	1500

Celite 292

Celite is a chalky sedimentary deposit composed of the skeletal remains of single cell aquatic plants called diatoms. It has been hypothesized that the unique particle shapes interlock within the asphalt film to help transfer stress between aggregate particles. It is believed to stabilize the mix and prevent rutting and shoving. Physical and chemical properties are listed in Table 3.

Table 3. Properties of Celite 292

Physical	
325 Mesh Residue, %	3.7
Specific Gravity	2.10
Loose Weight, lb/cu ft	6.4
Median Particle Size, microns	7.5
Surface Area, sq meters/gram	20-30
Chemical	
H_2O	3.0
Ignition Loss	5.9
SiO_2	86.0
Al_2O_3	3.6
Fe_2O_3	1.3
P_2O_5	0.2
TiO_2	0.2
CaO	0.5
MgO	0.6
Na_2O and K_2O	1.1

Mix Designs

The preliminary mix design for the S-5 mix was performed by the contractor, APAC-Virginia, Inc., and approved by the Virginia Department of Highways and Transportation (Table 4).

Table 4. Preliminary Mix Design

Sieve	% Passing
1/2"	100
#4	58 ± 4
#30	20 ± 3
#200	4.4 ± 1
A.C.	5.7 ± 0.3

60% No. 8 crushed stone - Vulcan Materials, South Boston
25% No. 10 crushed stone - Vulcan Materials, South Boston
15% No. 10 washed crushed stone - Vulcan Materials, South Boston

Froehling and Robertson, Inc., an independent testing laboratory, was retained by APAC-Virginia as specified in the highway maintenance contract to perform Marshall designs for each mix containing a different additive. A summary of the design data for each mix, which is contained in Appendix A, indicates that the asphalt content should have been appreciably higher than the preliminary asphalt content design of 5.7%, with the exception of the mix using Polybilt 100. The mix with Celite 292 was thought to possibly require more asphalt than the conventional mix. The Marshall design was duplicated in the Research Council laboratory for the mixes with Celite 292 and Ultrapave 70 as a check. The results listed in Appendix B indicate that the preliminary asphalt content design of 5.7% provided a sufficient quantity of asphalt to attain desirable void content levels. It is possible that the aggregates may have varied between the times that the different designs were performed, thereby accounting for differences in the design asphalt contents. It was decided to use 5.7% asphalt in the field mixes, but to increase the asphalt content of the mix with Celite to 5.9%, as recommended by the Celite representative. The control mix containing hydrated lime contained 5.6% asphalt cement.

TEST SECTIONS

The five test sections containing additives and the control section with hydrated lime were constructed in the westbound traffic lane on an

8-mi stretch of Route 58 in Halifax County (Figure 1). Also shown are test sections containing antistripping additives, which will be reported on separately.

Prior to paving, 2-5 in of defective stripped pavement was milled, removed, and replaced with B-3 base mix. The Department elected to split the 1.5-in thick experimental surface mix into a 0.5-in "scratch" layer and a 1.0-in surface layer in an attempt to obtain a smooth riding surface. No density tests were performed on the "scratch" layer, which was not rolled. The general paving plan was to pave a test section in the traffic lane each morning, and "square up" the adjoining passing lane in the afternoon with the conventional recycled asphalt pavement (RAP) mix.

A 2.5-ton batch plant with automatic plant controls located adjacent to Vulcan Materials Quarry at South Boston was used to produce the mix. Batch bin weights and asphalt weights were changed slightly from mix to mix (Table 5) by the contractor in an attempt to correct low density problems, and pugmill mixing times were adjusted as recommended by each product representative (Table 6). Mixing temperatures and laydown temperatures were approximately the same for the mixes; however, the mix containing Ultrapave 70 required higher temperatures.

Table 5. Batch Bin Weights, lbs.

Bin	Polybilt 100	Styrelf 13	Celite 292	Downright HM-100L	Ultrapave 70	Hydrated Lime
#1 (fine)	2150	2150	2150	2150	2150	2250
#2	1700	1650	1650	1650	1600	1650
#3 (coarse)	865	915	910	915	965	820
Asphalt cement	270	285	290	285	285	280
Additive	14	*	50	1.7 gal	1.4 gal	50

*Preblended in asphalt cement

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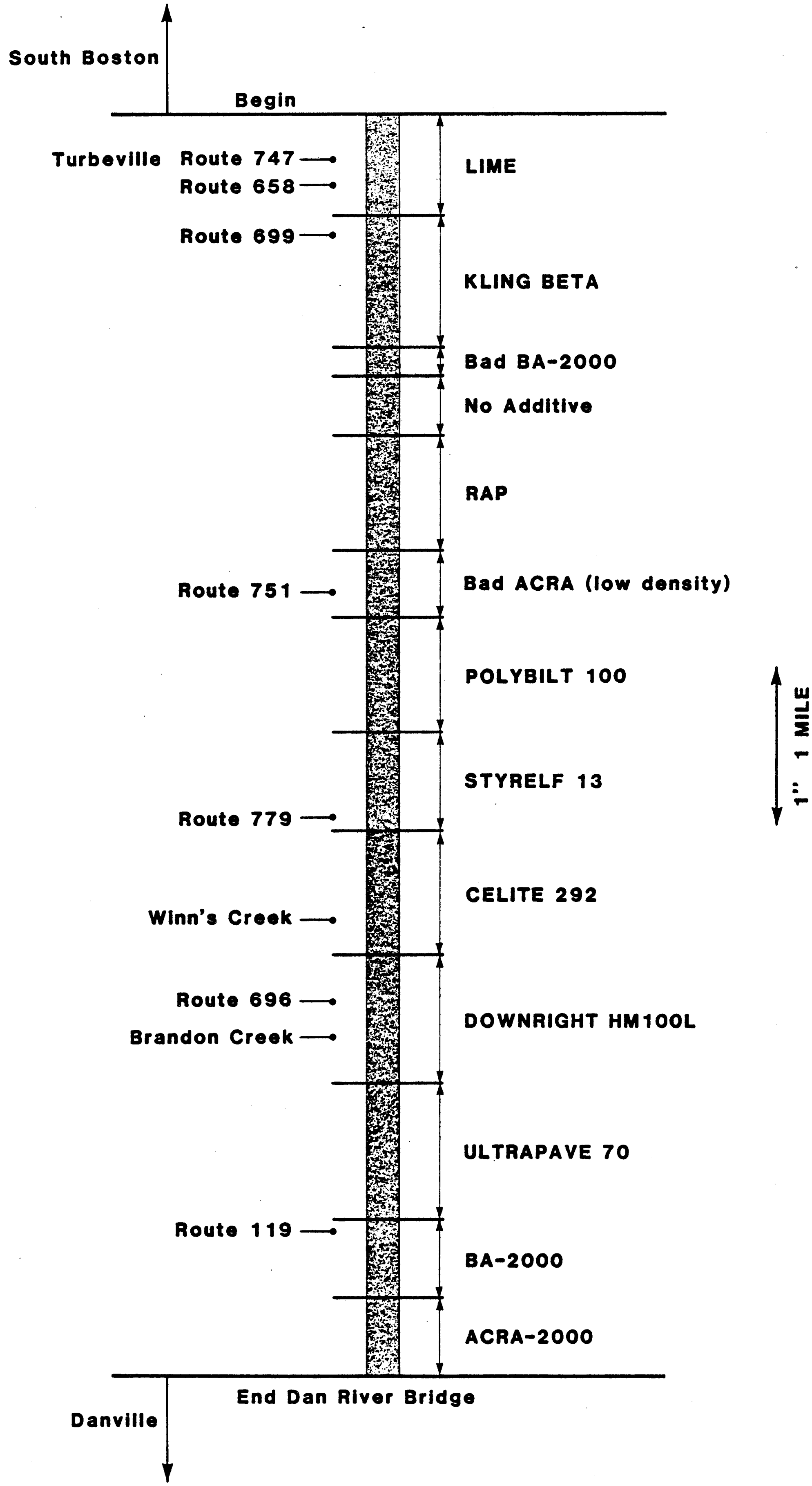

