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16. Abstract

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MIXTURE DESIGN METHODS FOR EMULSION TREATED BASES AND SURFACES

by

Dallas N. Little, Jon A. Epps and Bob M. Gallaway

Research Report 41-1
Bituminous Treated Bases
Research Study No. 2-6-74-41

Sponsored by
The Texas State Department of Highways and Public Transportation
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PREFACE

This report is issued under Research Study 2-6-74-41, "Bituminous Treated Bases," and presents a review of mixture design methods for emulsion treated bases and surfaces together with a suggested mixture design method for use by the Texas State Department of Highways and Public Transportation. This project was initiated based on results of a limited type B study titled "Bituminous Treated Bases - An Exploratory Study."

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

ACKNOWLEDGEMENTS

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ABSTRACT

Types of tests and criteria for the mixture design of emulsion treated bases and surfaces have been reviewed. A laboratory testing program was conducted to investigate the effort of curing conditions and compaction on the stability and resilient modulus of emulsion stabilized sands. Based on the laboratory study, several sands have been suggested for use as pavement base courses. An interim test method has been suggested for use by the Texas State Department of Highways and Public Transportation.

KEY WORDS

Emulsion Stabilization, Mix Design Methods, Stability, Resilient Modulus

SUMMARY

Emulsion stabilized aggregates have become a viable paving material. To date the use of this material for base courses has been limited mainly to the west and midwest; however, shortages of high quality aggregates together with certain economic and energy considerations make the use of emulsion in Texas appear appealing.

A brief review of emulsion mix design methods indicates that several methods exist but only a few have criteria which allow the engineer to select the optimum emulsion content. Most of these current methods are based on the use of the Hveem stabilimeter and the Marshall apparatus. Criteria for the most part have been developed without the benefit of long term field performance information.

A laboratory testing program was undertaken to establish an emulsion mix design method suitable for use by the Texas State Department of Highways and Public Transportation. This program was established to correlate existing Chevron and Asphalt Institute testing methods with testing methods currently utilized in Texas. For example, the method of compaction commonly utilized in Texas is gyratory as compared to the kneading compaction used in the Chevron and Asphalt Institute procedures. Thus if the Chevron and Asphalt Institute criteria are to be utilized, a suitable criterion has to be established.

Based on the laboratory study, a mix design method has been suggested which allows the engineer to select the optimum emulsion content as well as determine the thickness of the layer in a pavement section. In addition several aggregates have been identified which are suitable for use as base courses. The districts in which these materials are located are encouraged

to make use of this economical material as a base course in order that field performance information can be obtained.

IMPLEMENTATION STATEMENT

A mixture design method for emulsion treated bases and surfaces has been recommended in this report. The Texas State Department of Highways and Public Transportation is encouraged to make use of this method on an interim basis and to correlate its results with the method proposed by Smith utilizing the large Texas Gyratory Compactor and compression testing machine.

Several aggregates were identified in this study that can be used as base courses if stabilized with emulsion. Districts are encouraged to use these materials in order that field performance information can be obtained.

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INTRODUCTION

Emulsified asphalt stabilization has been used in the United States since the late 1920's (1). Since these initial efforts, emulsion stabilization has become popular in the West and Midwest. However, very little stabilization with emulsion has been attempted in the state of Texas.

Emulsion stabilizated aggregates appears to be a viable material for pavement construction in Texas. Potential applications include the following, (2)

1. Construction aid
2. Upgrading of marginal aggregate mixes
3. Subbase
4. Temporary wearing surface in stage construction
5. Asphalt base
6. Open-graded surface
7. Dense graded surface

Mixture design methods therefore need to be identified or developed which will aid the engineer in the selection of the type and amount of emulsion to utilize for a particular aggregate and specific application. Additionally, aggregate sources need to be identified in Texas which can produce economic emulsion stabilized mixtures.

This report briefly reviews existing mixture design methods and through a laboratory correlation study suggests an interim mixture design method for use in Texas. As a result of this correlation study, several aggregate sources have been identified which can be satifactorily utilized as emulsion treated bases.

