THE EFFECT OF ANTI-STRIPPING AGENTS ON THE TENSILE STRENGTH OF BITUMINOUS MIXTURES

DHT-5

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16. Abstract

The study of tensile strength of asphalt mixtures is associated with the prevention of moisture damage in asphaltic concrete pavement. District 12 is located in the populated Gulf Coast area, and, in addition to the heavy volume of traffic and poor topsoil conditions (Beaumont clays in triaxial strength classification of 5 or 4), the heavy annual rainfall of 52"/year contributes to more complicated asphaltic concrete pavement problems. Raveling and cracking distress of asphaltic concrete pavement is caused in part by water sensitivity. This distress is a phenomenon of the loss of bond strength between the asphalt cement and aggregate and/or loss of strength in the presence of water. The damage due to water sensitivity will lead to reduced pavement life. District 12 adopted Test Method Tex-531-C, "Prediction of Moisture-Induced Damage to Bituminous Paving Mixtures Using Molded Specimens." This test is used to evaluate the stripping potential or water-sensitivity of asphaltic concrete mixture Items 340 and 292. District 12 considers this an important test in the quality control of bituminous mixtures and discusses this investigation in this report.

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THE EFFECT OF ANTI-STRIPPING AGENTS ON THE TENSILE STRENGTH OF BITUMINOUS MIXTURES

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The study of tensile strength of asphalt mixtures is associated with the prevention of moisture damage in asphaltic concrete pavement. District 12 is located in the populated Gulf Coast area, and, in addition to the heavy volume of traffic and poor subsoil conditions (Beaumont clays in triaxial strength classification of 5 or 4), the heavy annual rainfall of 52"/year contributes to more complicated asphaltic concrete pavement problems. Raveling and cracking distress of asphaltic concrete pavement is caused in part by water sensitivity. This distress is a phenomenon of the loss of bond strength between the asphalt cement and aggregate and/or loss of strength in the presence of water. The damage due to water sensitivity will lead to reduced pavement life. Hence, we adopted Test Method Tex-531-C, "Prediction of Moisture-Induced Damage to Bituminous Paving Mixtures Using Molded Specimens." This test is used to evaluate the stripping potential or water-sensitivity of asphaltic concrete mixture Items 340 and 292. We consider this an important test in the quality control of bituminous mixtures. At present, a general note to Items 340 and 292 is included in all proposals for District 12. This note reads as follows:

> The proposed mixture will be tested for water damage susceptibility by Test Method Tex-531-C. Mixtures will not be used that have a ratio of conditioned to dry specimen strength of less than 0.7 when tested in accordance with Tex-531-C. In lieu of substituting other materials, the contractor may try an additive approved by the Engineer to improve the water susceptibilities of the mixtures when tested under Test Method Tex-531-C. In the event the contractor uses an additive shown to perform satisfactorily, the Engineer will periodically resample the paving mixture throughout the course of the work and test the sample under Test Method Tex-531-C.
>
> If any sample fails to perform satisfactorily under this test, all paving operations shall stop immediately and remain so until such time as the mixture, materials or design can be corrected to show satisfactory performance.

This water susceptibility test requirement is one of the recommendations suggested by professors Benson and Gallaway in Research Report 285-5F, published by Texas Transportation Institute. The report is entitled Recommended Changes to Item 340 of the 1982 Standard Specifications.

Because we gave the contractors freedom in choosing additives, the contractors working in District 12 have been using only liquid anti-strip chemicals as additives due to the cost advantage and ease of handling during construction. Therefore, I have restricted my presentation to liquid anti-strip chemicals and one anti-rutting additive which we are testing.

We have been using two chemical additives for construction in District 12. Like most chemical additives, they are dark brown or black in color with an ammonia odor. These additives must be mixed thoroughly with the asphalt to achieve the desired properties. They can be added directly to asphalt in storage tanks or put into empty tank trucks before filling with asphalt. They can be metered into asphalt transfer lines at a bulk terminal or mixing plant, and can be pumped at temperatures above 30°F.

The procedure used for Test-531-C test is a modified Lottman test. Eight specimens are molded and compacted in the laboratory to 93% ± one percent of the theoretical density. One group of four specimens is then placed in a desiccator and stored until the indirect tensile strength is to be determined. Another group of four specimens is subjected to vacuum saturation for five minutes. (The necessary level of filled voids, in this case, was achieved at twenty (20) inches Hg.) These saturated specimens are then placed in plastic bags, separately, and these bagged specimens are placed inside another plastic bag. Ten milliliters of water are added to the outside bag, which is then sealed. The double-bagged specimens are placed in a freezer at 0° to 2° F for 15 hours. The frozen specimens are next unwrapped and submerged in a 140° F water bath for twenty-four hours, then submerged in a 77° F water bath for approximately two to four hours. Another group of four (4) dry specimens is then removed and placed in the 77° F water bath for two to four hours in order to insure that 77° F has been obtained. The second set of specimens is kept dry by plastic bags.

After specimens have been in the 77° F water bath for two to four hours, they are removed and tested immediately by indirect tensile loading to failure. The indirect tensile strength (S_T) and the tensile strength ratio are then calculated as:

$$S_T = \frac{0.156\ (F_{tv})}{h}$$

$$TSR = \frac{\text{Average Indirect Tensile Strength - Conditioned Specimens (Wet)}}{\text{Average Indirect Tensile Strength - Dry Specimens}}$$

h = height of specimen in inches
F_{tv} = total applied vertical load at failure (pounds)

The effectiveness of anti-stripping agents may vary widely with different aggregate-asphalt combinations, types of aggregate and sources of asphalt. The investigation we performed is based on the same aggregate-asphalt combination with different kinds of chemical additives and dosages. Comparison of tensile strength of asphalt mixtures with and without anti-strip agents after a freeze-thaw cycle is presented below:

1) Test results shown on Figures 1 to 5C indicated an increase in tensile strength in mixtures which contained liquid anti-strip additives in comparison to control mixtures without additives. This increase depends upon the amount of additive contained in the mix, usually 0.5% to 1.5% by weight of asphalt. However, in many cases, when the amount of additive exceeds 2.0%, stability drops to failure. Also, the tensile strength does not increase.

2) Test results of field cores taken on roadways after one year of service produced tensile strength which were similar to the predicted tensile strength values obtained from preconstruction mixtures. These pavements performed well during the first year of pavement life. Results of cores also indicated no significant

change in mixture strength during the first year of life. (See Figures 6 through 6E.)

3) Our test records show:

a) For Item 340 surface mixtures without chemical additives, only 5% of mixtures passed the required 0.7 strength ratio, as shown on Figure 7.
74% of mixtures with 0.5% additives passed, as shown on Figure 8.

63% of mixtures with 1.0% additives as shown on Figure 9.

b) For Item 340 Level Up mixtures without chemical additives, only 16.7% of mixtures passed strength ratio requirements. See Figure 10.

100% of mixtures with 0.5% additives passed. See Figure 11.

66.7% of mixtures with 1.0% additives as shown on Figure 12.

c) For Item 292 Asphaltic Stabilized Base without chemical additives, only 12.5% of mixtures passed strength ratio 0.7 requirement. See Figure 13.

71% of mixtures with 0.5% additives passed, as shown on Figure 14.

67% of mixtures with 1.0% additives passed. See Figure 15.

29% of mixtures with 1.5% additives passed, as shown on Figure 16.

4) In some mixtures, the chemical additives increased the tensile strength in dry specimens and conditioned specimens, but failed to meet strength ratio 0.7 requirement. This is shown in Figures 17B, 17C and 17D.

5) Some mixtures met the minimum tensile strength 0.7 requirement although their actual tensile strength was very low. See Figure 18A.

6) Statistics of tensile strength on bituminous mixtures with passing ratio (0.7) are shown on Figures 19 through 20F. In particular, Figures 19B and 20B show the maximum, minimum and mean wet (conditioned) tensile strength of 37 surface mixtures with additives and 20 Level Up mixtures with additives, respectively. The mean wet tensile strength of surface mixes is 77 p.s.i. and that of Level Up mixes is 90 p.s.i.

In conclusion, the adoption of test 531-C in District 12 did not result in a noticeable increase in bid item prices. This fact may be due to the highly competitive crude oil market and the poor economic environment in Texas. The price of asphalt mixtures actually decreased about $3.00 to $4.00 per ton from 1984 to the present. However, our recent survey of the construction industry indicates that $0.50 to $0.60 per ton has been added to the cost of asphalt mixtures. We believe that the use of chemical additives improved the performance and life of the bituminous pavements in District 12, and the final savings in maintenance expenditures will probably exceed both the cost of chemical additives and the administrative costs of contracts.

Our investigation and research are very preliminary. It appears that the actual wet (conditioned) tensile strength should be considered instead of tensile strength ratio. The value of wet (conditioned) tensile strength must be determined in our further research and observations of the performance of bituminous mixtures before a valid conclusion is reached.

APPENDIX A

Test Results

DESIGN GRADATION OF HOT MIX ASPHALTIC CONCRETE (Item 340, "D")

TYPE OF MIXTURE: Surface   Plant: McKinney & James, SH 6

COMBINATION OF AGGREGATES: 36% "D" Limestone - Parker Brothers

24% Sandstone -Delta

23% Limestone Screenings-Downing Bro.

17% Sand - Hillard

ASPHALT GRADE AND PRODUCER: AC - 20 Exxon

TYPE OF ANTI-STRIPPING ADDITIVE: Perma-tac Plus

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum%	maximum%
Pass 1/2"	100	100	
Pass 3/8"	92.9	85	100
3/8"-- 4	31.8	21	53
4 -- 10	21.8	11	32
+ 10	60.7	54	74
10 -- 40	14.7	6	32
40 -- 80	10.5	4	27
80 -- 200	10.6	3	27
Pass 200	3.5	1	8
Asphalt %	5.2 - 4.8	4	8

FIG. 1

NO ADDITIVE Item 340, "D", Surface Mix McKinney & James, SH 6						
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.543	5.0	47	dry:		ave. 131.4	
			93.1		133.5	2.01
			92.7		123.0	2.03
			93.1		135.8	2.01
			92.9		133.2	2.02
			wet:		ave. 71.4	
			92.9	72	72.2	2.01
			93.1	67	80.0	2.00
			93.0	71	68.0	2.02
			92.8	75	65.3	2.03

FIG. 1A

NO ADDITIVE Item 340,"D", Surface Mix McKinney & James, SH 6						
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.612	5.2	45	dry:		ave. 116.6	
			92.7		119.9	2.05
			92.7		102.1	2.04
			92.8		119.9	2.05
			93.0		124.6	2.04
			wet:		ave. 71.4	
			92.8	63	70.7	2.03
			92.8	64	71.1	2.03
			92.9	62	76.5	2.04
			92.7	66	67.4	2.06

FIG. 1B

1.0% ADDITIVE Item 340, "D", Surface Mix — McKinney & James, SH 6						
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.767	5.2	46	dry:		ave. 112.0	
			93.2		117.2	2.05
			93.0		108.3	2.06
			92.8		107.5	2.06
			92.7		115.1	2.06
			wet:		ave. 85.9	
			92.8	64	81.4	2.09
			92.7	67	80.6	2.07
			93.2	62	91.0	2.04
			93.1	65	90.6	2.05

FIG. 1C

1.0% ADDITIVE Item 340,"D", Surface Mix — McKinney & James, SH 6						
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.706	4.8	--	dry:		ave. 192.7	
			93.0		202.0	2.02
			93.1		207.8	2.03
			92.7		180.1	2.04
			92.9		180.8	2.03
			wet:		ave. 135.9	
			93.0	77	118.2	2.03
			92.9	68	140.9	2.02
			93.3	64	158.6	1.99
			92.8	76	126.2	2.04

FIG. 1D

DESIGN GRADATION OF HOT MIX ASPHALTIC CONCRETE (Item 340, "D")

TYPE OF MIXTURE: Level-Up Plant: Parker Brothers, Brittmore

COMBINATION OF AGGREGATES: 62% "D" Limestone - Parker Brothers
15% Limestone Screenings-Parker Bro.
23% Field Sand - Brazos River

ASPHALT GRADE AND PRODUCER: AC - 20 Exxon

TYPE OF ANTI-STRIPPING ADDITIVE: Perma-tac Plus

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum%	maximum%
Pass 1/2"	100	100	
Pass 3/8"	99.6	85	100
3/8"-- 4	36.1	21	53
4 -- 10	24.7	11	32
+ 10	61.2	54	74
10 -- 40	14.2	6	32
40 -- 80	14.2	4	27
80 -- 200	7.4	3	27
Pass 200	3.0	1	8
Asphalt %	5.8 - 5.4	4	8

FIG. 2

NO ADDITIVE Item 340, "D", Level-Up — Parker Brothers, Brittmore						
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
					ave.	
0.650	5.8	50	dry:		77.9	
			92.2		71.1	2.05
			92.8		84.1	2.04
			92.4		79.5	2.03
			92.4		76.8	2.03
					ave.	
			wet:		50.6	
			92.6	62	49.1	2.05
			92.5	64	53.5	2.04
			92.4	66	53.5	2.04
			92.4	63	46.2	2.04

FIG. 2A

1.0% ADDITIVE Item 340,"D", Level-Up — Parker Brothers, Brittmore						
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
					ave.	
			dry:		81.5	
0.881	5.4	44	92.7		94.1	2.03
			92.7		62.1	2.04
			92.7		86.0	2.04
			92.5		83.7	2.05
					ave.	
			wet:		78.4	
			92.6	70	79.5	2.05
			92.7	70	78.0	2.05
			92.6	66	78.0	2.04
			92.5	64	78.0	2.05

FIG. 2B

DESIGN GRADATION OF HOT MIX ASPHALTIC CONCRETE (Item 340, "D")

TYPE OF MIXTURE: Level-Up Plant: Jones Finke, Clodine

COMBINATION OF AGGREGATES: 62% "D" Limestone - Parker Brothers

15% Limestone Screenings-Parker Bros.