Figure 1. Test sections - Route 58.

Table 6. Pugmill Mixing Times, Sec.

Section	Dry	Wet
Polybilt 100	12	50
Styrelf 13	2	30
Celite 292	2	45
Downright HM 100L	2	30
Ultrapave 70	2	50
Hydrated Lime	2	30

Polybilt 100

The 0.7-mi section containing Polybilt 100 polymer was paved on August 11, 1986, under partly cloudy conditions and a high temperature of 90°F. The plastic bags containing the correct amount of polymer were placed into the pugmill through a preexisting opening at the beginning of the dry mix cycle. No problems were encountered during the production or laying of the mix.

Styrelf 13

The 0.6-mi section using the Styrelf 13 polymer asphalt cement was paved on August 14, 1986, under overcast skies and a high ambient temperature of 82°F. The polymer had been specially preblended with an AC-10 asphalt cement in Indiana and shipped by tanker truck to Virginia. A line was attached directly from the tanker truck to the plant's asphalt pump and the material was pumped directly into the asphalt weigh-bucket. No other changes were made in the plant and there were no problems in producing or laying the mix.

Celite 292

The mix containing Celite 292 was placed in a 0.8-mi section on August 15, 1986, under overcast conditions with some drizzle and a high ambient temperature of 84°F. The Celite 292 was dumped by hand into the pugmill at the beginning of the two-second dry mix cycle and then mixed for 45 seconds after the asphalt cement was added. Normal mix temperature was used; however, the asphalt content was increased 0.2%, as recommended by the Celite representative. Storage space was minimal on the pugmill platform and frequent delays were necessary to transfer the bags of Celite to the platform using a front-end loader.

Downright HM 100L

The mix was placed in a 0.8-mi test section on August 18 and 21, 1986, with high ambient temperatures of approximately 68^{o}F. Paving had to be stopped on the 18th because of rain and it was completed on the 21st.

The latex was shipped to the plant in 50-gallon metal drums, the tops were removed, a "skim" removed from the surface, and it was mixed by hand before using. A metal pipe was welded into the pugmill by APAC, and the product representatives were responsible for hooking their pumping equipment to the pipe and assuring that the correct amount was pumped into each batch. The pump and necessary equipment were transported and/or contained in a small trailer owned by the latex producer. An adjustable timer connected to the asphalt plant automatically controlled the time the latex was introduced and the quantity pumped into each batch. The equipment worked well and it was relatively easy to set up.

A paver breakdown on August 18 caused a two hour delay thereby allowing the mix to cool in trucks, which were waiting to be unloaded. The mix temperature dropped 10-20^{o}F causing some "pulling" of the pavement surface when paving resumed. The mix temperature was back to normal on August 21, but because the mix was stiff it was difficult to handle and work by hand.

Small coin-size blotches of asphalt accumulated on the rear of the paver screed and were deposited on the pavement surface, especially near the edges of the pavement; however, these did not appear to be detrimental.

Ultrapave 70

The mix containing Ultrapave 70 was placed in a 0.8-mi section on August 21, 1986, under partly cloudy conditions and a high ambient temperature of 89^{o}F.

The latex was shipped in 50-gallon drums and it was prepared for pumping similarly to the Downright HM 100L. The basic equipment was very similar to that described in the previous application with the exception that the switch that initiated pumping of the latex had to be controlled manually by the asphalt plant operator. There were some times when the operator was very busy and forgot to push the button to inject the latex into the pugmill; therefore, there were a few batches that did not contain latex.

The mix temperature of the first six loads was 300°F and then it was raised to approximately 325°F. The temperature of several truck loads reached as high as 350°F. The higher temperature made the mix easier to handle and work by hand than the mix containing Downright HM 100L.

Table 7. Mix Temperature at Plant and Laydown, °F

Section	Plant	Laydown
Polybilt 100	285	270
Styrelf 13	270	260
Celite 292	285	270
Downright HM 100L	285	270
Ultrapave 70	300 - 325	275 - 310
Hydrated Lime	285	270

FIELD CONTROL TESTS

Void Tests

The voids of 4-in x 4-in plugs that were removed immediately from the pavement were measured by Department inspectors and then the plugs were transported back to the Research Council lab and measured again. The results (Table 8) of the two measurements agreed within the expected experimental testing error.

Table 8. Average Pavement Voids (VTM), %

Mix	Field	Lab
Polybilt 100	9.7	10.1
Styrelf 13	8.0	7.9
Celite 292	11.0	10.7
Downright HM 100L	7.7	8.1
Ultrapave 70	8.4	8.8
Lime	8.6	8.7

The allowable maximum average void content was 8.5%; therefore, several sections were very close to or outside of the specification. It can be seen from the field Marshall results in the next section that high values of VMA indicated a possible deficiency in the gradation that could have caused the high pavement voids.