MIX DESIGN METHODS

The engineer is faced with providing a bituminous stabilized mixture to satisfy the needs of a particular situation. Certainly these demands vary from construction project to construction project and are dependent upon such factors as environment, loading conditions and location within the structural pavement section, among others. In an attempt to consider these factors the engineer must define the following mixture characteristics and their relative importance for a particular utilization of the bituminous stabilized materials:

1. stability
2. durability
3. fatigue behavior
4. tensile behavior
5. flexibility
6. workability

Test methods have been developed to measure these properties (3); however, most of these methods, with the exception of those determining stability and durability, are not performed routinely. Additionally criteria associated with these tests have been largely established based on the materials adequacy as a surface course rather than a base or subbase mix.

This apparant lack of a definitive mix design methods has been recognized and several agencies have been engaged in research to produce a comprehensive mix design method. Among the more active research groups are the following;

1. Chevron, USA (4,5)
2. ARMAK (6)
3. Asphalt Institute (7)
4. University of Illinois (8, 9)
5. Purdue University (10, 11)
6. University of Mississippi (12, 13)

7. Texas A&M University (14)
8. Texas State Department of Highways and Public Transportation (15)
9. United States Air Force (16)
10. United States Forest Service (17, 19)
11. Federal Highway Administration (19)

From review of the publications resulting from these research projects (3, 20) it is evident that the standard stability tests utilizing both the Hveem and Marshall approaches are popular. For example, research performed by Chevron and the Asphalt Institute is based primarily on the Hveem test methods while research at ARMAK, Purdue and University of Mississippi is based on the use of the Marshall apparatus. The United States Air Force Academy, the United States Forest Service and Texas A&M University performed tests utilizing both the Hveem and Marshall testing techniques.

The approach to emulsified asphalt mix design in Texas has been based on the use of Test Method Tex-119-E "Soil Asphalt Strength Test Method (21). This method involves impact compaction of a 6-inch by 6-inch sample, curing at 140°F for 5 days, pressure wetting and triaxial testing. A new method involving gyratory compaction, dry curing, pressure wetting and compression testing has recently been developed by Smith for use in Texas (15).

From the above brief review of the literature it is apparent that a number of test methods have been developed. Unfortunately, only a few of the methods developed and reported to date have offered criteria from which an emulsion content can be selected. Furthermore, if criteria have been offered for identical test equipment, difference in compaction and curing of the samples prior to testing make it difficult to establish desired correlations.

Since the purpose of this project is to suggest an appropriate testing method for use by the Texas State Department of Highways and Public Transportation, a listing of desirable features of the test method follows:

1. The test should be capable of defining as many mixture properties as possible (i.e., stability, durability, fatigue resistance, etc.).

2. Test geometry, loading conditions and specimen preparation should represent actual field conditions.

3. The test should be simple, easy to perform and the results should be easily interpreted.

4. The test should be suitable for construction control, mixture evaluations and pavement design.

5. The test should adequately delineate between acceptable and unacceptable mixtures.

6. Criteria for selection of emulsion content based on laboratory test results should be correlated with field performance.

From this listing of desirable features and a knowledge of existing technology, the authors feel that the approach presently utilized by Chevron, USA and the Asphalt Institute offered the best opportunity for easy adoption by the Texas State Department of Highways and Public Transportation. Specifically, the Chevron and Asphalt Institute procedures offer the following advantages:

1. The Hveem testing equipment is utilized.(This equipment is presently utilized for surface course design in Texas.)

2. The testing equipment can be used together with appropriate curing conditions to determine both stability and durability properties.

3. The loading conditions are triaxial and to a degree similar to field loading conditions.

4. The test is relatively simple, easy to perform and the results are relatively easy to interpret.

5. The test is suitable for mixture evaluation and construction quality control.

6. Chevron makes use of the resilient modulus test which can be used for pavement design.

7. A history of satisfactory field performance mixes designed by the method dates to 1965 (2, 17).

Established criteria for the two procedures are shown in Table 1.

Several differences exist in the Chevron and Asphalt Institute procedures that need to be resolved. Additionally, compaction methods utilized in Texas are of a gyratory or impact nature and not the kneading type as suggested for use by Chevron and the Asphalt Institute. A testing program was devised to study the significance of differencs and to establish correlations which would allow adoption of these methods. This study is described below.