23% Sand - Sand Supply

ASPHALT GRADE AND PRODUCER: AC - 20 Texaco

TYPE OF ANTI-STRIPPING ADDITIVE: Perma-tac

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum%	maximum%
Pass 1/2"	100	100	
Pass 3/8"	99.7	85	100
3/8"-- 4	35.9	21	53
4 -- 10	25.0	11	32
+ 10	61.2	54	74
10 -- 40	15.9	6	32
40 -- 80	15.6	4	27
80 -- 200	4.0	3	27
Pass 200	3.3	1	8
Asphalt %	4.8	4	8

FIG. 3

NO ADDITIVE Item 340, "D", Surface Mix					Jones Finke, Clodine	
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
					ave.	
0.354	4.7	54	dry:		114.4	
			92.9		111.2	2.00
			93.2		118.0	1.99
			92.6		114.0	2.01
			92.7		114.4	2.01
					ave.	
			wet:		40.5	
			92.8	66	37.8	2.00
			93.1	65	46.4	2.00
			92.6	73	38.0	2.03
			92.9	69	39.9	2.01

FIG. 3A

1.0% ADDITIVE Item 340,"D", Surface Mix					Jones Finke, Clodine	
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
					ave.	
			dry:		127.2	
0.704	4.6	55	93.2		133.8	2.03
			93.0		128.2	2.01
			93.0		123.8	2.02
			93.0		122.9	2.03
					ave.	
			wet:		89.5	
			92.8	69	81.8	2.01
			93.2	65	90.9	2.02
			93.0	67	93.5	2.03
			93.0	67	91.7	2.02

FIG. 3B

DESIGN GRADATION OF HOT MIX ASPHALTIC CONCRETE (Item 340, "D")

TYPE OF MIXTURE: Surface & Level Up   Plant: Troy Dodson, IH-10

COMBINATION OF AGGREGATES: 62% Limestone - West Lake Quarry
10% Limestone Screenings-Parker Bro.
28% Sand - Bittner Pit

ASPHALT GRADE AND PRODUCER: AC - 10 Texaco

TYPE OF ANTI-STRIPPING ADDITIVE: Perma-tac Plus

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum%	REQUIRED GRADATION maximum%
Pass 1/2"	100	100	
Pass 3/8"	92.8	85	100
3/8"-- 4	35.6	21	53
4 -- 10	15.7	11	32
+ 10	58.5	54	74
10 -- 40	10.5	6	32
40 -- 80	20.3	4	27
80 -- 200	5.9	3	27
Pass 200	4.8	1	8
Asphalt %	5.3 - 5.0	4	8

FIG. 4

NO ADDITIVE

Item 340, "D", Surface Mix & Level Up   Troy Dodson, IH-10

Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.519	5.3	52	dry:		ave. 69.4	
			92.8		57.0	2.03
			93.1		56.4	2.02
			93.5		89.5	2.02
			93.3		74.7	2.04
			wet:		ave. 36.0	
			93.3	78	36.8	2.04
			93.6	70	40.8	2.01
			93.1	71	33.6	2.04
			92.8	76	32.9	2.04

FIG. 4A

1.0% ADDITIVE

Item 340,"D", Surface Mix & Level-Up   Troy Dodson, IH-10

Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
			dry:		ave. 68.8	
0.709	5.0	46	93.2		73.8	1.99
			92.9		64.4	2.01
			93.1		67.1	2.00
			93.0		69.9	2.00
			wet:		ave. 48.8	
			92.9	65	51.3	2.00
			93.1	65	46.4	2.02
			93.1	64	48.5	1.99
			93.1	62	48.8	2.00

FIG. 4B

EXPERIMENTAL-HOT MIX --- SH 6, Waller and Grimes County

HMAC TYPE	ADDITIVE %	TENSILE STRENGTH DRY p.s.i.	TENSILE STRENGTH WET p.s.i.	TENSILE STRENGTH RATIO	STABILITY @97% DENS.
Surface Item 340-D 1285L-39A	0	84.2	24.9	0.296	56
Surface Item 340-D 1285L-39A1	1.0	155.2	122.8	0.791	50
Level-Up Item 340-D 1285L-39B	0	74.3	26.4	0.355	57
Level-Up Item 340-D 1285L-39B1	1.0	134.8	119.2	0.884	52
Base Item 292,Gr.3 1285L-39C2	0	132.0	48.3	0.366	38
Base Item 292,Gr.3 1285L-39C1	1.0	125.5	110.7	0.882	35
Base Item 292,Gr.3 1285L-39C	10.0	26.2	19.9	0.760	22

FIG. 5

DESIGN GRADATION OF HOT MIX ASPHALTIC CONCRETE (Item 340, "D")

TYPE OF MIXTURE: Experimental Surface Mix

COMBINATION OF AGGREGATES: 36% "D" Limestone - Parker Brothers

24% Sandstone - Delta

15% Limestone Screenings-Downing Bro.

25% Field Sand - O'Connor

ASPHALT GRADE AND PRODUCER: AC - 20 Exxon

TYPE OF ANTI-STRIPPING ADDITIVE: Perma-tac Plus

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum%	maximum%
Pass 1/2"	100	100	
Pass 3/8"	95.4	85	100
3/8"-- 4	32.7	21	53
4 -- 10	20.0	11	32
+ 10	57.3	54	74
10 -- 40	11.9	6	32
40 -- 80	16.8	4	27
80 -- 200	9.5	3	27
Pass 200	4.5	1	8
Asphalt %	5.1	4	8

FIG. 5A

DESIGN GRADATION OF HOT MIX ASPHALTIC CONCRETE (Item 340, "D")

TYPE OF MIXTURE: Experimental Level-Up

COMBINATION OF AGGREGATES: 50% "D" Limestone - Parker Brothers
15% Gravel Screenings - Lone Star
11% Limestone Screenings-Downing Bro.
24% Field Sand - O'Connor

ASPHALT GRADE AND PRODUCER: AC - 20 Exxon

TYPE OF ANTI-STRIPPING ADDITIVE: Perma-tac Plus

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum%	maximum%
Pass 1/2"	100	100	
Pass 3/8"	99.6	85	100
3/8"-- 4	24.3	21	53
4 -- 10	32.0	11	32
+ 10	56.7	54	74
10 -- 40	14.4	6	32
40 -- 80	16.2	4	27
80 -- 200	8.6	3	27
Pass 200	4.1	1	8
Asphalt %	5.1	4	8

FIG. 5B

DESIGN GRADATION OF EXPERIMENTAL ASPHALT STABILIZED BASE

Item 292, Grade 3

Mixed in District 12, SDHPT Laboratory

Combination of Aggregates:

40% Gem Sand - Lone Star

25% Gravel Screenings - Lone Star

35% Field Sand - O'Connor

Asphalt Grade and Producer: AC - 20 Exxon

Type of Anti-strip Additive: Perma-tac Plus

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum %	maximum%
+ 1 3/4	0	--	0
+ 40	64.9	60	85
Asphalt %	5.0	3	9

FIG. 5C

DISTRICT 12 LABORATORY

EXPERIMENTAL HOT MIX ASPHALTIC CONCRETE

Surface, Level-Up and Base Mixes

with Anti-Stripping Additive Perma-tac Plus

For State Highway 6 - Grimes and Waller Counties

DESIGN GRADATION OF ASPHALT STABILIZED BASE

Item 292, Grade 3

Plant: McKinney & James, SH 6

Combination of Aggregates:

44% Gem Sand - Lone Star

26% Gravel Screenings - Lone Star

30% Sand - O'Conner

Asphalt Grade and Producer: AC - 20 Exxon

Type of Anti-strip Additive: Perma-tac Plus

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION	
		minimum %	maximum%
+ 1 3/4	0	--	0
+ 40	67	60	85
Asphalt %	4.6	3	9

FIG. 6

0% ADDITIVE Item 292, Grade 3, Base					McKinney & James, SH 6	
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.366	5.0	--	ave:		ave. 132.0	
					143.6	2.01
			92.9		125.5	2.02
					129.1	2.03
					129.7	2.02
				wet ave:	ave. 48.3	
				65.0	36.5	2.03
					53.2	2.01
					56.0	2.02
					47.5	2.02

FIG. 6A

1.0% ADDITIVE Item 292, Grade 3, Base					McKinney & James, SH 6	
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
			dry:		ave. 123.4	
0.842	4.1	37	93.1		119.5	1.99
			92.8		138.0	1.99
			92.6		123.4	2.01
			92.8		112.5	2.01
			wet:		ave. 104.0	
			92.8	61	105.0	2.02
			93.0	60	109.2	2.00
			92.6	60	92.4	2.01
			93.0	60	109.2	2.00

FIG. 6B

1.0% ADDITIVE - ROAD SAMPLES

Item 292, Grade 3, Base — McKinney & James, SH 6

Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.846	--	--	dry:		ave. 167.8	
			96.3		188.2	3.00
			96.2		177.2	3.13
			94.5		156.0	2.38
			94.2		149.7	2.19
			wet:		ave. 141.9	
			95.8	60	169.8	1.94
			93.5	62	107.9	2.31
			95.2	62	132.9	2.31
			96.6	68	156.8	2.31

FIG. 6C

1.0% ADDITIVE - ROAD SAMPLES

Item 292, Grade 3, Base — McKinney & James, SH 6

Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
			dry:		ave. 155.6	
0.781	--	--	96.5		184.4	2.75
			96.1		150.9	2.75
			96.0		155.2	2.88
			95.7		131.7	2.81
			wet:		ave. 121.5	
			95.5	64	118.1	2.81
			96.4	67	98.0	2.50
			96.1	64	119.2	2.81
			96.5	63	150.8	3.00

FIG. 6D

1.0% ADDITIVE - ROAD SAMPLES Item 292, Grade 3, Base McKinney & James, SH 6						
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.750	--	--	dry:		ave. 206.2	
			96.6		217.1	3.00
			96.6		201.5	3.00
			96.9		189.8	2.94
			95.8		216.5	3.19
			wet:		ave. 154.6	
			95.6	59	118.8	3.25
			97.2	61	189.0	3.00
			96.7	61	163.3	2.94
			96.6	59	147.3	2.94

FIG. 6E

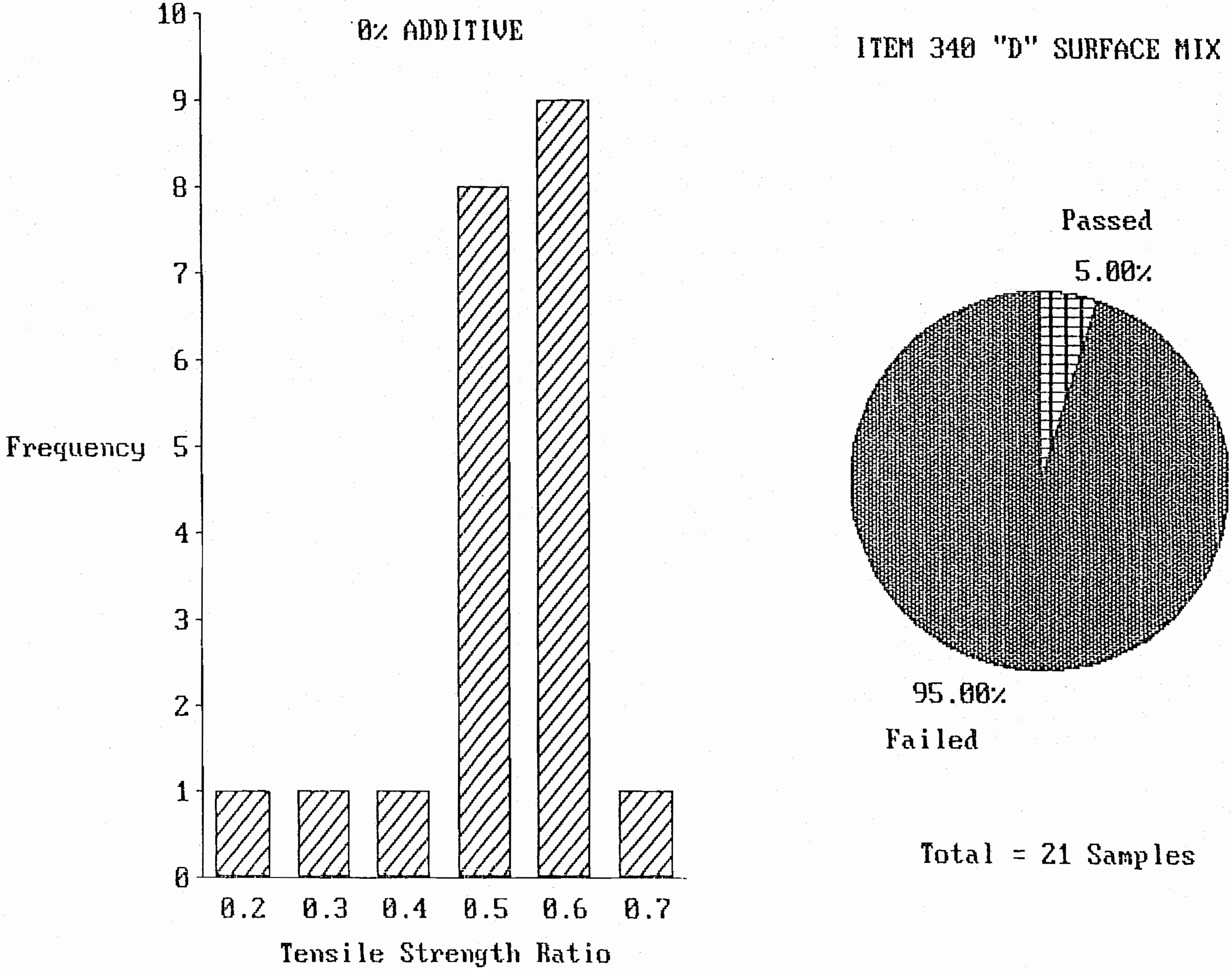

0% ADDITIVE
Frequency
10
9
8
7
6
5
4
3
2
1
0
0.2
0.3
0.4
0.5
0.6
0.7
Tensile Strength Ratio
ITEM 340 "D" SURFACE MIX
Passed
5.00%
95.00%
Failed
Total = 21 Samples