Field Marshalls

The Lynchburg District Materials lab obtained field Marshall data on a minimum of two samples of each mix (Table 9).

Table 9. Average Field Marshall Results by Lynchburg District Materials Lab

Mix	Voids Total Mix, %	Voids Filled %	Voids Mineral Aggregate, %	Stability lbs.
Polybilt 100	5.8	68.8	18.6	2530
Styrelf 13	5.5	70.4	18.7	2470
Celite	3.9	77.4	17.5	2690
Downright HM 100L	6.9	65.3	19.9	2160
Ultrapave 70	6.2	67.8	19.3	2570
Lime	5.3	70.2	17.6	2770

Froehling and Robertson, Inc., (F&R) were required to run field Marshall tests on three samples for each mix (Table 10). The lower VTM and VMA and higher VFA's from F&R's data indicated that F&R probably applied a higher compactive effort than the Lynchburg District lab did. Also, this assumption is in agreement with the average stability from F&R being approximately 600 lbs higher than the average stability measured by the Lynchburg District lab.

Table 10. Average Field Marshall Results by Froehling and Robertson

Mix	Voids Total Mix (VTM),%	Voids Filled (VFA) %	Voids Mineral Aggr. (VMA) %	Stability lbs.
Polybilt 100	4.2	76.6	18.0	3340
Styrelf 13	3.8	78.2	17.3	2770
Celite	3.4	80.9	17.6	3170
Downright HM 100L	4.8	73.8	18.2	3020
Ultrapave 70	4.8	73.4	18.2	3280

FIELD TESTS

Dynaflect

Pavement deflection measurements were made with a Dynaflect device before and after placing the experimental mixes. The Dynaflect applies a steady-state harmonic load to the pavement through two 4-in wide steel wheels with a 16-in diameter spaced 20 in apart. The peak-to-peak deflections are measured by using five geophones located midway between the two steel wheels and at four other locations 1 ft apart. The results were used to determine the thickness index, a measure of pavement strength, of each section. Measurements were taken at 100-ft intervals and the average-thickness indices of each section are listed in Table 11.

Table 11. Thickness Indices of Test Sections, in.

Section	Before Paving	After Paving
Polybilt 100	6.9 (1.5)	8.0 (1.1)
Styrelf 13	9.2 (1.9)	7.0 (1.3)
Celite 292	8.4 (1.4)	8.1 (1.7)
Downright HM 100L	7.8 (1.8)	9.2 (1.4)
Ultrapave 70	7.5 (1.9)	8.5 (1.6)
Hydrated Lime	10.8 (2.8)	12.5 (2.5)

NOTE: Standard deviation is in parenthesis.

As expected, the thickness index, which is a measure of pavement strength, generally increased after paving with a 1.5-in surface course; however, a decrease was observed in the sections with Styrelf 13 and Celite 292. Further analysis of the dynaflect data indicated that the decrease of strength had occurred in the subgrade. There was a considerable period of dry weather before the initial dynaflect measurements were made, and a significant amount of rainfall occurred before the final measurements; therefore, moisture probably affected the subgrade modulus of the two sections. The subgrade and base conditions vary considerably over the 8-mi length of test sections, and it is possible that moisture might have affected some sections but not others. The control section appears to have a significantly higher thickness index than many of the other sections.

Rut Depth

Rut depth measurements were performed on the sections immediately after paving and approximately five weeks after paving. As expected, there was no significant rutting recorded; therefore, this data will be reported after subsequent measurements are made.

LABORATORY TESTS

Resilient modulus tests and indirect tensile tests were performed on each mix that was sampled during construction of the test sections. Penetration, viscosity, and ductility tests are currently being conducted on the original asphalt cements without additive and on those with additive if sampling was possible.

Resilient Modulus

The Marshall procedure was used with variable compaction efforts to produce 4-in diameter x 2.5-in thick specimens having the approximate density of the pavement test sections. Resilient modulus tests were performed in the indirect tensile test mode with a load pulse of 0.1 sec and stress level of approximately 4 psi. The resilient modulus tests were performed at 55°F, 72°F, and 104°F to determine the temperature susceptibility of the mixtures (Table 12, Figure 2a, Figure 2b).

Table 12. Resilient Modulus Tests

Mix	Voids (VTM), %			Resilient Modulus, 10^3 psi		
	55°F	72°F	104°F	55°F	72°F	104°F
Polybilt 100	10.0	10.4	9.4	2,730	918	77
Styrelf 13	8.5	8.4	8.4	926	115	18
Celite 292	11.5	10.8	11.1	2,100	295	21
Downright HM 100L	8.0	8.1	8.2	2,070	540	47
Ultrapave 70	8.5	9.1	8.6	2,720	519	46
Hydrated Lime	8.7	9.0	8.7	472	309	29

The mixes containing lime and Styrelf 13 were not as stiff as the other mixes at 55°F; therefore, these mixes should resist cracking at low temperature better than the other mixes. The mixes containing Polybilt 100 and Ultrapave 70 were significantly stiffer than the mix with lime at a 95% confidence level when tested at 104°F. The stiffer mixes may be more resistant to rutting. Although the mix with Downright HM 100L also appeared to be stiffer than the mix with hydrated lime, the individual tests were quite variable and a significant difference did not exist.