DESCRIPTION OF LABORATORY STUDY

The laboratory study involved the determination of mixture stability (S value and R value), resilient modulus and indirect tension testing after the prepared samples were compacted and subjected to various curing conditions as dictated by the Chevron and Asphalt Institute procedures. The main variables investigated were 1) the effect of the difference in lateral confinement provided by the Texas Hveem stabilometer from that provided by the apparatus used to measure R values in the Chevron and Asphalt Institute procedures, 2) the effect of gyratory and kneading compaction on stability and resilient modulus and 3) the effect of the different curing conditions employed by the Chevron and Asphalt Institute on stability and resilient modulus.

Table 1: Mixture Design Criteria

	Test Method		Use of Material				
			Base	Temporary Surface		Permanent Surface	
			Dense Graded	Dense Graded	Open Graded	Dense Graded	Open Graded
Chevron	Resistance Rt - value @73°F ± 5°F	Initial Cure (1)	70 min.	70 min.	NA	NA	NA
Chevron	Resistance Rt - value @73°F ± 5°F	Fully cured + Vacuum Saturation (2)	78 min.	78 min.	NA	NA	NA
Chevron	Stabilometer S-value @140°F ± 5°F	Fully Cured (2)	NA	NA	NA	30 min.	NA
Chevron	Cohesiometer C-value @ 73°F ± 5°F	Initial Cure (1)	NA	50 min.	NA	NA	NA
Chevron	Cohesiometer C-value @ 73°F ± 5°F	Fully cured + Vacuum Saturation (2)	NA	100 min.	NA	NA	NA
Chevron	Cohesiometer C-value @ 140°F ± 5°F	Fully Cured (2)	NA	NA	NA	100 min.	NA
Asphalt Institute	Resistance Rt - value @73°F ± 5°F	Early Cure (4)	70 min.	70 min.	NA	NA	NA
Asphalt Institute	Resistance Rt - value @73°F ± 5°F	Fully Soaked + Water Soaked (5)	78 min.	78 min.	NA	NA	NA
Asphalt Institute	Stabilometer S - value @ 140°F ± 5°F (5)		NA	NA	NA	30 min.	NA
Asphalt Institute	Cohesiometer C-value @73°F ± 5°F	Early Cure (4)	NA	50 min.	NA	NA	NA
Asphalt Institute	Cohesiometer C-value @73°F ± 5°F	Fully Soaked + Water Soaked	NA	100 min.	NA	NA	NA
Asphalt Institute	Cohesiometer C-value @ 140°F ± 5°F (5)		NA	NA	NA	100 min.	NA
Asphalt Institute	Moisture Pick-up Percent by Vacuum Soak Procedures		5.0 max.	NA	NA	NA	NA

(1) Cured in mold for a total of 24 hours at a temperature of 73 ± 5°F.

(2) Cured in mold for a total of 72 hours at a temperature of 73 ± 5°F plus 4 days vacuum desiccation at 10 - 20 MM Mercury.

(3) Vacuum saturation at 100 MM of Mercury.

(4) Cured in mold for a total of 24 hours at a temperature of 73 ± 5°F.

(5) Cured in mold for a total of 72 hours at a temperature of 73 ± 5°F plus vacuum saturation.

The Texas method utilizing the Hveem stabilometer for mixture design requires that the stabilometer cell have slightly different lateral confining characteristics than conventionally utilized. The effect of this variable was investigated in the laboratory study.

Texas uses gyratory compaction to fabricate samples for surface courses and for some base course design methods. The existing method for bituminous stabilization employs impact compaction. In order to make the testing methods for base course and surface course compatible it was desirable to investigate the suitability of gyratory compaction as compared to kneading compaction upon which the Chevron and Asphalt Institute criteria are based.

Chevron and Asphalt Institute mix design criteria are similar. However, different curing procedures are utilized, thus it was desirable to ascertain whether or not these procedures yielded compatible criteria.

Other important variables that were investigated include;

1. The relationship between the stability (S) and the resistance value (R),

2. The effect of curing condition on resilient modulus,

3. The effort of curing condition on indirect tension and

4. The relative value of stability and resilient modulus of emulsion stabilized mixtures compared to asphalt concrete mixtures.