FIG. 7

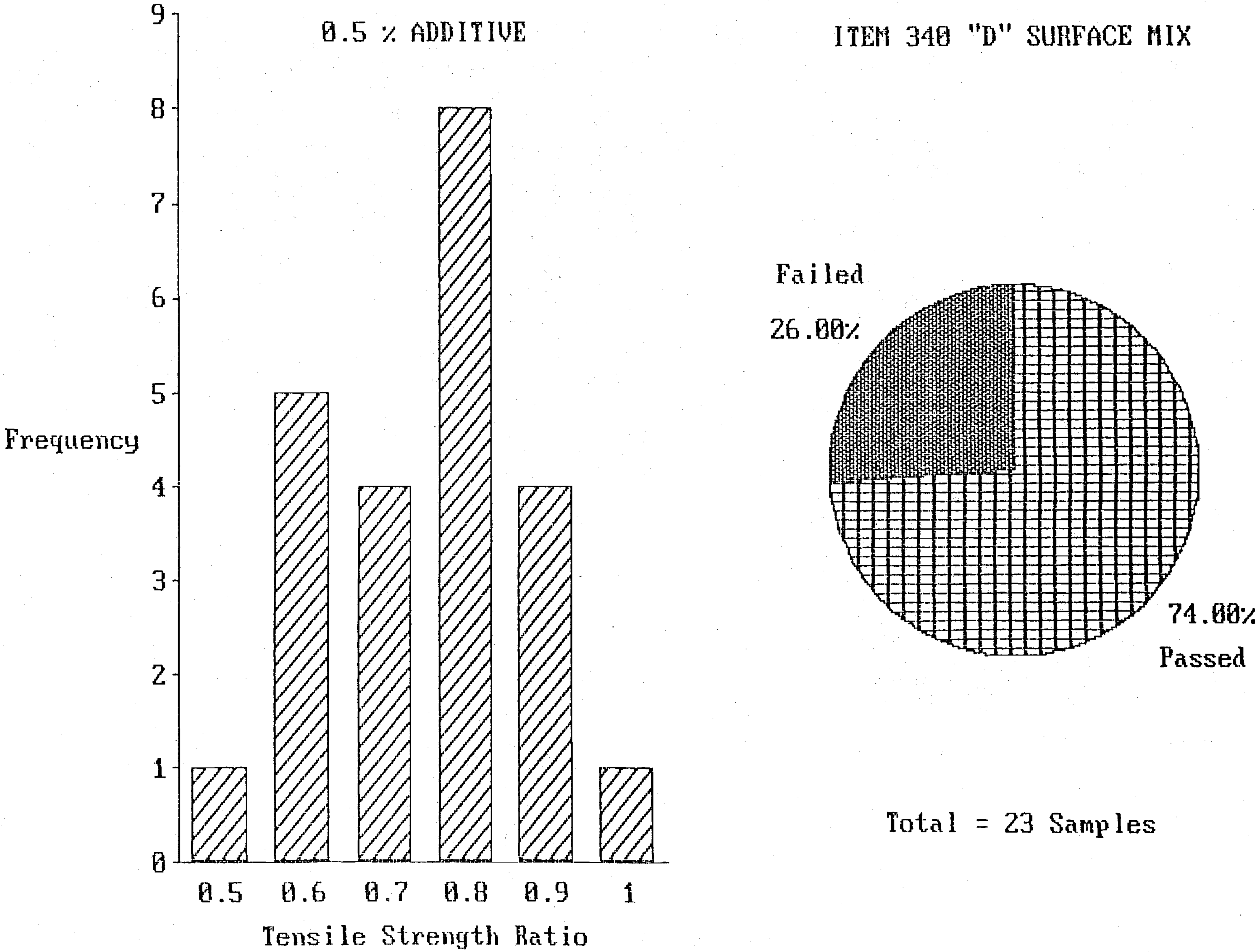

0.5 % ADDITIVE
9
8
7
6
5
4
3
2
1
0
Frequency
0.5
0.6
0.7
0.8
0.9
1
Tensile Strength Ratio
ITEM 340 "D" SURFACE MIX
Failed
26.00%
74.00%
Passed
Total = 23 Samples

FIG. 8

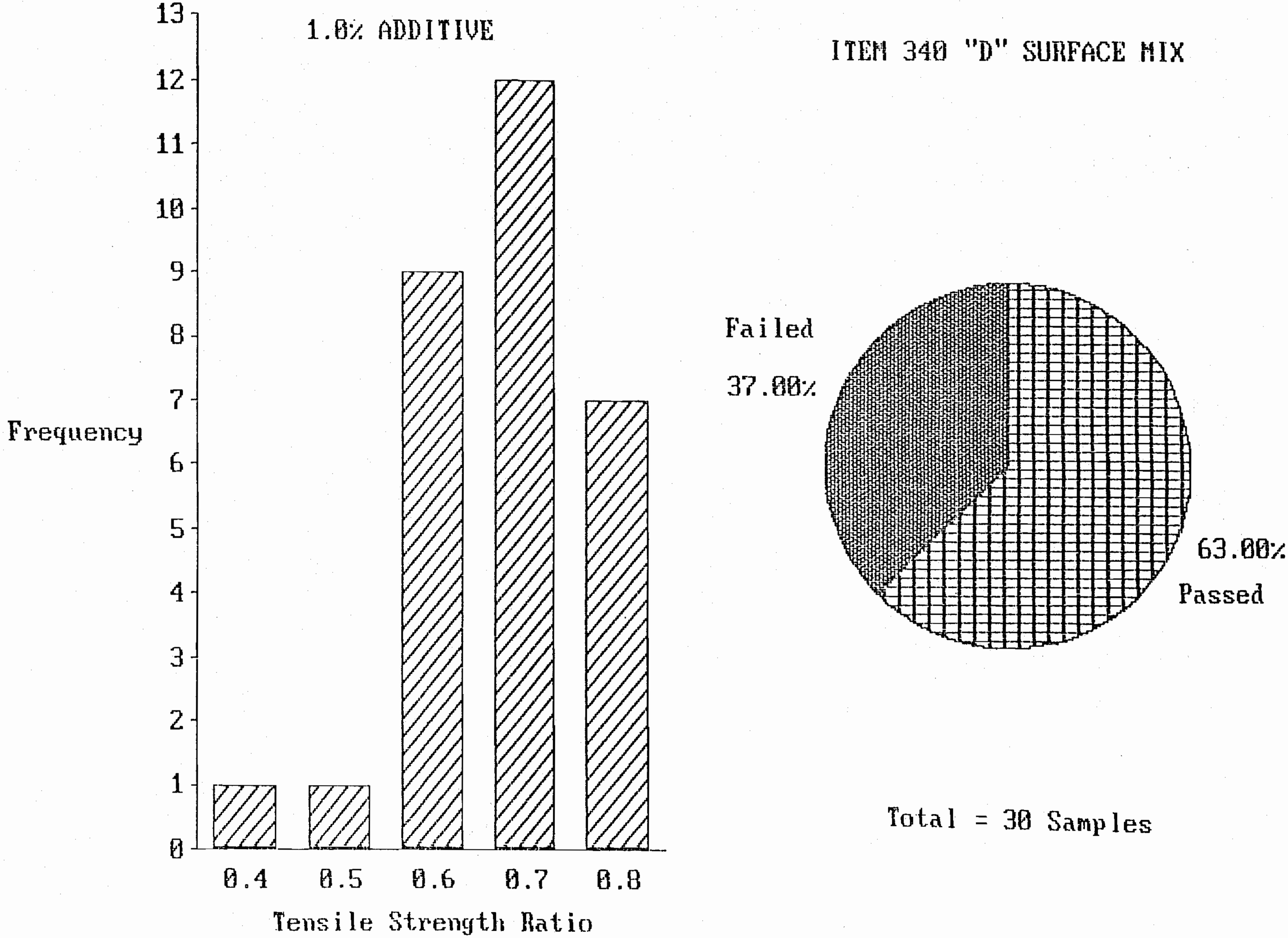

1.0% ADDITIVE
ITEM 340 "D" SURFACE MIX
Frequency
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0.4
0.5
0.6
0.7
0.8
Tensile Strength Ratio
Failed
37.00%
63.00%
Passed
Total = 30 Samples

FIG. 9

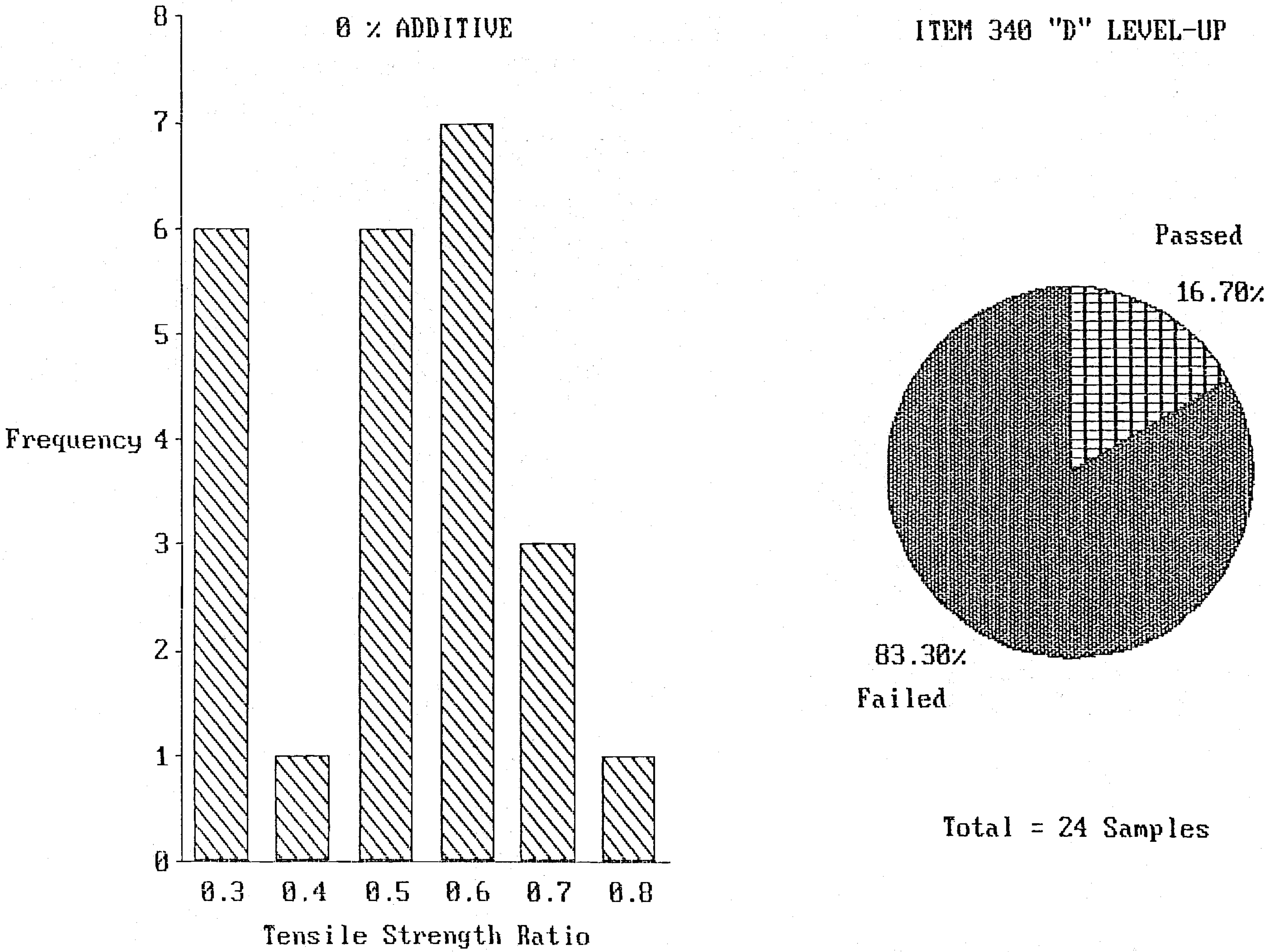

0 % ADDITIVE
8
7
6
5
Frequency 4
3
2
1
0
0.3
0.4
0.5
0.6
0.7
0.8
Tensile Strength Ratio
ITEM 340 "D" LEVEL-UP
Passed
16.70%
83.30%
Failed
Total = 24 Samples

FIG. 10

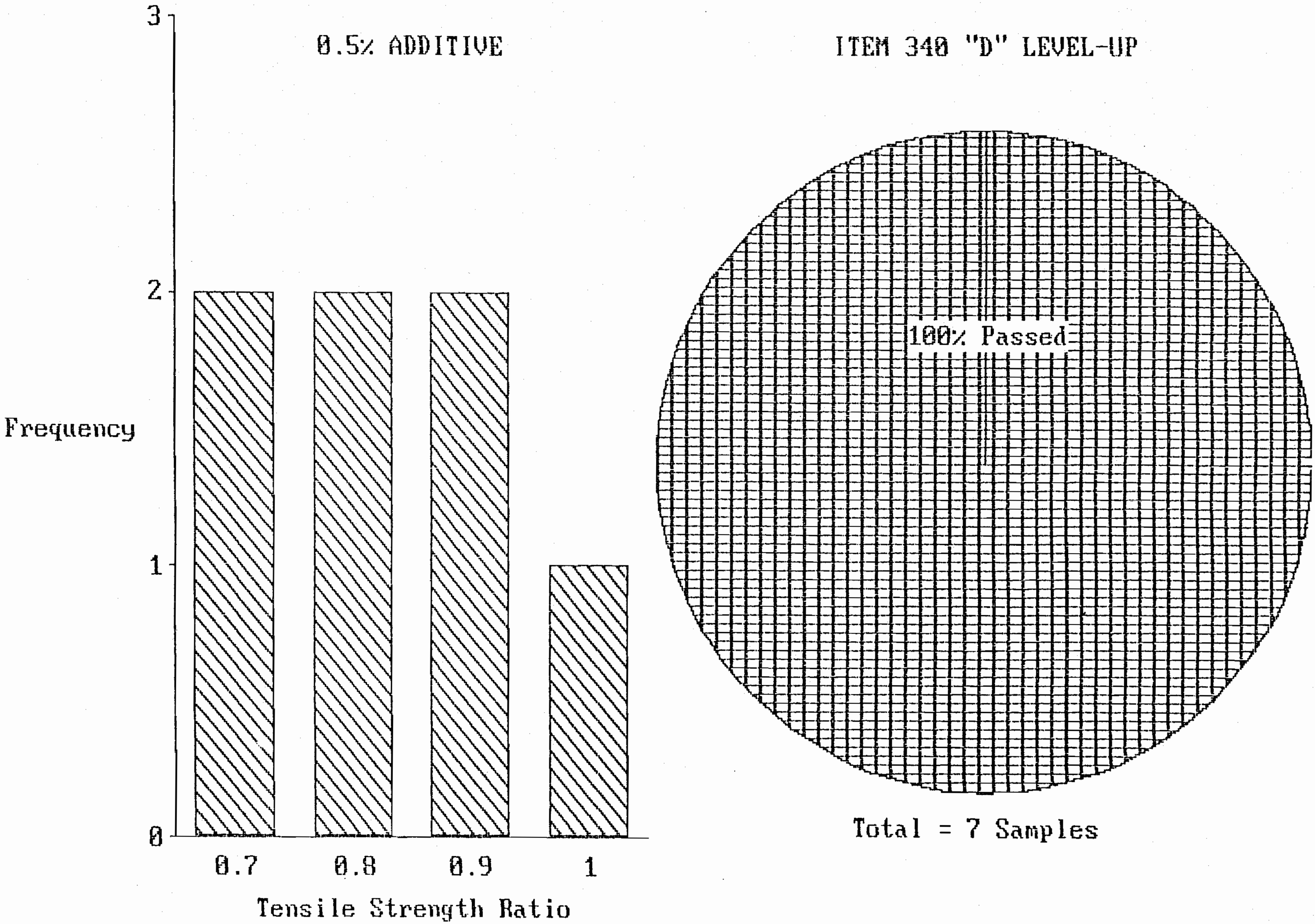

0.5% ADDITIVE
3
2
1
0
Frequency
0.7
0.8
0.9
1
Tensile Strength Ratio
ITEM 340 "D" LEVEL-UP
100% Passed
Total = 7 Samples