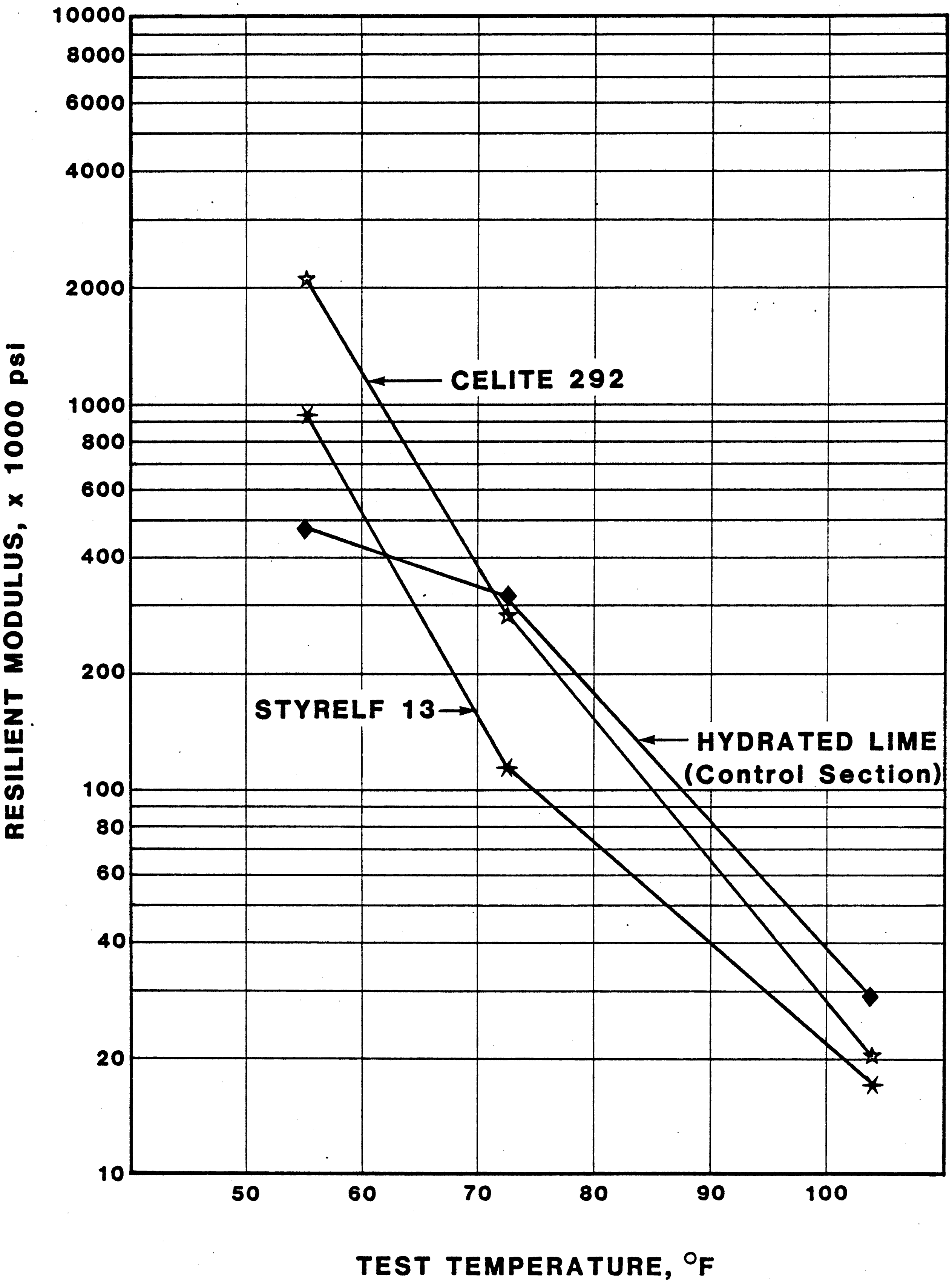

Figure 2a. Resilient modulus vs. test temperature.

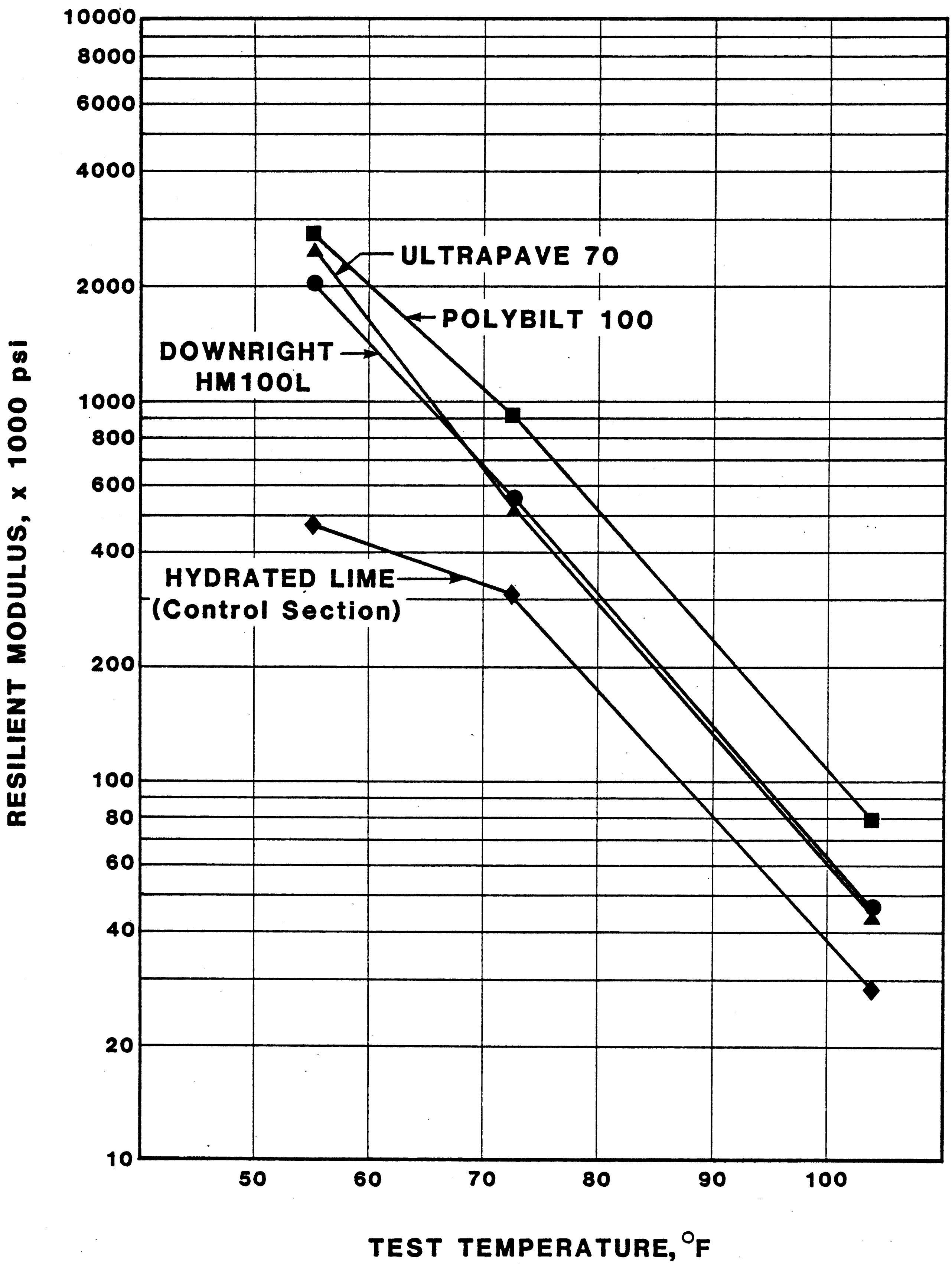

Figure 2b. Resilient modulus vs. test temperature.