Materials

Aggregates. Aggregates utilized in the laboratory study were selected from sources which are either presently utilized with asphalt as stabilized bases or are under consideration for use as an asphalt stabilized base (Table 2). The sand from Lamb County is typical of the wind blown sands found in West Texas. The sand from Kleberg County is a beach sand typical

Table 2: Properties of Aggregates Used in Laboratory Mix Design

Sieve Sizes	20 - SH87 Jefferson Co. Shoulders	20 - FM255 Newton Co. Pit #3	25 - FM3182 Wheeler Co. S. End Sweetwater Creek	16 - PR.22 Kleberg Co. Padre Is. Dune Sand	11 - Angelina Co. Daniels Sand	11 - Trinity Co. Faliche #3736	11 - Angelina Co. Gibson Sand	5 - EM168 Lamb Co. S. of Olton
	Percent Retained							
1 inch	---	---	---	---	---	---	---	---
3/5 inch	2.7	---	---	---	---	---	---	---
1/2 inch	3.7	---			---	---	---	---
3/8 inch	5.0	0	---	---	---	---	---	---
No. 4	12.5	0	---	---	.3	---	---	---
No. 8	19.3	.05	---	---	0.7	.2	.07	---
No. 10	20.4	.07	.06	---	0.7	.7	.08	---
No. 16	24.5	.2	.3	.07	.08	11.5	0.1	.01
No. 30	29.1	2.2	3.4	.2	1.8	56.2	0.8	0.1
No. 40	30.9	7.0	11.6	.4	6.1	67.0	11.7	.3
No. 50	33.0	27.4	44.3	.5	19.5	73.6	49.3	2.8
No. 60	37.1	41.6	59.4	.8	33.8	77.8	73.1	26.0
No. 80	63.7	69.7	67.9	26.7	48.6	83.2	91.6	73.3
No. 100	73.6	75.0	76.8	58.9	54.0	84.9	94.0	86.8
No. 200	88.6	84.7	96.1	98.2	71.4	88.0	97.1	97.2
Sand Equivalent	38.8	31.5	41.3	97.6	19.9	71.7	57.5	41.0
Fines Modulus	1.92	1.05	1.25	.597	0.77	2.26	1.44	.897
Plastic Index	0	0	0	0	0	0	0	0
Liquid Limit	22.5	18.3	20.3	24.8	22.0	13.2	23.8	21.0
Plastic Limit	NP	NP	NP	NP	NP	NP	NP	NP
Kc	1.95	—	—	—	—	—	—	—
Kf	0.92	1.1	—	0.7	—	0.95	—	—
Km	0.97	—	—	0.83	—	—	—	—

of those found along the Texas Gulf Coast. The other materials noted on Table 2 are river and wind blown sands from West Texas (Wheeler County) and East Texas (Jefferson, Newton, Angelina, and Trinity Counties).

All of the aggregates are subangular in shape except the Jefferson County material which is angular and the Lamb County sand which is subrounded. All of the sands are primarily quartz except the Jefferson County sand which is highly calcareous and the Wheeler County sand which is moderately calcareous.

Asphalt. The emulsion utilized in the study was a cationic slow setting emulsion (CSS-1) conforming to the specifications shown in Table 3.

Laboratory Test Sequence

The laboratory test sequence is outlined in Figures 1 through 4. As shown in Figure 1, test sequence I is the standard Chevron procedure (2) while test sequence II is the Asphalt Institute procedure (7). The Asphalt Institute procedure actually calls for determination of the resistance or R value immediately after the specimen is removed from vacuum saturation. Figure 3 shows that this was not the case in the laboratory investigation. Instead, the R value and S value were determined after drying the specimen to constant weight. This alteration in the testing sequence was necessary so that the final resilient moduli values could be obtained from the Asphalt Institute procedure at a location within the curing scheme similar to its location in the Chevron curing scheme, which is following vacuum dessication. Stabilometer testing of these samples prior to final resilient modulus evaluation would have been invalid due to the

Table 3. Properties of Emulsion

Property	
Emulsion	Cationic SS-1
Furol viscosity @28°C	35 to 65
Residue (by distillation), percent	64.0 to 68.0
Cement mixing, percentage broken	0.1
Base Asphalt	
Penetration @ 28°C, 100 g, 5s, mm/10	149 to 180
Solubility in CS_2, percent	-----
Ductility @ 28°C, 5 ch/min,cm	100+