FIG.11

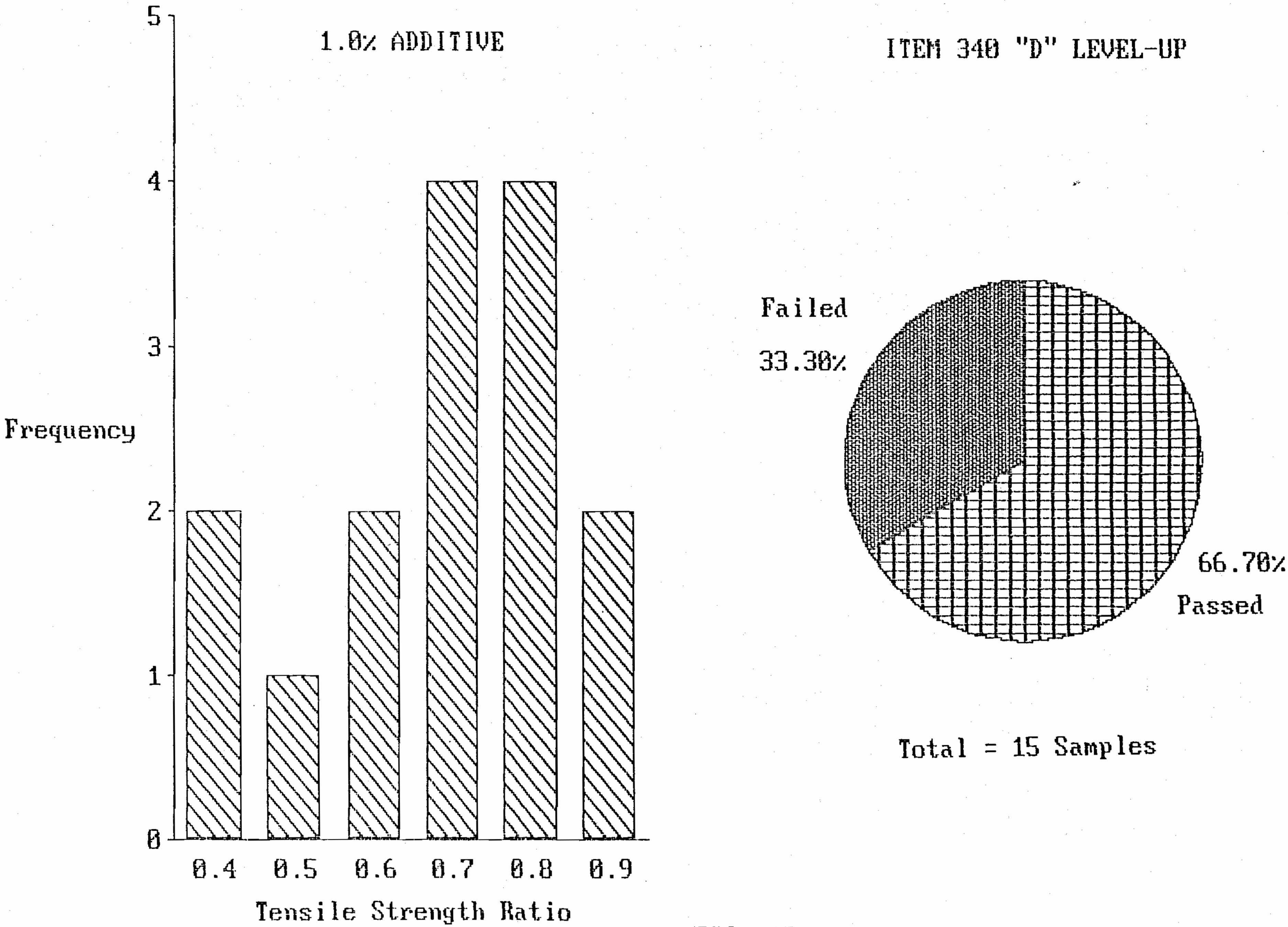

1.0% ADDITIVE
5
4
3
2
1
0
Frequency
0.4
0.5
0.6
0.7
0.8
0.9
Tensile Strength Ratio
ITEM 340 "D" LEVEL-UP
Failed
33.30%
66.70%
Passed
Total = 15 Samples

FIG. 12

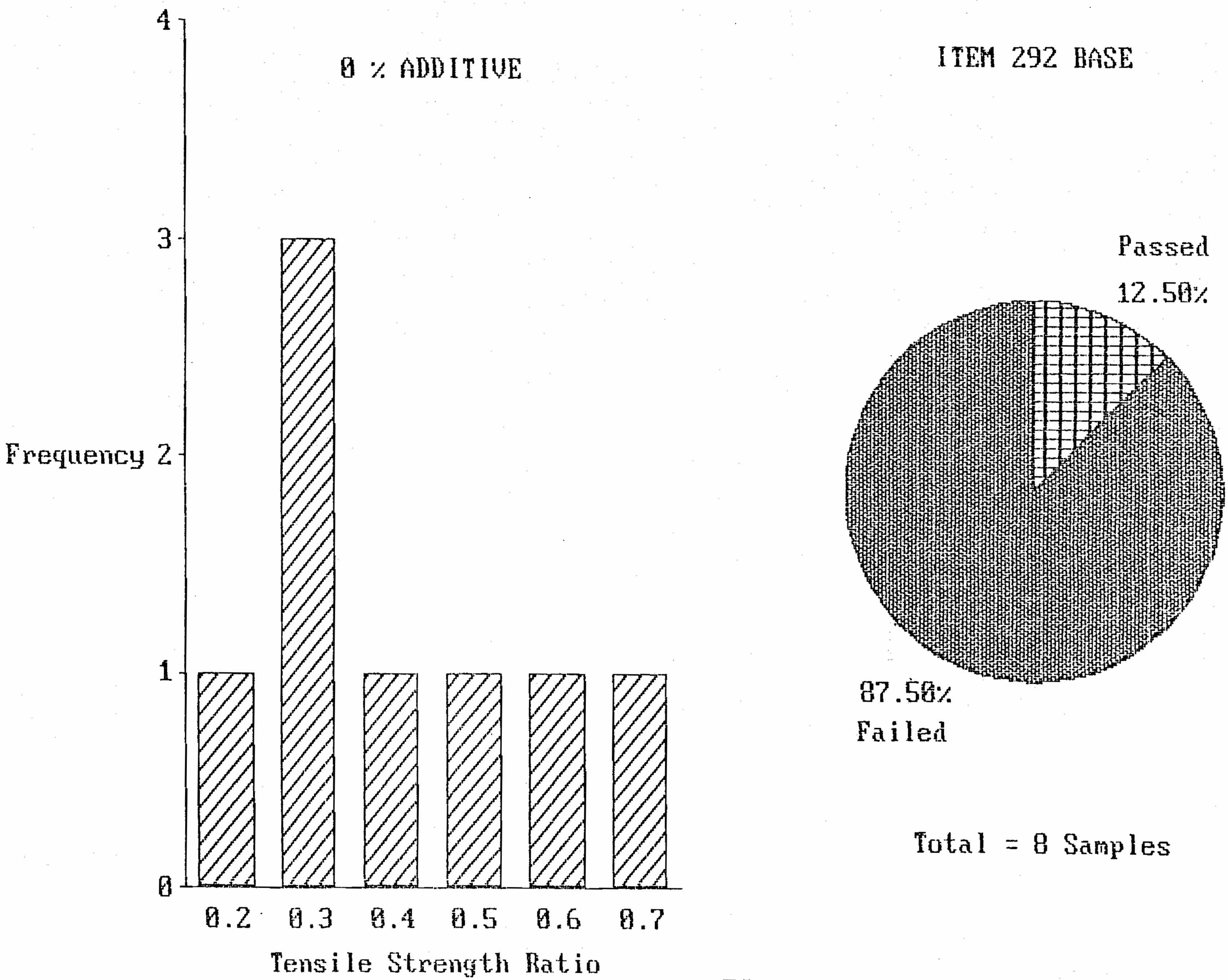

0 % ADDITIVE
Frequency
4
3
2
1
0
0.2
0.3
0.4
0.5
0.6
0.7
Tensile Strength Ratio
ITEM 292 BASE
Passed
12.50%
87.50%
Failed
Total = 8 Samples

FIG. 13

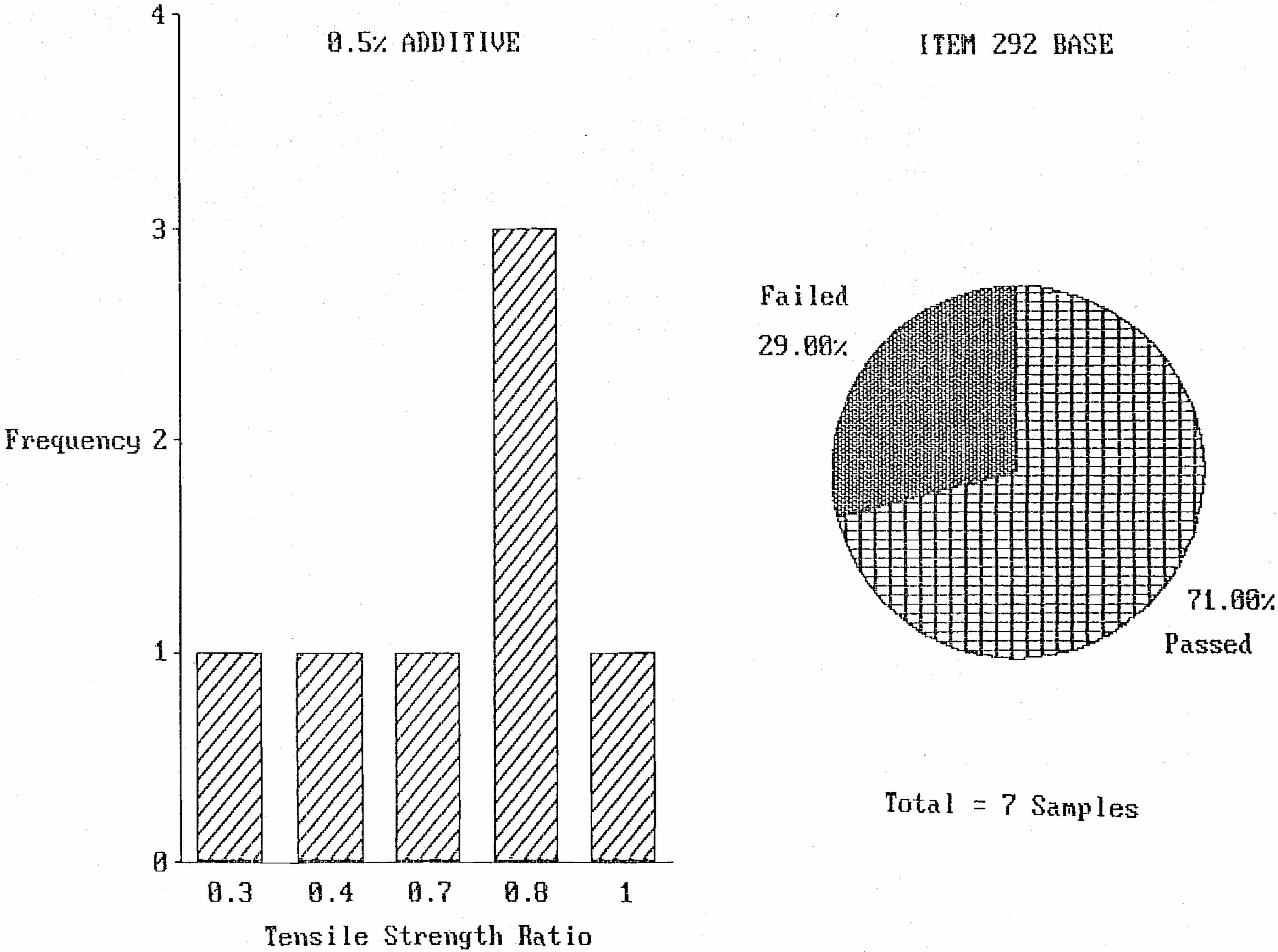

0.5% ADDITIVE
Frequency
4
3
2
1
0
0.3
0.4
0.7
0.8
1
Tensile Strength Ratio
ITEM 292 BASE
Failed
29.00%
71.00%
Passed
Total = 7 Samples

FIG. 14

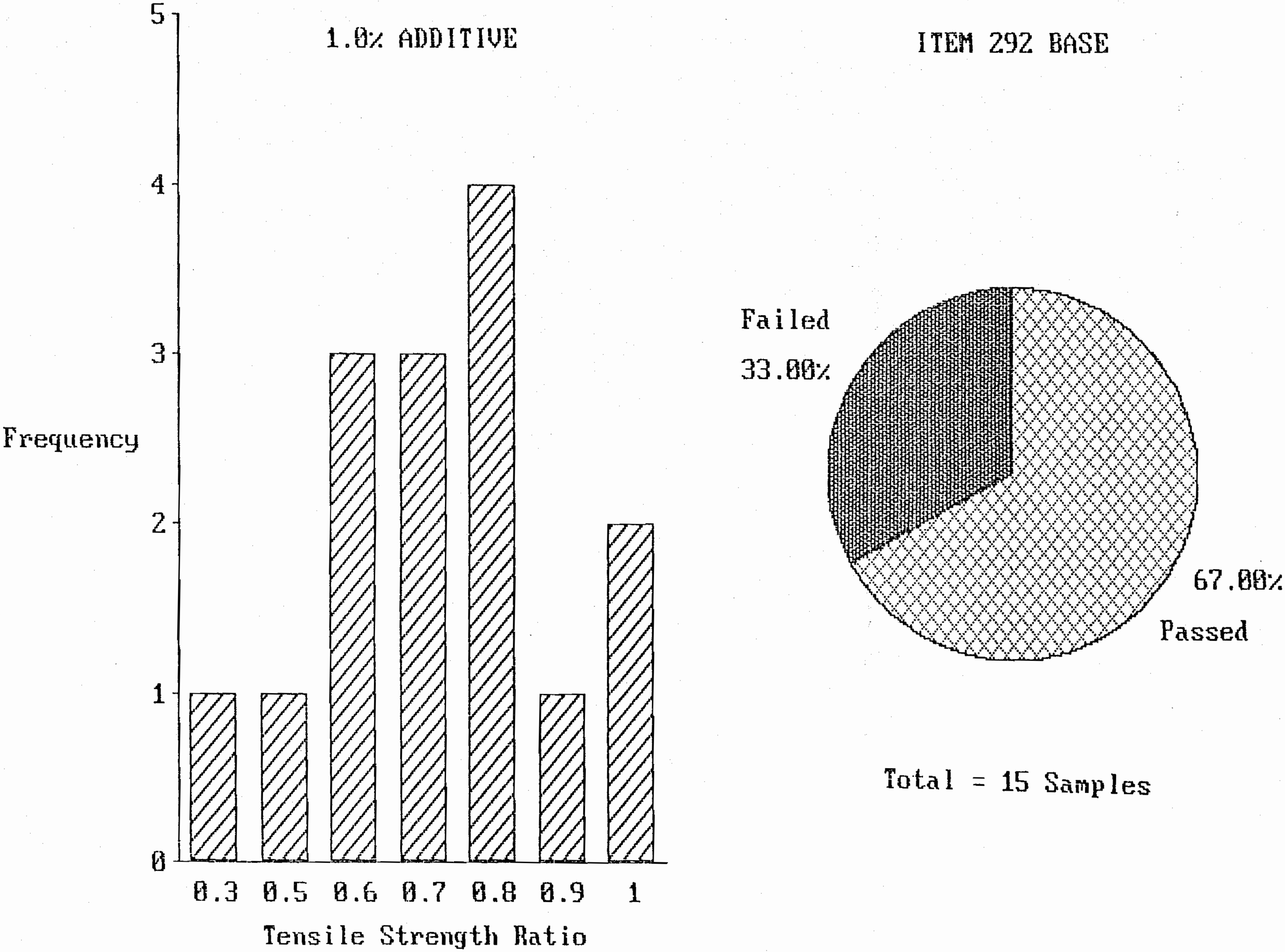

1.0% ADDITIVE
Frequency
5
4
3
2
1
0
0.3
0.5
0.6
0.7
0.8
0.9
1
Tensile Strength Ratio
ITEM 292 BASE
Failed
33.00%
67.00%
Passed
Total = 15 Samples