COST

The cost of each mix at the asphalt plant is listed in Table 13. These costs do not include costs for transportation to the paving site or laydown costs.

Table 13. Costs of Asphalt Concrete

Additive	Costs, per ton
Hydrated Lime	$16.04
Polybilt 100	24.19
Styrelf 13	26.83
Celite 292	21.99
Downright HM 100L	19.44
Ultrapave 70	19.93
No Additive (used in adjacent section)	15.19

FUTURE WORK

Density, rut depth, strength (Dynaflect), and roughness will be measured again in the spring of 1987 and annually thereafter.

The general condition of the pavement will be assessed at the same time.

APPENDIX A

Marshall Designs by Froehling and Robertson

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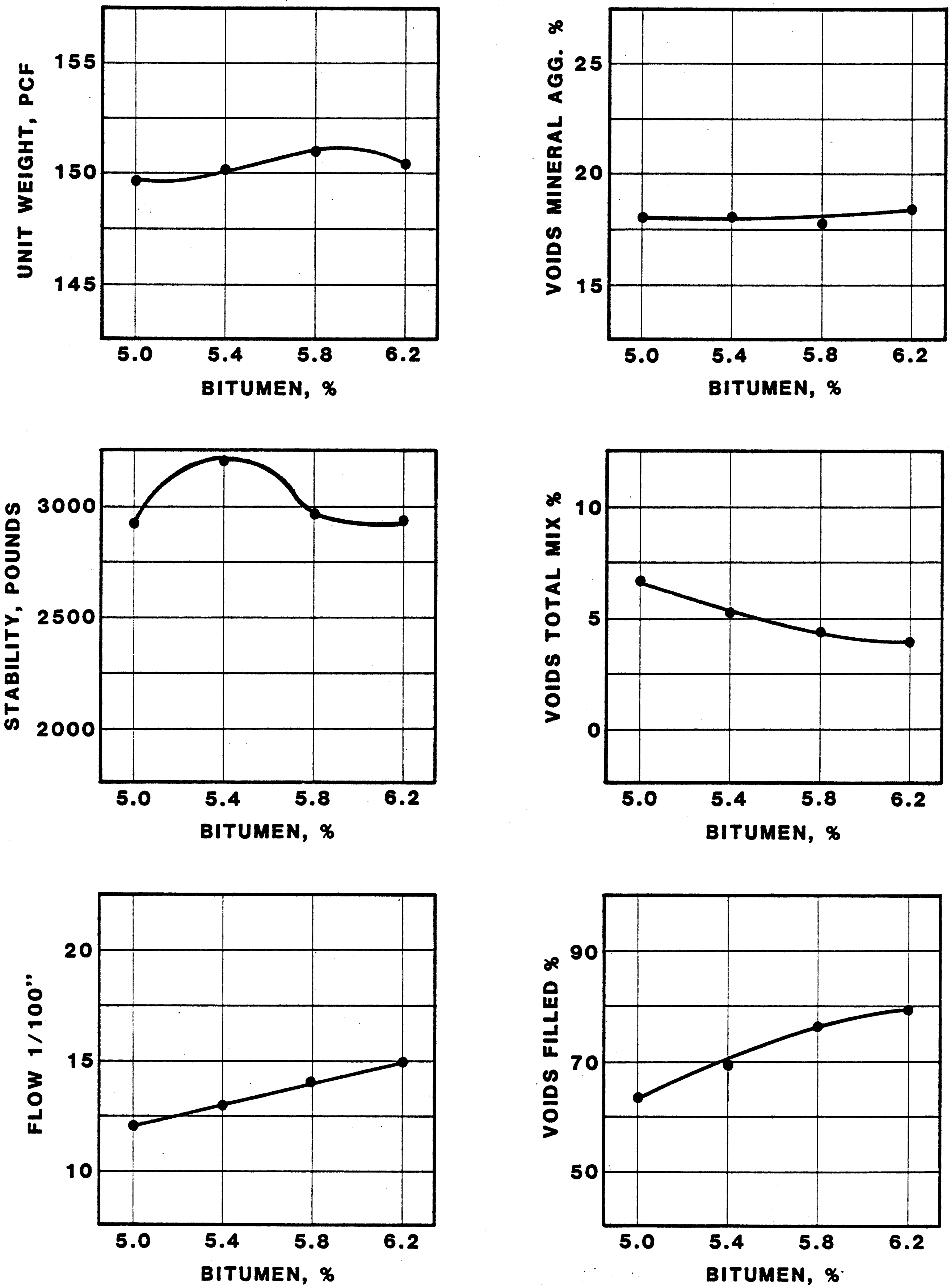
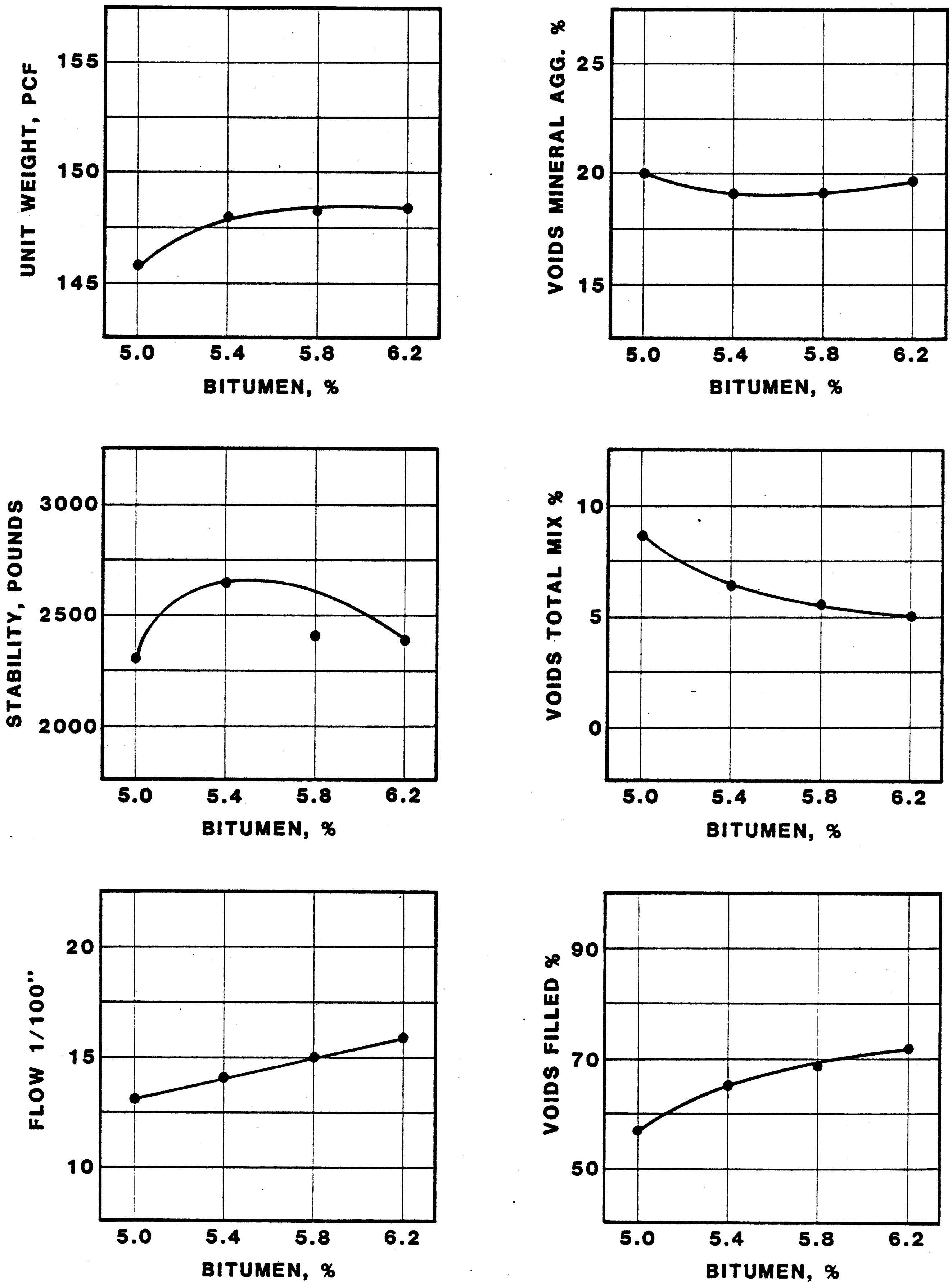
S-5 MIX with POLYBILT 100