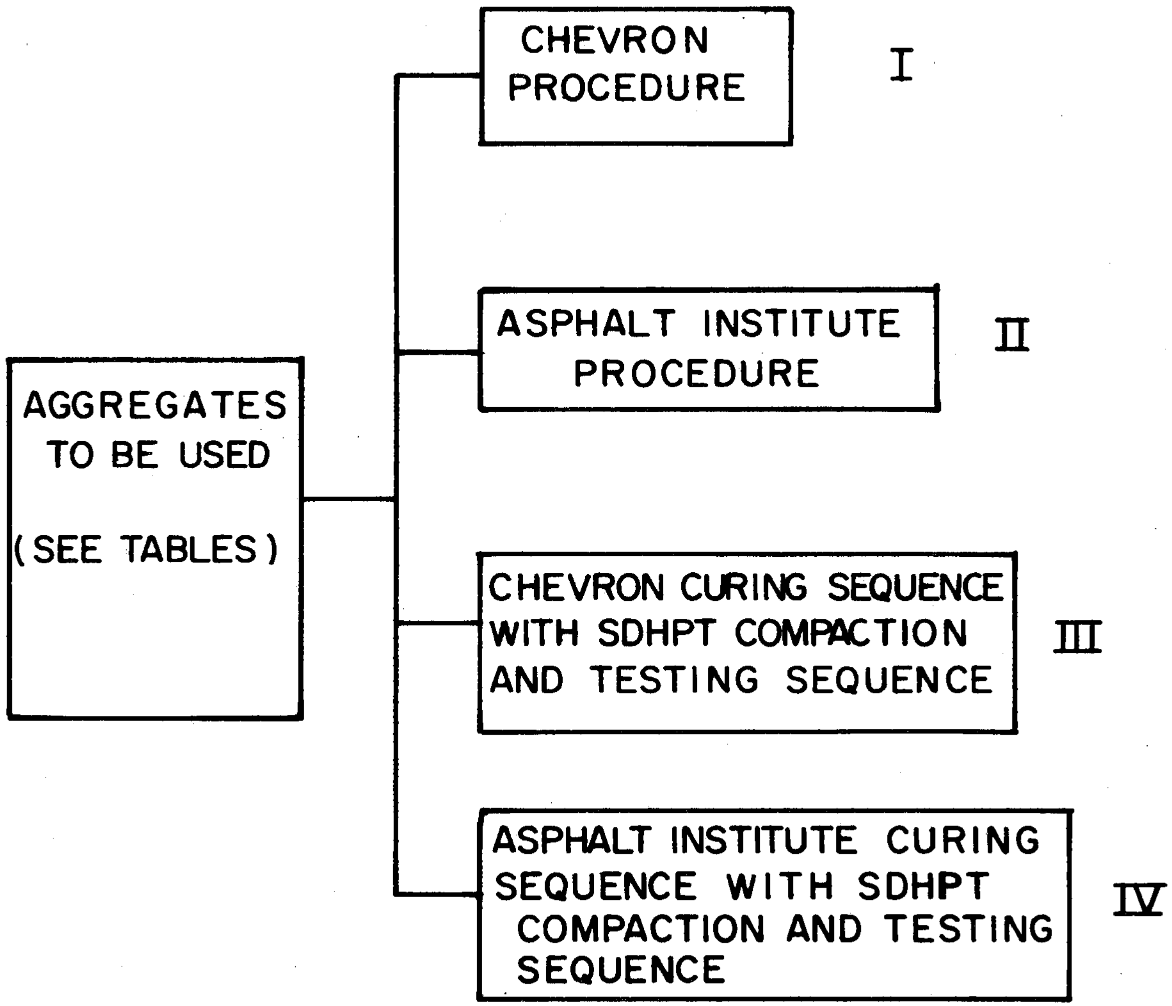


Figure 1. General Laboratory Test Program.