FIG. 15

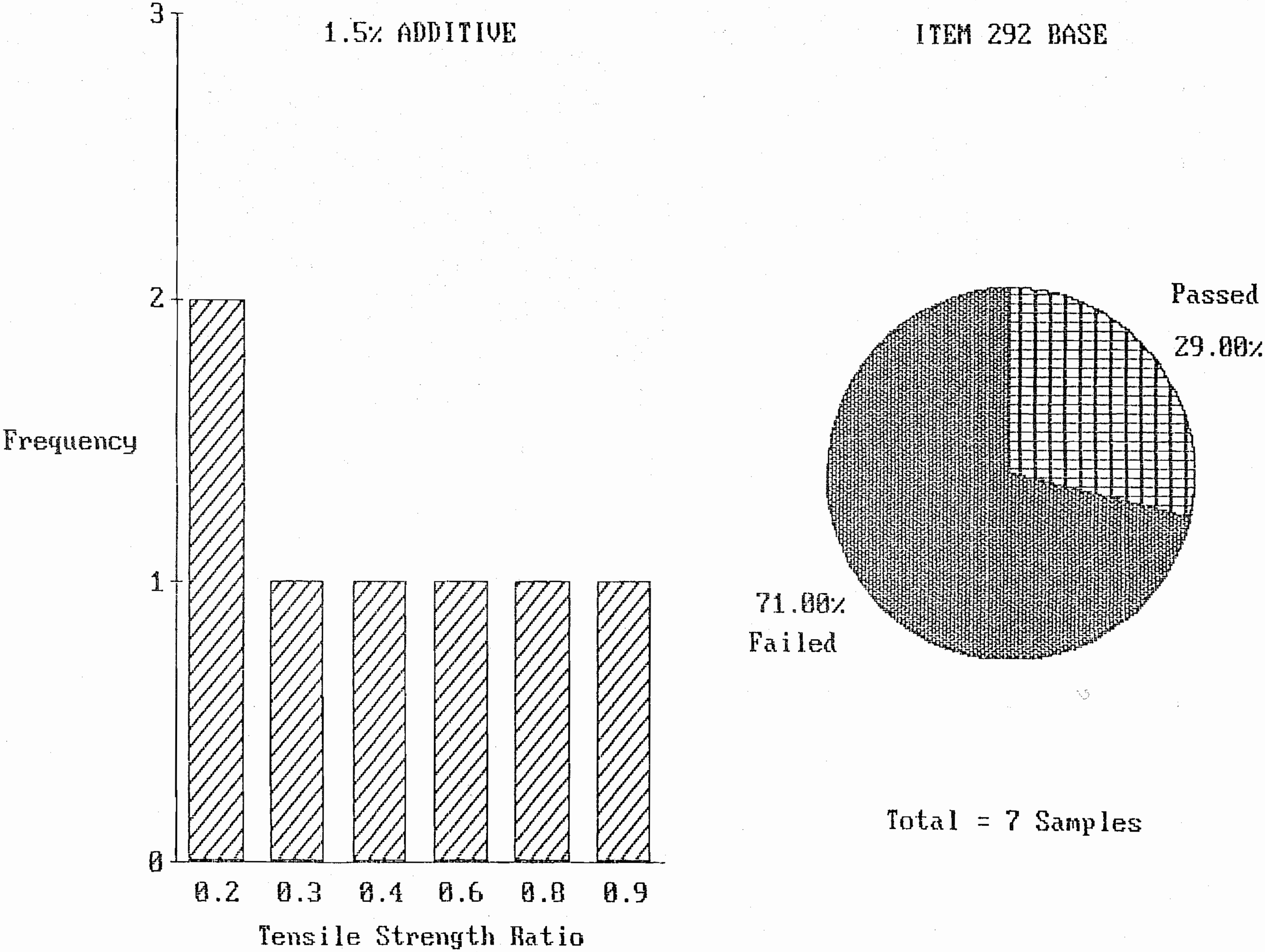

1.5% ADDITIVE
ITEM 292 BASE
Frequency
3
2
1
0
0.2
0.3
0.4
0.6
0.8
0.9
Tensile Strength Ratio
Passed
29.00%
71.00%
Failed
Total = 7 Samples

FIG. 16

A SAMPLE OF HOT MIX WITH FAILING RATIO AND HIGH INDIRECT TENSILE STRENGTH

Failing Ratio / High I.T.S.

DESIGN GRADATION OF HOT MIX ASPHALTIC CONCRETE (Item 340, "D")

TYPE OF MIXTURE: Level-Up Plant: Dravo, Galena Park

COMBINATION OF AGGREGATES: 31.6% "D" Limestone-Redland Worth
28.4% "F" Limestone - Redland Worth
13.7% Limestone Screenings- Rdld.Worth
26.3% Field Sand - Best Sand, Crosby

ASPHALT GRADE AND PRODUCER: AC - 10 Exxon

TYPE OF ANTI-STRIPPING ADDITIVE: None

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum%	maximum%
Pass 1/2"	100	100	
Pass 3/8"	98.7	85	100
3/8"-- 4	27.6	21	53
4 -- 10	27.6	11	32
+ 10	56.5	54	74
10 -- 40	10.1	6	32
40 -- 80	22.0	4	27
80 -- 200	8.0	3	27
Pass 200	3.4	1	8
Asphalt %	5.1	4	8

FIG. 17

Failing Ratio / High I.T.S.

0% ADDITIVE Item 340, "D", Level-Up						Dravo, Galena Park
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.684	5.1	50	dry:		ave. 126.1	
			93.2		126.8	2.03
			93.6		130.0	2.01
			93.4		124.0	2.02
			93.0		123.7	2.03
			wet:		ave. 86.3	
			93.1	65	88.4	2.03
			93.2	63	83.8	2.03
			93.5	63	89.3	2.01
			93.3	72	83.8	2.03

FIG. 17 A

DESIGN GRADATION OF HOT MIX ASPHALTIC CONCRETE (Item 340, "D")

TYPE OF MIXTURE: Level-Up Laboratory experimental mixture

COMBINATION OF AGGREGATES: 55% "D" Limestone, Gifford Hill
20% Limestone Screenings,Gifford Hill
25% Cyclone Sand, Brazos Materials

ASPHALT GRADE AND PRODUCER: AC - 20 Exxon

TYPE OF ANTI-STRIPPING ADDITIVE:
Anti-Rut (Dow)

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum%	maximum%
Pass 1/2"	100	100	
Pass 3/8"	98.5	85	100
3/8"-- 4	29.1	21	53
4 -- 10	28.7	11	32
+ 10	59.3	54	74
10 -- 40	12.8	6	32
40 -- 80	10.9	4	27
80 -- 200	11.3	3	27
Pass 200	5.7	1	8
Asphalt %	5.4	4	8

FIG. 17B

0% ADDITIVE Item 340, "D", Level-Up Experimental Mix						
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.449	5.4	46	dry:		ave. 141.5	
			93.3		138.6	2.08
			93.7		154.1	2.08
			93.2		138.4	2.09
			92.6		134.8	2.12
			wet:		ave. 63.5	
			92.5	75	56.0	2.11
			93.1	77	61.5	2.08
			93.5	75	64.7	2.08
			93.7	73	71.6	2.07

FIG. 17 C

5.0% ANTI-RUT (Dow) Item 340, "D", Level-Up Experimental Mix						
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
0.676	5.4	52	dry:		ave. 177.0	
			93.7		194.1	2.07
			93.6		188.9	2.07
			92.9		162.8	2.08
			93.1		162.3	2.09
			wet:		ave. 119.7	
			93.6	64	119.3	2.06
			93.5	71	116.3	2.07
			93.2	62	131.8	2.06
			93.4	69	111.5	2.07

FIG.17D

A SAMPLE OF HOT MIX WITH PASSING RATIO AND LOW INDIRECT TENSILE STRENGTH

Passing Ratio / Low I.T.S.

DESIGN GRADATION OF HOT MIX ASPHALTIC CONCRETE (Item 340, "D")

TYPE OF MIXTURE: Surface Mix   Plant: Dravo, Galena Park

COMBINATION OF AGGREGATES: 24.2% Sandstone - Delta Materials
20.4% "D" Limestone - Redland Worth
19.0% "F" Limestone - Redland Worth
15.3% Limestone Screenings-Rdld.Worth
21.1% Field Sand, Best Sand, Crosby

ASPHALT GRADE AND PRODUCER: AC - 20 Gulf States

TYPE OF ANTI-STRIPPING ADDITIVE: 0.5% Pave Bond LP

SIEVE SIZE	DESIGN GRADATION %	REQUIRED GRADATION minimum%	maximum%
Pass 1/2"	100	100	
Pass 3/8"	97.2	85	100
3/8"-- 4	32.4	21	53
4 -- 10	23.1	11	32
+ 10	58.9	54	74
10 -- 40	12.5	6	32
40 -- 80	16.0	4	27
80 -- 200	8.1	3	27
Pass 200	4.5	1	8
Asphalt %	5.1	4	8

FIG 18

Passing Ratio / Low I.T.S.

0.5% ADDITIVE Item 340, "D", Surface Mix					Dravo, Galena Park	
Tensile Strength Ratio	Asphalt %	Stability %	Density %	Air Voids Filled %	Indirect Tensile Strength (psi)	Sample Height (inch)
					ave.	
0.819	5.1	48	dry:		58.7	
			92.5		60.2	2.06
			92.6		63.3	2.07
			92.2		56.9	2.07
			92.1		54.4	2.08
					ave.	
			wet:		48.1	
			92.7	62	50.2	2.05
			92.2	67	46.2	2.06
			92.5	69	51.4	2.05
			92.1	68	44.5	2.05

FIG. 18A

TENSILE STRENGTH STATISTICS ON HOT MIX SAMPLES WITH PASSING RATIOS

ADDITIVE %	HMAC TYPE	WET OR DRY	TOTAL NO. SAMPLES	INDIRECT TENSILE STRENGTH (p.s.i.) MAXIMUM	MINIMUM	MEAN
0	Surface	Dry	5	77.4	54.3	67.4
present	Surface	Dry	37	192.7	57.1	102.9
0	Surface	Wet	5	60.7	41.2	53.5
present	Surface	Wet	37	135.9	48.1	76.7
0.5	Surface	Dry	16	125.8	58.7	87.0
1.0	Surface	Dry	17	192.7	57.1	114.2
0.5	Surface	Wet	16	98.9	48.1	73.7
1.0	Surface	Wet	17	135.9	48.8	87.8

FIG. 19

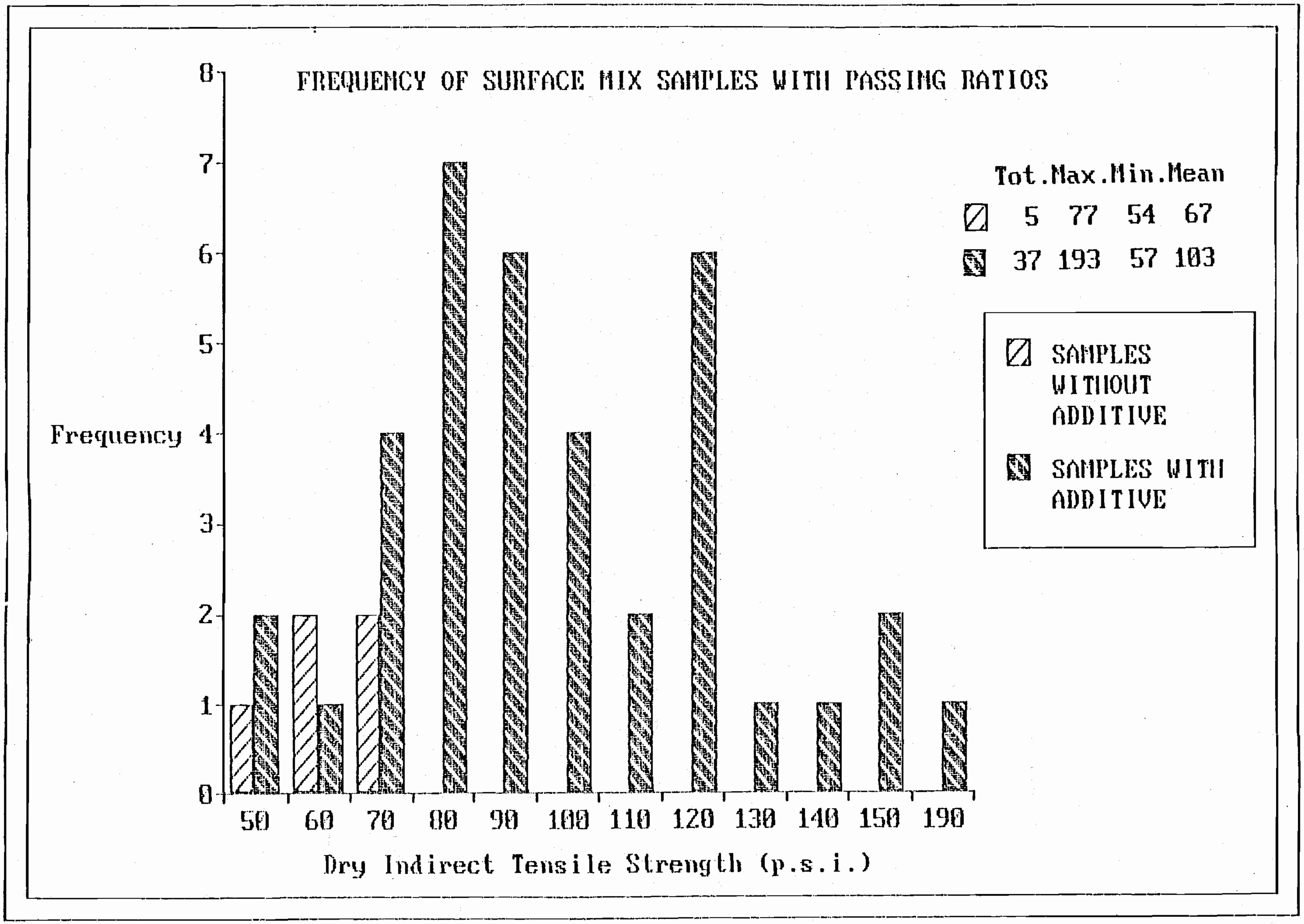

FREQUENCY OF SURFACE MIX SAMPLES WITH PASSING RATIOS
Frequency
0
1
2
3
4
5
6
7
8
50
60
70
80
90
100
110
120
130
140
150
190
Dry Indirect Tensile Strength (p.s.i.)
Tot.Max.Min.Mean
5 77 54 67
37 193 57 103
SAMPLES WITHOUT ADDITIVE
SAMPLES WITH ADDITIVE