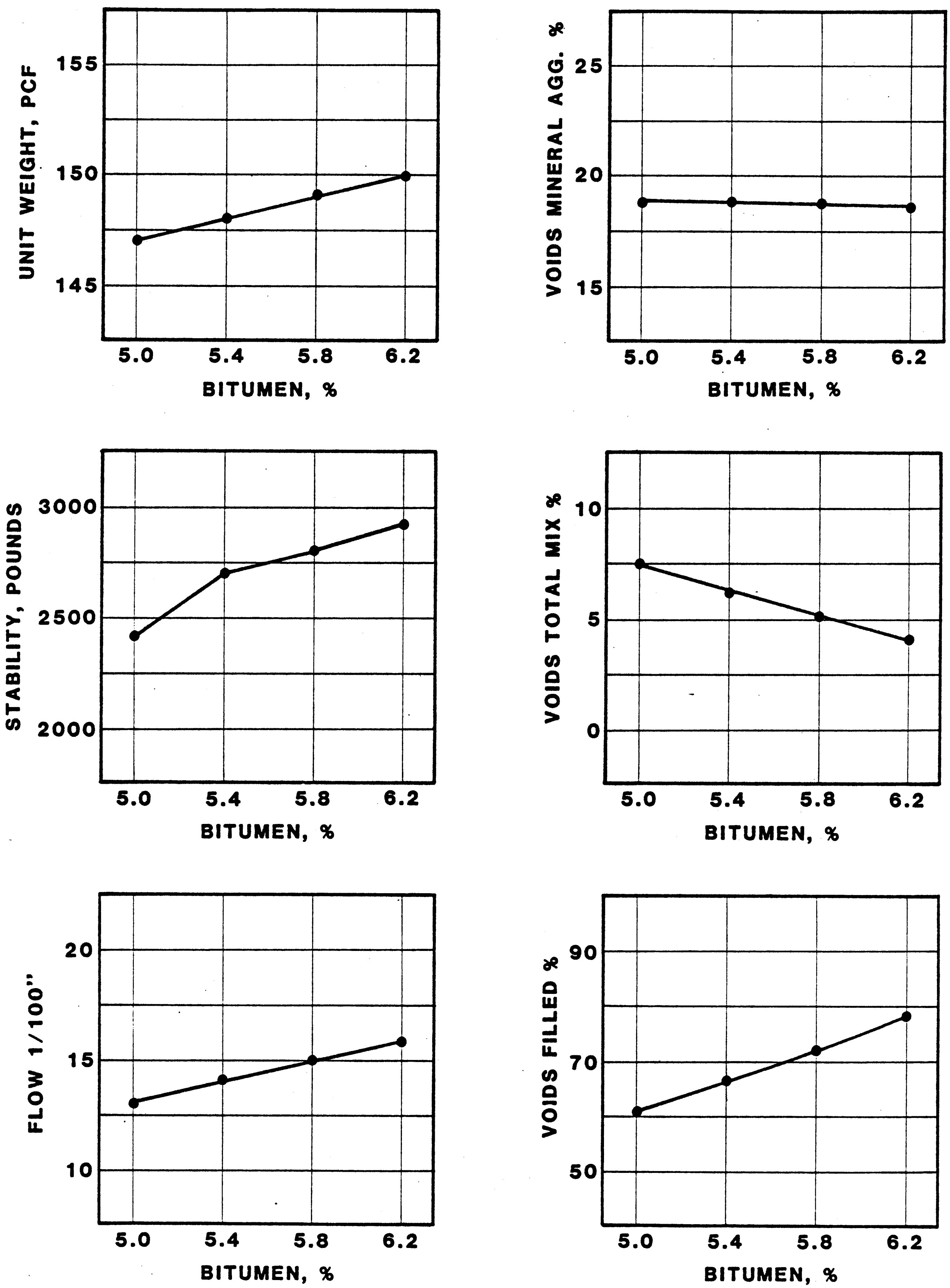
DESIGN AC = 5.7% at 4.5% VTM

S-5 MIX with STYRELF 13



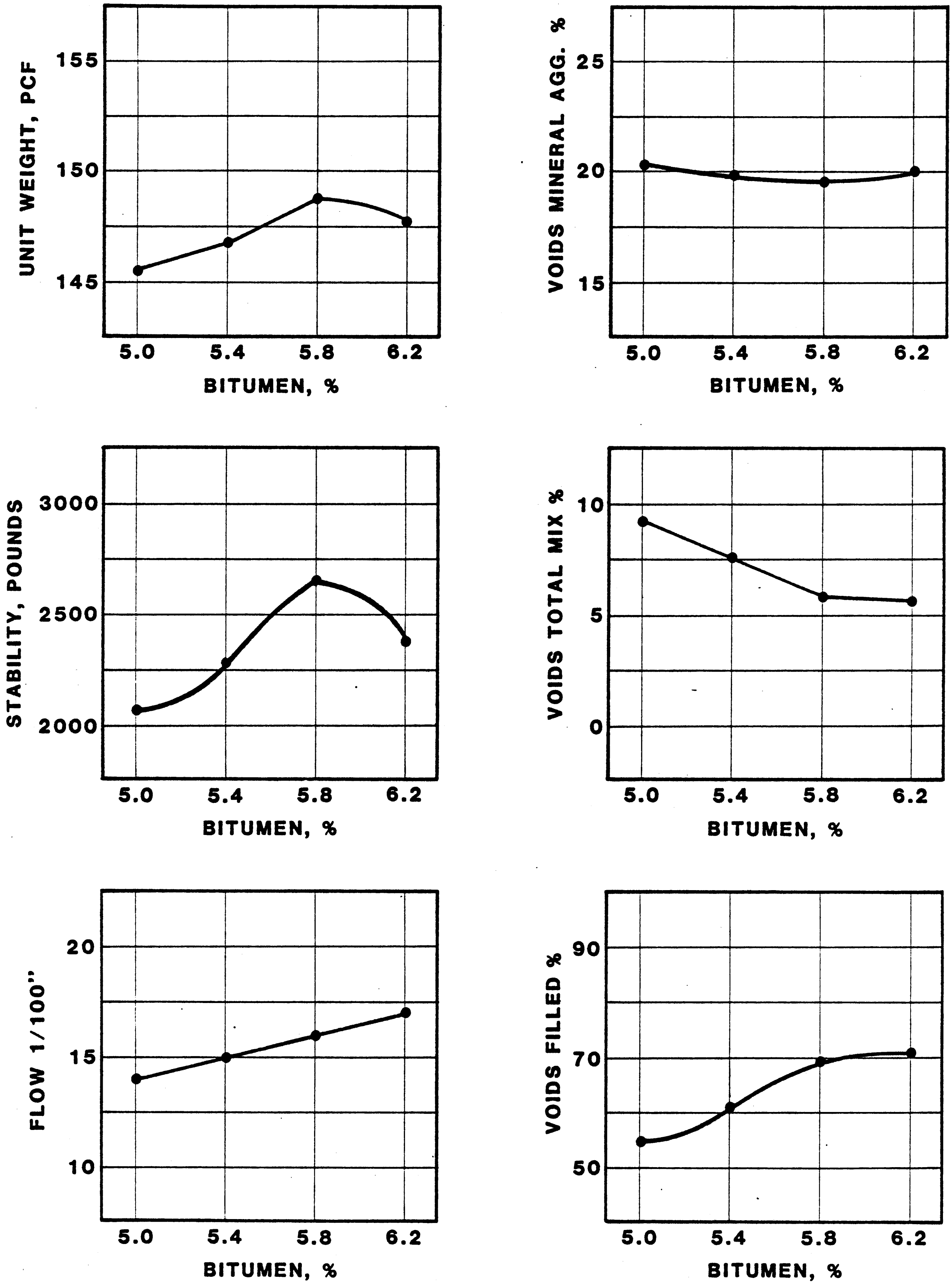
DESIGN AC>6.2% at 4.5% VTM

S-5 MIX with CELITE 292