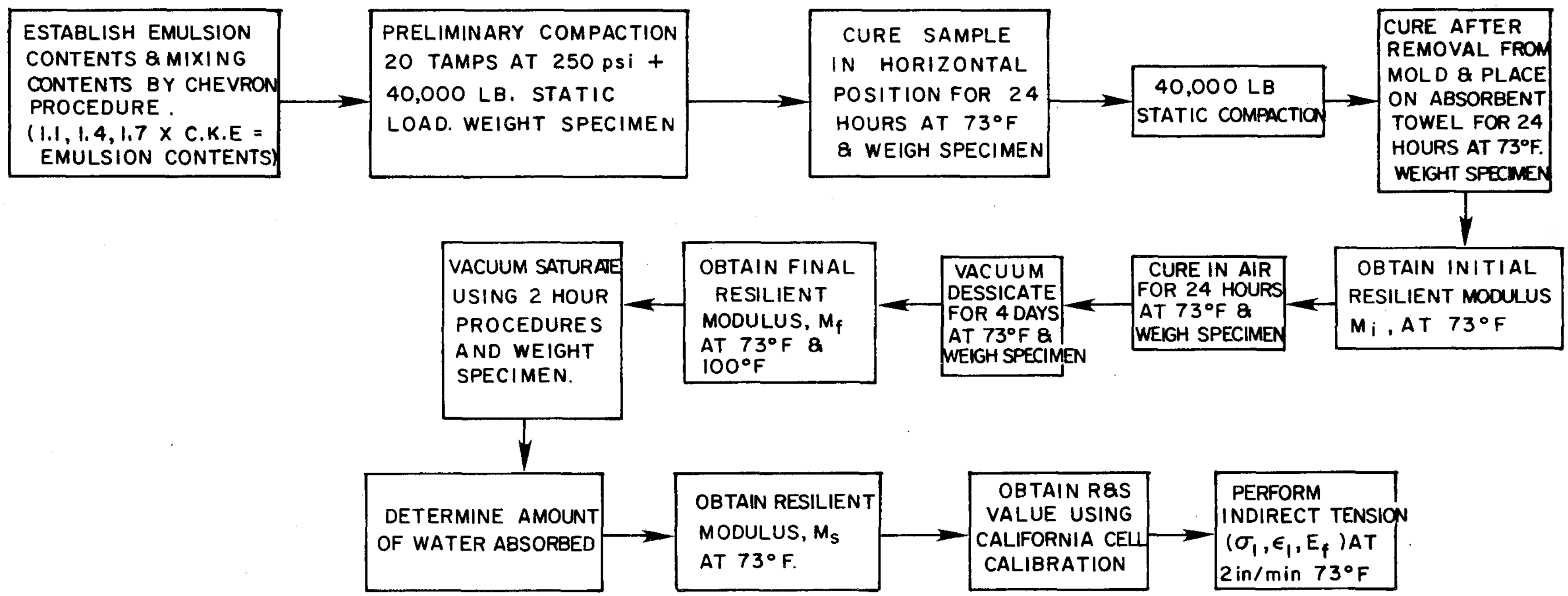
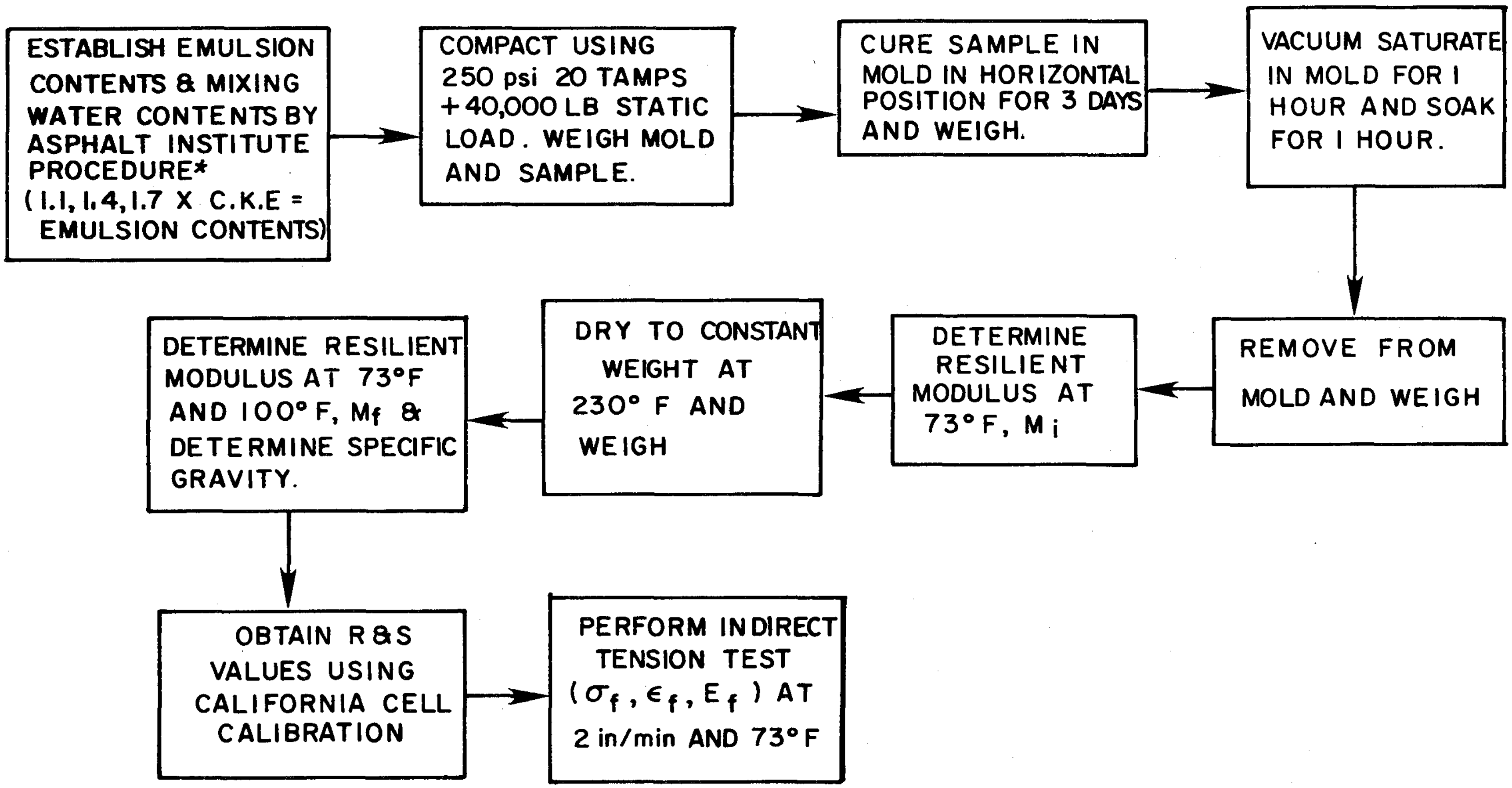