FIG. 19A

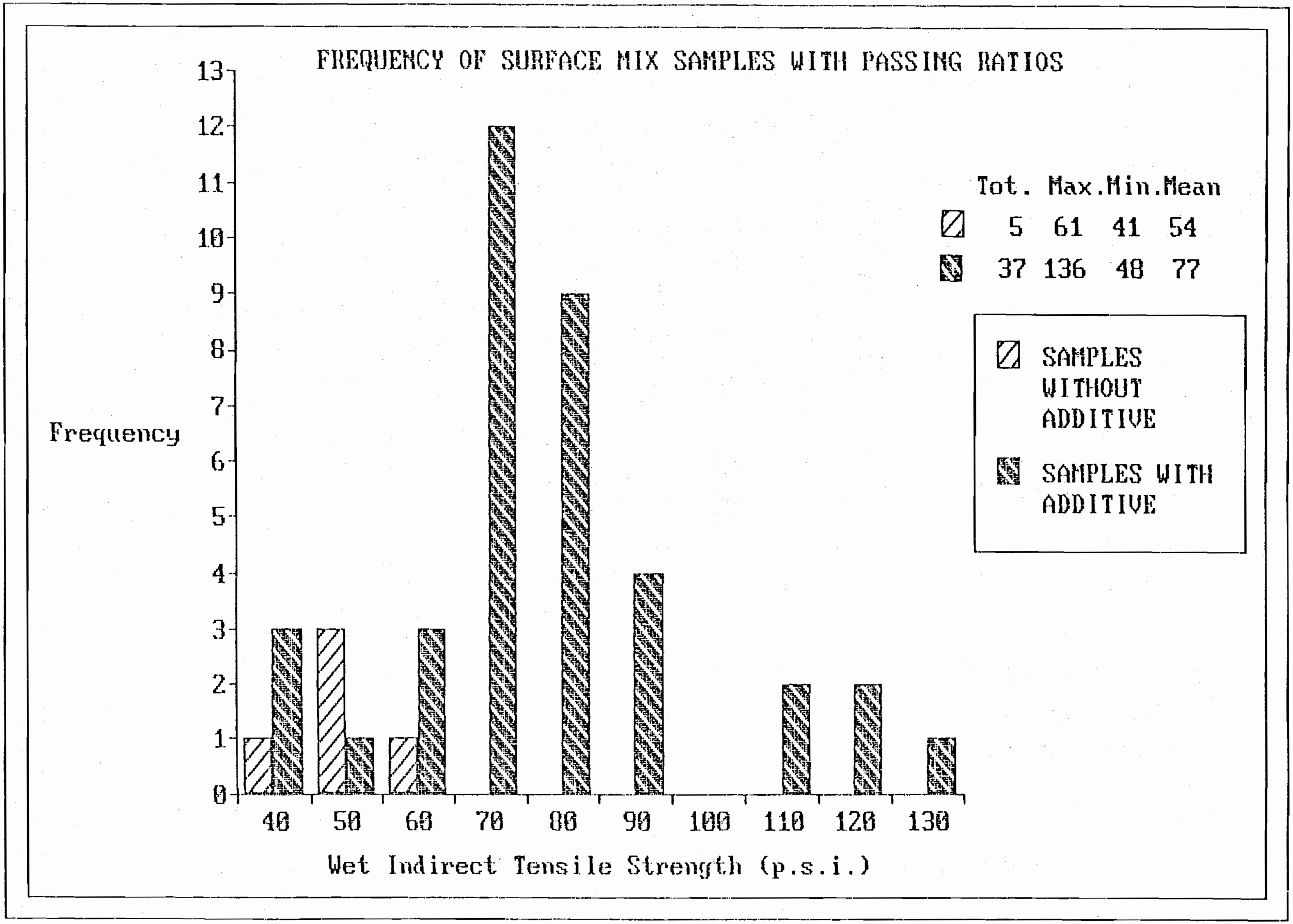

FREQUENCY OF SURFACE MIX SAMPLES WITH PASSING RATIOS
Frequency
13
12
11
10
9
8
7
6
5
4
3
2
1
0
40
50
60
70
80
90
100
110
120
130
Wet Indirect Tensile Strength (p.s.i.)
Tot. Max. Min. Mean
5 61 41 54
37 136 48 77
SAMPLES WITHOUT ADDITIVE
SAMPLES WITH ADDITIVE

FIG. 19B

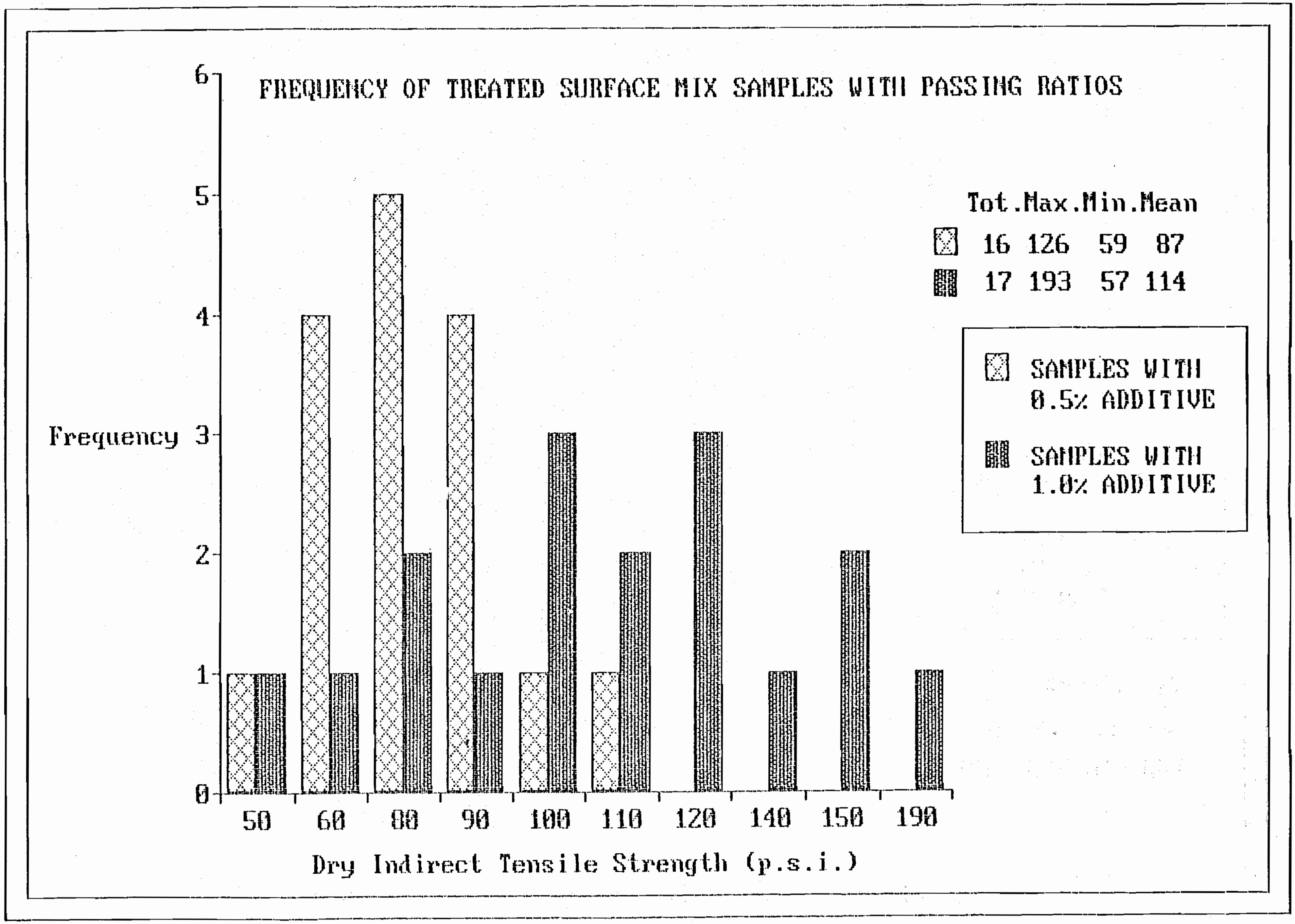

FREQUENCY OF TREATED SURFACE MIX SAMPLES WITH PASSING RATIOS
Tot. Max. Min. Mean
16 126 59 87
17 193 57 114
SAMPLES WITH 0.5% ADDITIVE
SAMPLES WITH 1.0% ADDITIVE
Frequency
0
1
2
3
4
5
6
50
60
80
90
100
110
120
140
150
190
Dry Indirect Tensile Strength (p.s.i.)

FIG. 19C

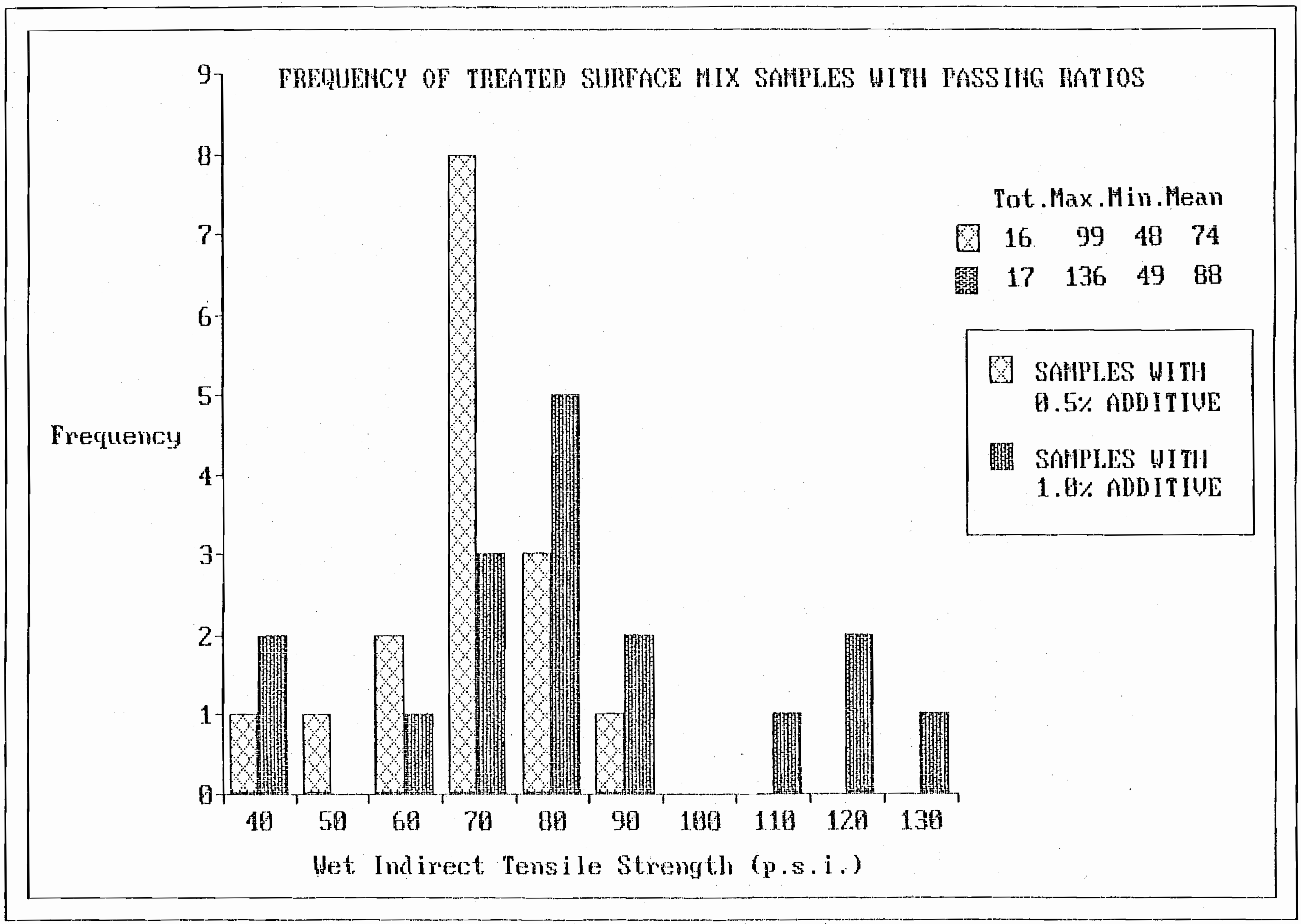
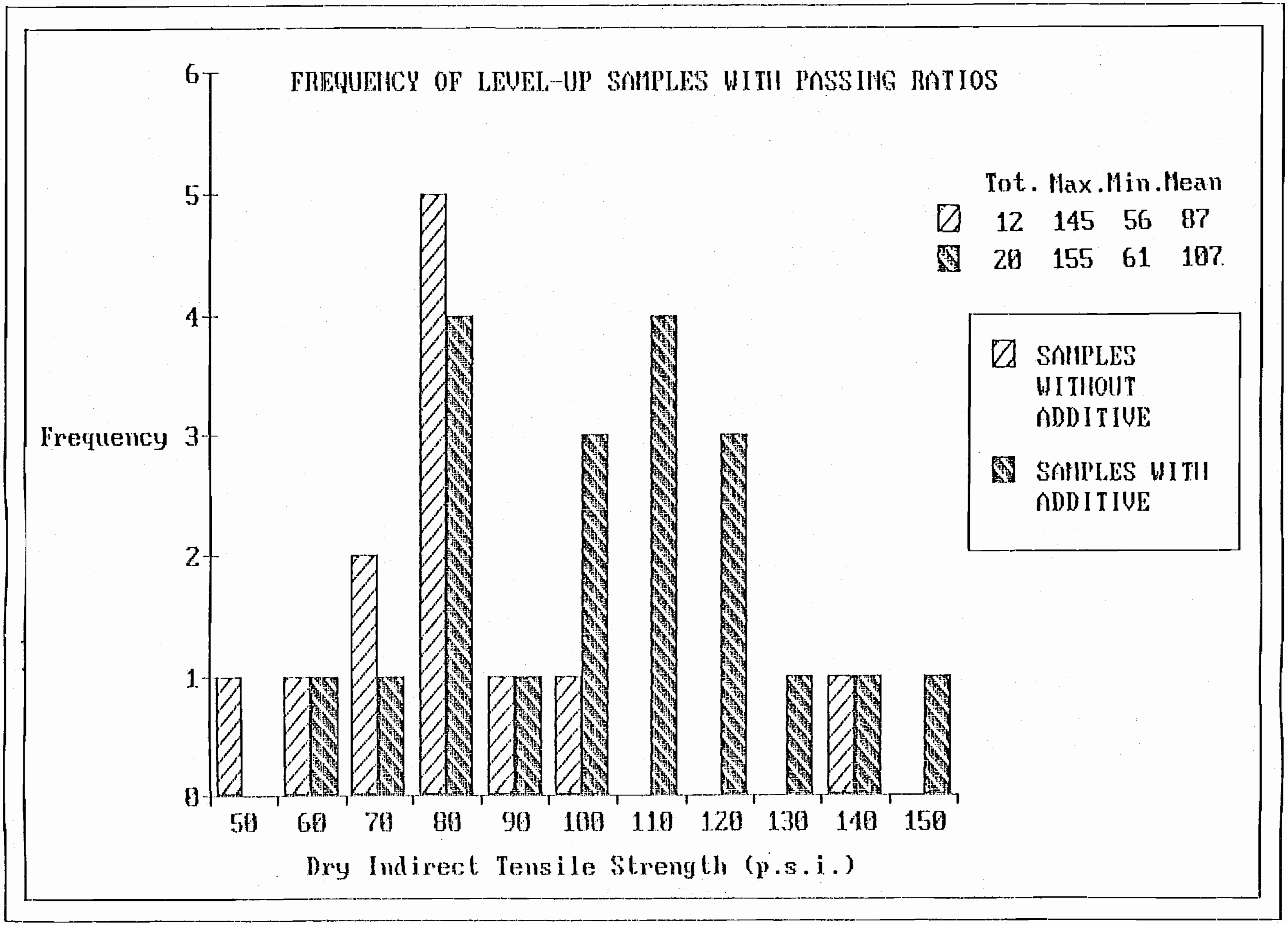