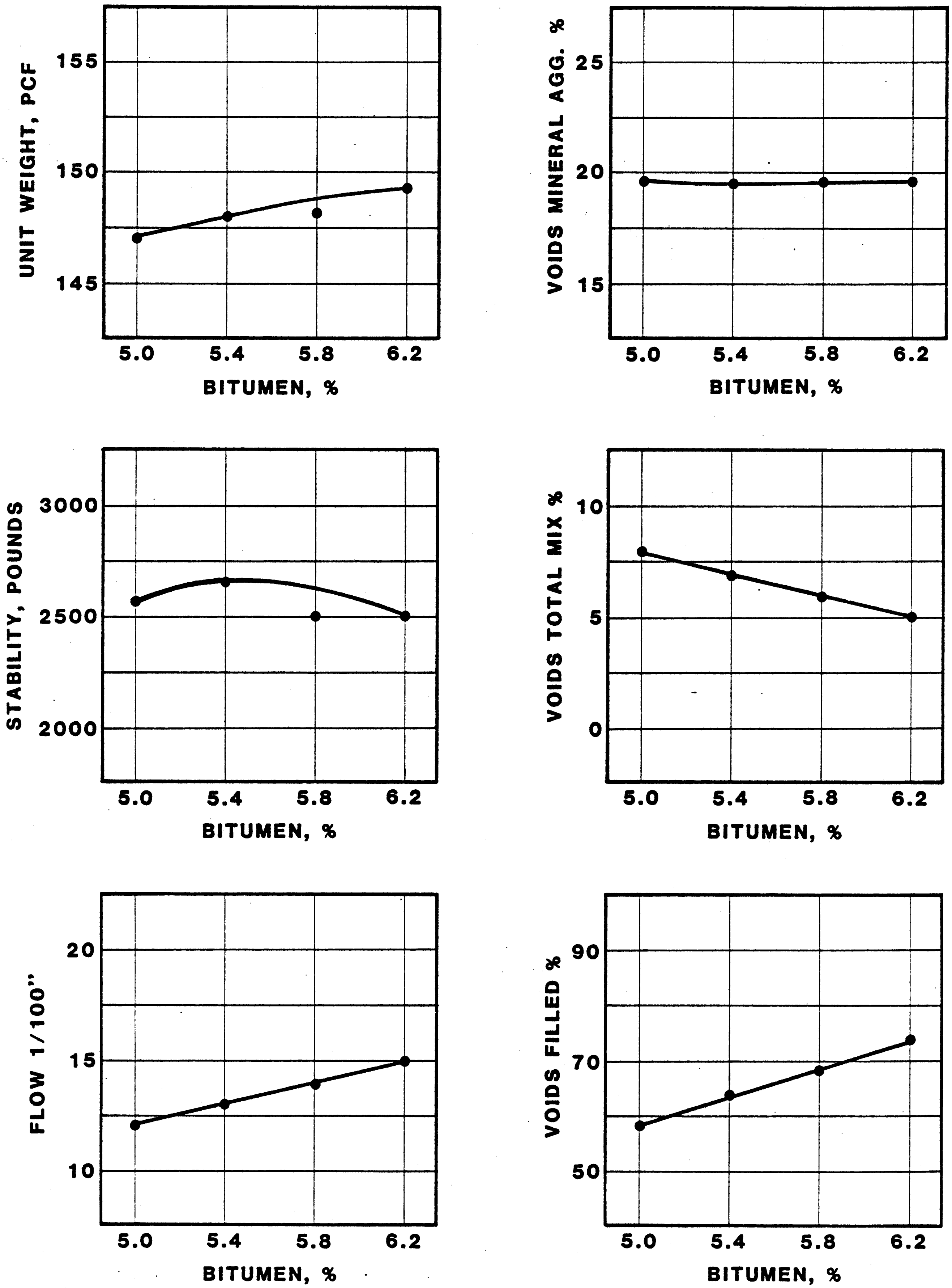
DESIGN AC = 6.0% at 4.5% VTM

S-5 MIX with DOWNRIGHT HM100L



DESIGN AC>6.2% at 4.5% VTM

S-5 MIX with ULTRAPAVE 70



DESIGN AC 6.2% at 4.5% VTM

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