FREQUENCY OF TREATED SURFACE MIX SAMPLES WITH PASSING RATIOS
Frequency
0
1
2
3
4
5
6
7
8
9
40
50
60
70
80
90
100
110
120
130
Wet Indirect Tensile Strength (p.s.i.)
Tot. Max. Min. Mean
16 99 48 74
17 136 49 88
SAMPLES WITH 0.5% ADDITIVE
SAMPLES WITH 1.0% ADDITIVE

FIG. 19 D

TENSILE STRENGTH STATISTICS ON HOT MIX SAMPLES WITH PASSING RATIOS

ADDITIVE %	HMAC TYPE	WET OR DRY	TOTAL NO. SAMPLES	INDIRECT TENSILE STRENGTH (p.s.i.) MAXIMUM	MINIMUM	MEAN
0	Level-Up	Dry	12	145.6	56.0	86.8
present	Level-Up	Dry	20	155.2	61.3	107.5
0	Level-Up	Wet	12	105.4	47.1	67.3
present	Level-Up	Wet	20	120.4	62.5	89.5
0.5	Level-Up	Dry	7	122.5	61.3	97.0
1.0	Level-Up	Dry	11	143.5	80.8	112.2
0.5	Level-Up	Wet	7	107.4	62.5	84.2
1.0	Level-Up	Wet	11	120.4	73.9	92.8
0.5	Base	Dry	6	131.2	26.2	75.2
1.0	Base	Dry	7	125.5	64.1	96.5
0.5	Base	Wet	6	100.8	19.9	60.1
1.0	Base	Wet	7	110.7	54.1	87.3

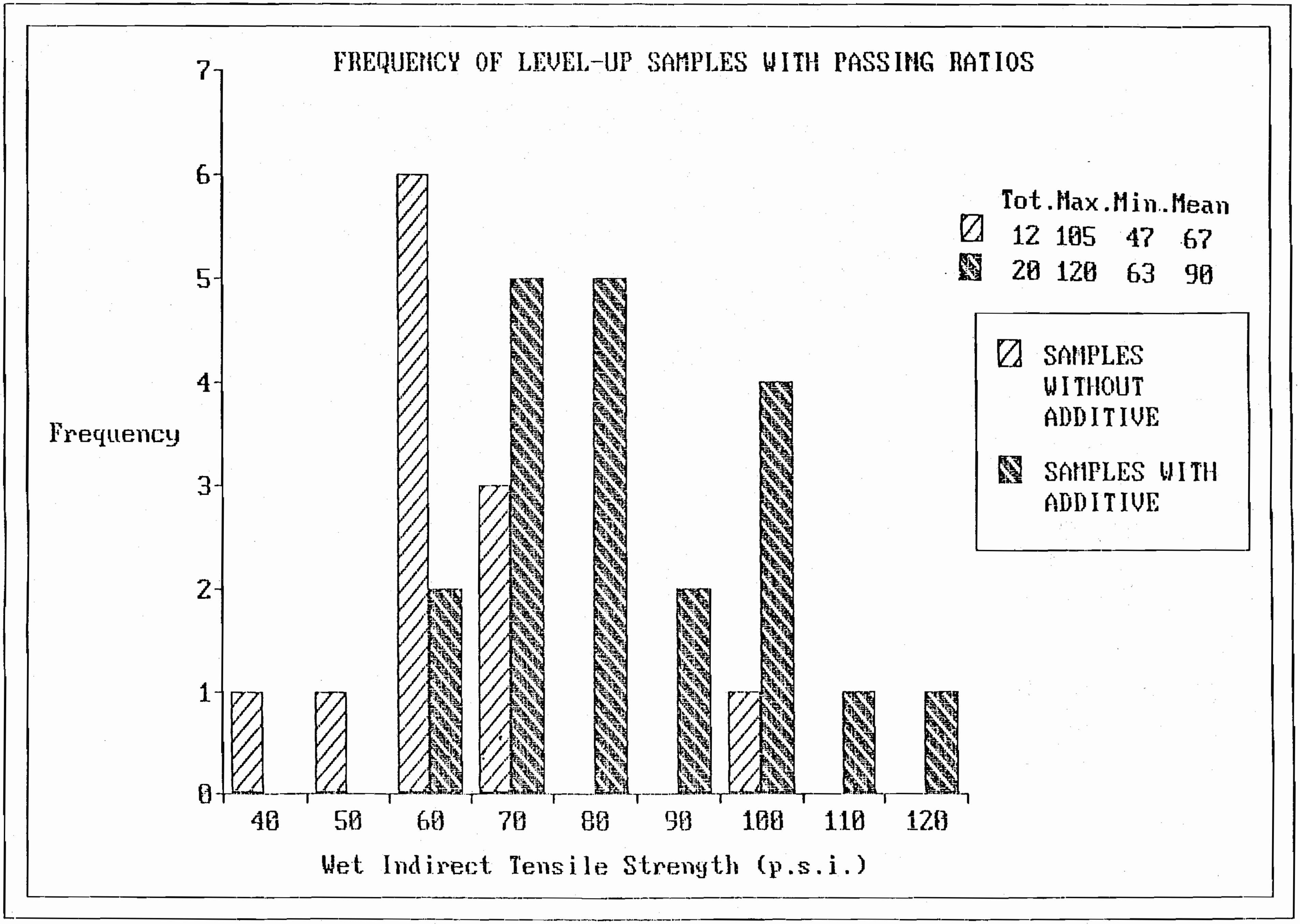
FIG. 20



FREQUENCY OF LEVEL-UP SAMPLES WITH PASSING RATIOS
Frequency
0
1
2
3
4
5
6
50
60
70
80
90
100
110
120
130
140
150
Dry Indirect Tensile Strength (p.s.i.)
Tot. Max. Min. Mean
12 145 56 87
20 155 61 107
SAMPLES WITHOUT ADDITIVE
SAMPLES WITH ADDITIVE

FIG. 20A

55



FREQUENCY OF LEVEL-UP SAMPLES WITH PASSING RATIOS
Frequency
0
1
2
3
4
5
6
7
40
50
60
70
80
90
100
110
120
Wet Indirect Tensile Strength (p.s.i.)
Tot. Max. Min. Mean
12 105 47 67
20 120 63 90
SAMPLES WITHOUT ADDITIVE
SAMPLES WITH ADDITIVE

FIG. 20B

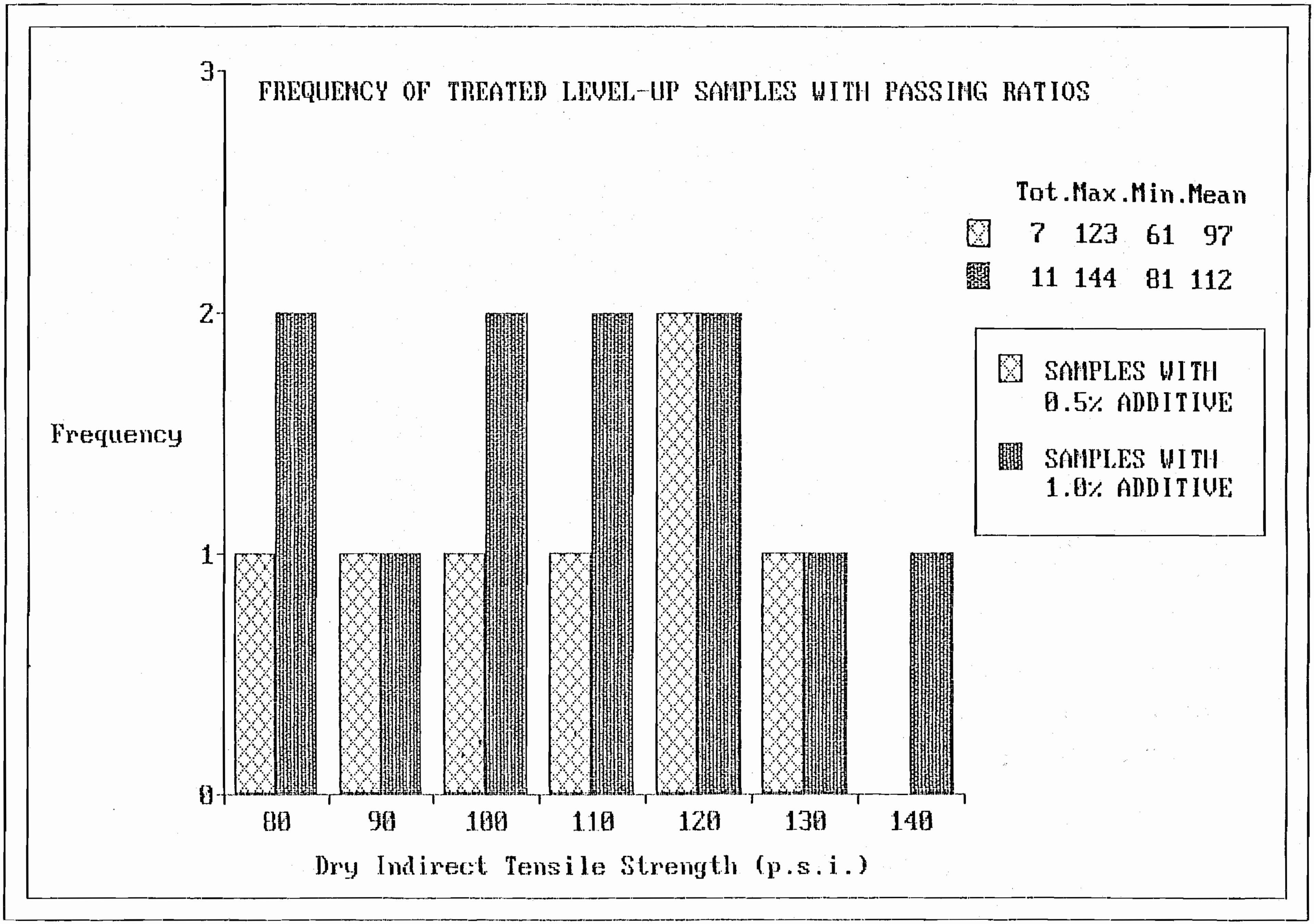

FREQUENCY OF TREATED LEVEL-UP SAMPLES WITH PASSING RATIOS
Frequency
0
1
2
3
Tot.Max.Min.Mean
7 123 61 97
11 144 81 112
SAMPLES WITH 0.5% ADDITIVE
SAMPLES WITH 1.0% ADDITIVE
80
90
100
110
120
130
140
Dry Indirect Tensile Strength (p.s.i.)

FIG. 20C

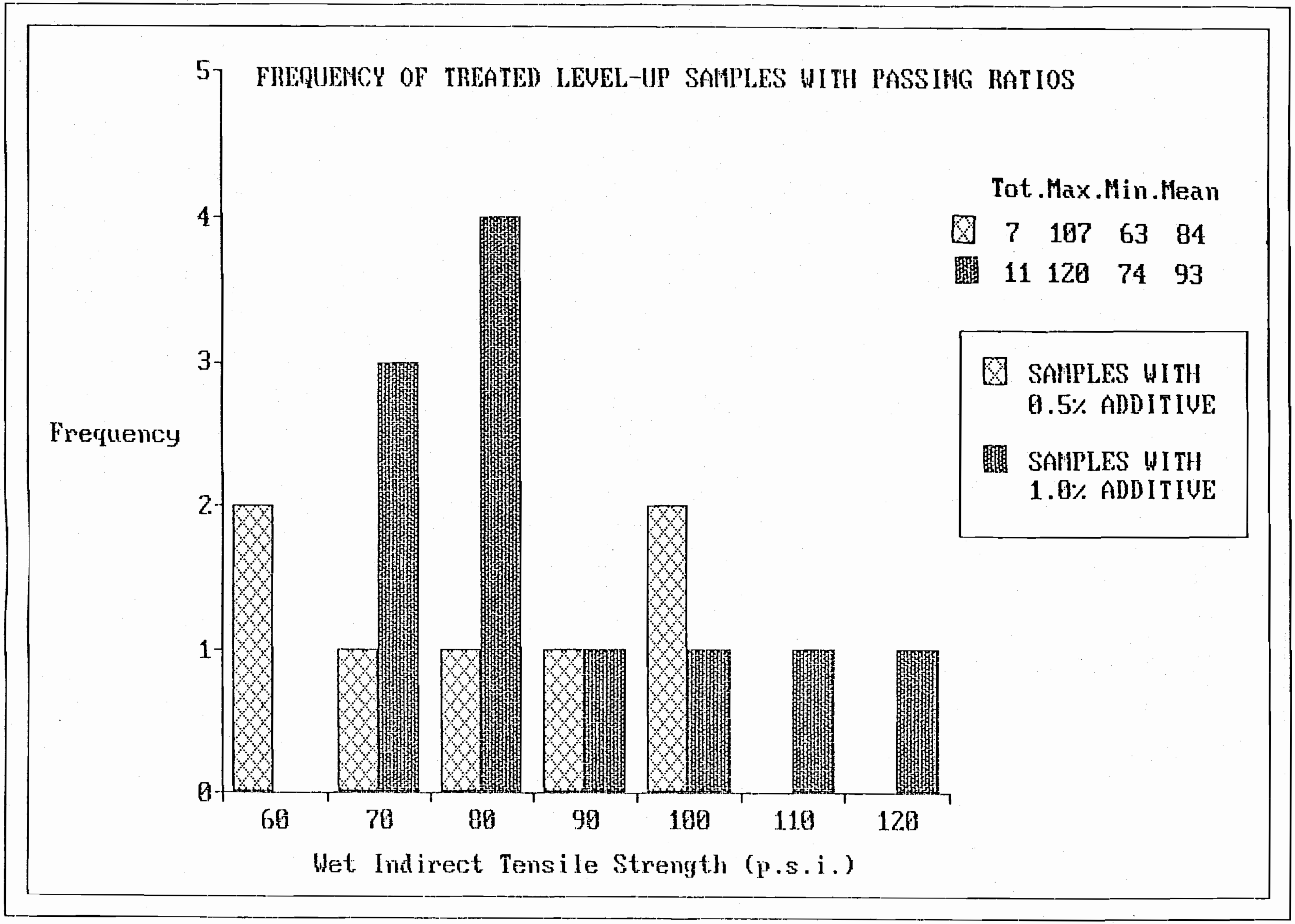

FREQUENCY OF TREATED LEVEL-UP SAMPLES WITH PASSING RATIOS
Frequency
5
4
3
2
1
0
60
70
80
90
100
110
120
Wet Indirect Tensile Strength (p.s.i.)
Tot.Max.Min.Mean
7 107 63 84
11 120 74 93
SAMPLES WITH 0.5% ADDITIVE
SAMPLES WITH 1.0% ADDITIVE

FIG. 20 D

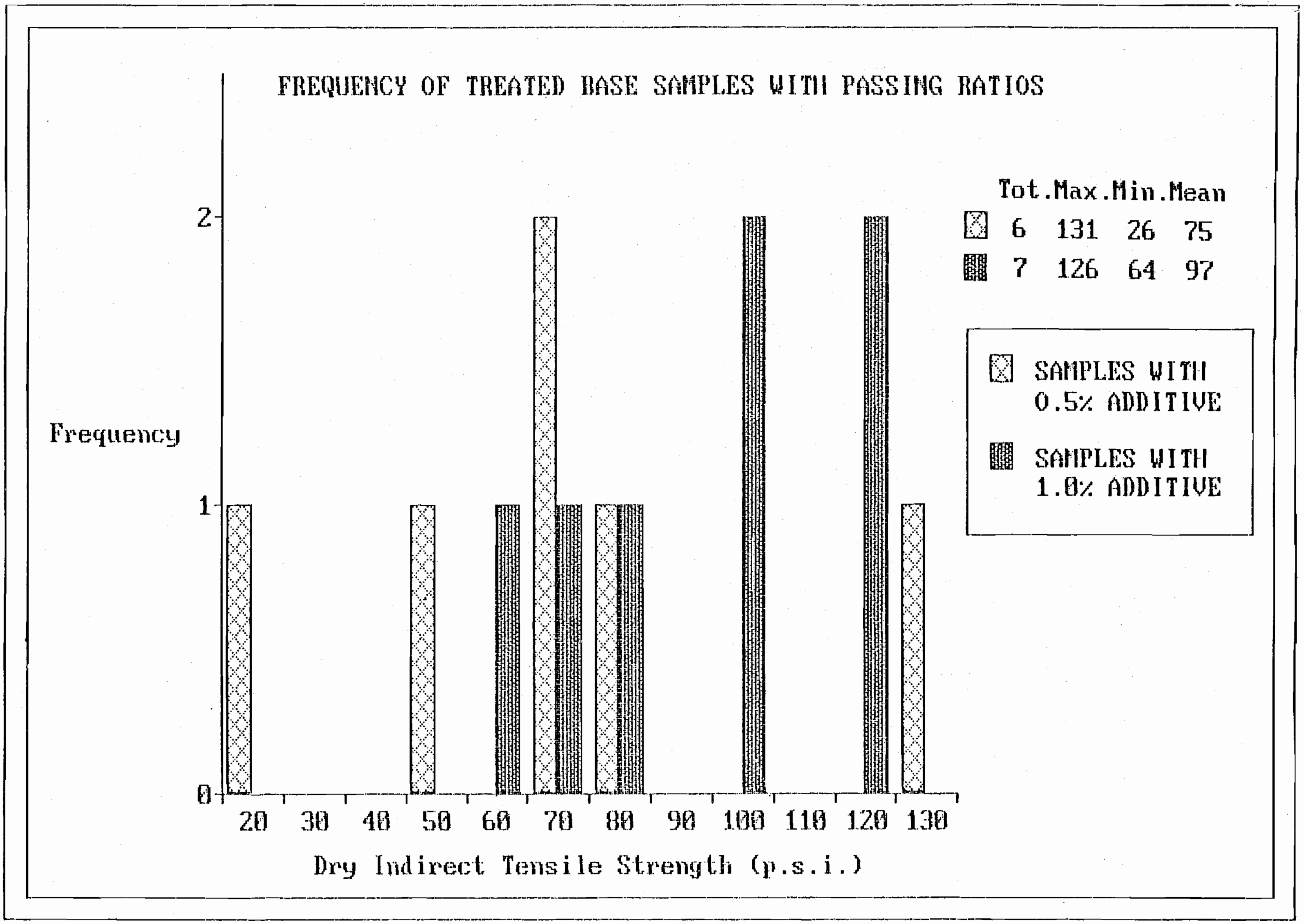

FREQUENCY OF TREATED BASE SAMPLES WITH PASSING RATIOS
Frequency
2
1
0
20 30 40 50 60 70 80 90 100 110 120 130
Dry Indirect Tensile Strength (p.s.i.)
Tot. Max. Min. Mean
6 131 26 75
7 126 64 97
SAMPLES WITH 0.5% ADDITIVE
SAMPLES WITH 1.0% ADDITIVE

FIG. 20E

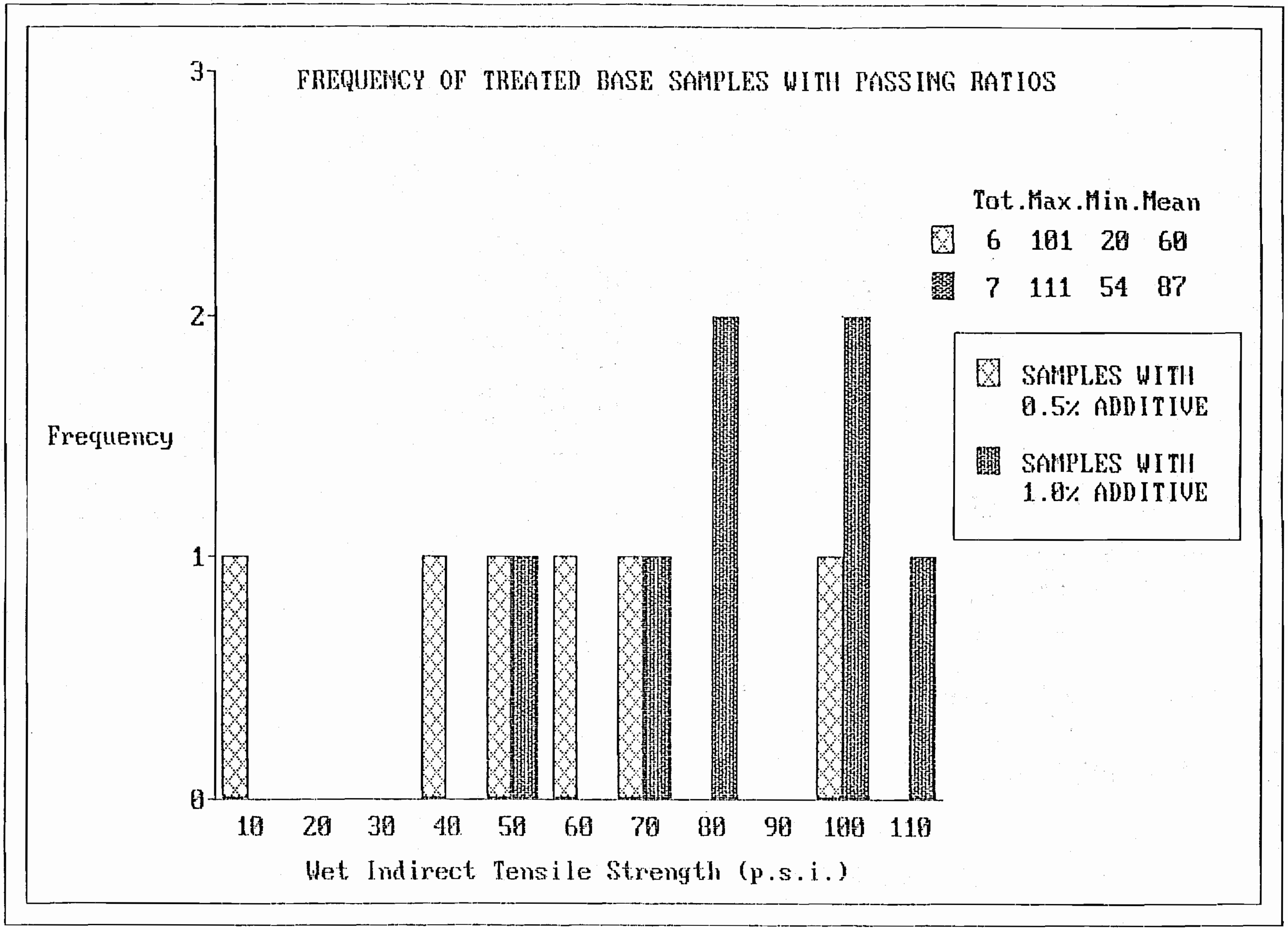

FREQUENCY OF TREATED BASE SAMPLES WITH PASSING RATIOS
Frequency
0
1
2
3
10 20 30 40 50 60 70 80 90 100 110
Wet Indirect Tensile Strength (p.s.i.)
Tot. Max. Min. Mean
6 101 20 60
7 111 54 87
SAMPLES WITH 0.5% ADDITIVE
SAMPLES WITH 1.0% ADDITIVE

FIG. 20F

APPENDIX B

Test Method
TEX-531-C

State Department of Highways and Public Transportation

Materials and Tests Division

PREDICTION OF MOISTURE-INDUCED DAMAGE TO BITUMINOUS PAVING MIXTURES USING MOLDED SPECIMENS

Scope

This procedure describes a stripping test utilizing molded Hveem specimens of complete mix. Some of these molded specimens are subjected to moisture conditioning and compared by indirect tensile strength to unconditioned specimens. The tensile strength ratio (TSR) of a mix may be calculated as the indirect tensile strength of the moisture-conditioned specimens divided by the indirect tensile strength of unconditioned specimens. The TSR is therefore an indication of loss of strength produced by the moisture conditioning (stripping). This procedure may be used to evaluate untreated mixes or evaluate the effectiveness of antistrip additives.

Apparatus

1. Equipment for mixing, molding, and density determination of Hveem specimens.
2. Desiccator cabinet.
3. Vacuum chamber capable of holding at least four specimens submerged in water.
4. Vacuum pump and gauge (or manometer).
5. Distilled or deionized water.
6. Plastic bags.
7. Freezer capable of 0 ± 5 F.
8. Water bath capable of 140 ± 1 F.
9. Water bath capable of 77 ± 2 F.
10. Apparatus capable of performing indirect tensile strength test.

Procedure

The procedure involves the construction of eight molded specimens. If additives are to be evaluated, they may be incorporated in the specimens either in the asphalt or aggregate, as required.

Mixing

a. Eight specimens are mixed, as described in Tex-205-F, using the design aggregates and asphalt except that mixing should take place at 300 F.

b. Cool mix specimens for 2.5 hours at room temperature.

c. Cure mix specimens at 140 F for 15 hours.

Molding

a. Heat mix specimens at 250 F for 2 hours.

b. Specimens should be molded as described in Tex-206-F except specimens should be compacted to 93 ± 1 percent of theoretical density. This involves a trial-and-error procedure initially to determine the proper compactive effort to achieve the density range desired. (See Note 1)

c. Cool the specimens to room temperature.

Density Determination

a. The percent of maximum theoretical density should be calculated as described in Tex-207-F except no wax should be used.

b. Molded specimens should be allowed to stand at room temperature for 24 hours.

c. The eight molded specimens should be divided into two groups of four specimens. This division should be based on achieving approximately the same average percent of maximum theoretical density in both groups. The height of each specimen should be measured for future use.

Conditioning of Specimens

a. One of the groups of four specimens is placed in a desiccator and stored until the indirect tensile strength is to be determined.

b. The second group of four specimens is subjected to moisture conditioning in an attempt to induce moisture-related damage (stripping). Moisture conditioning is accomplished as follows:

1. Vacuum saturation to 60-80 percent filled voids is accomplished by trial and error until the saturation level falls into the 60-80 percent range.

The specimens are placed in a vacuum chamber and the chamber is filled with enough water to submerge the molded specimens. An initial vacuum level is chosen and this vacuum is applied to the vacuum chamber for 5 minutes. The percent density of these specimens is measured and compared to the original percent of maximum theoretical density to determine the amount of voids filled with water. If this level of saturation is too low, the saturation procedure is repeated using a higher vacuum level. Exercise caution in this saturation procedure, since saturation in excess of 80 percent requires molding new specimens.

2. Each of the four saturated specimens is placed in a plastic bag and this bagged specimen is placed inside another plastic bag. Ten milliliters of water is added to the outer bag and then sealed. The double-bagged specimens are placed in a freezer at 0 F for 15 hours.

3. The specimens are taken from the bags and placed in a 140 F water bath for 24 hours.

Indirect Tensile Testing

Remove moisture-conditioned specimens from 140 F water bath and place them in a 77 F water bath. Remove the dry specimens from the desiccator and put in plastic bags and then place the bagged specimens in the 77 F water bath. The plastic bags should keep the desiccated specimens dry.

After the specimens have been in the 77 F water bath for three to four hours (to insure 77 F has been obtained), the specimens are all removed and tested immediately by indirect tensile loading to failure, as described in Tex-226-F. The Tensile Strength Ratio is then calculated as:

$$TSR = \frac{\text{Average Indirect Tensile Strength of Conditioned Specimens}}{\text{Average Indirect Tensile Strength of Dry Specimens}}$$

Sample data and calculation sheets follow.

Notes:

1. Compaction Procedure. Mix 4 trial specimens. Mold the 4 specimens using 2, 4, 6, and 8 sets of gyrations at 50 psi loading and a 1000 psi level-up load. Determine the density of these trial specimens and determine the compactive effort (i.e., number of gyrations at 50 psi with a 1000 psi level-up load) needed to achieve 93 ± 1% density for the test specimens.

2. For Item 350 material, the mixing and molding procedures are amended by mixing the design aggregates and the asphalt-primer blend (no water) at 200 ± 5 F, cooling at room temperature for 2.5 hours, curing mix a minimum of 15 hours at 140 F or until constant weight is attained, heating the mix specimens at 100 ± 5 F for two hours, and molding at 100 ± 5 F. Plant mixes may be tested by the modified procedure starting with the curing step.

3. Plant mixes may be tested by this procedure by starting at the molding section providing representative samples of the plant mix are weighed to produce mix specimens.