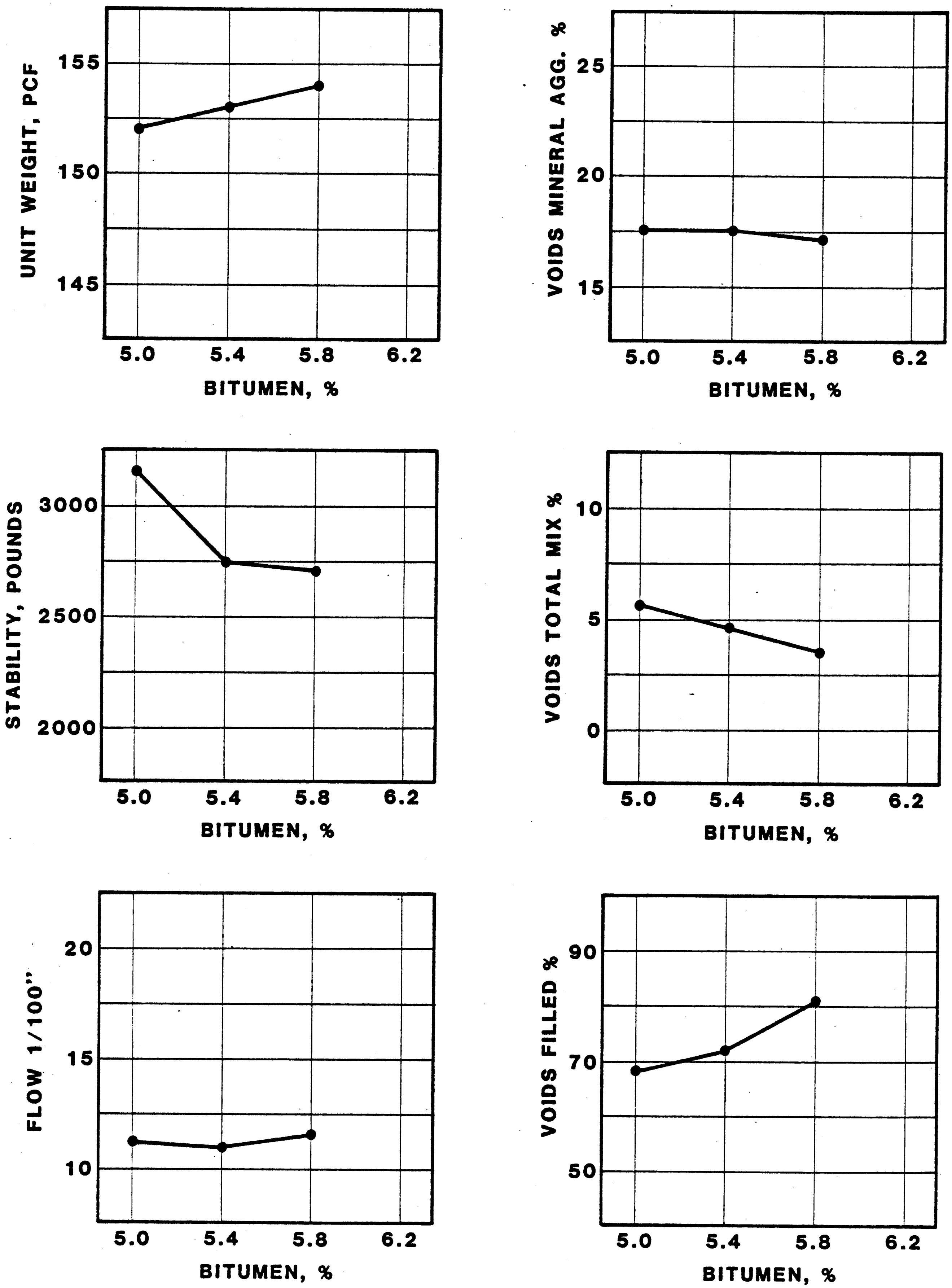
APPENDIX B

Marshall Designs by Research Council

S-5 MIX with CELITE 292



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S-5 MIX with ULTRAPAVE 70