Figure 2. Chevron Test Sequence And Curing Scheme.



* USE SAME EMULSION AND MIXING WATER CONTROLS FOR ALL TESTS.

Figure 3. Asphalt Institute Test Sequence And Curing Scheme.

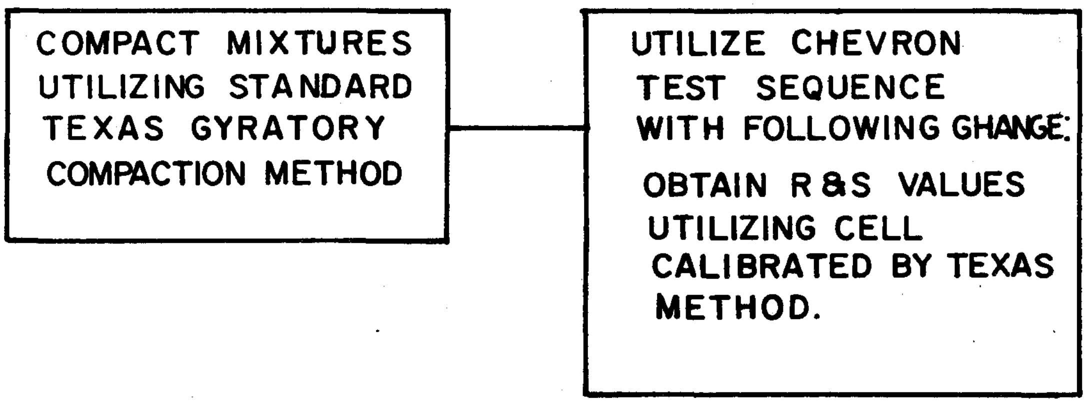


Figure 4a. Texas Compaction And Testing With Chevron Curing Sequence.

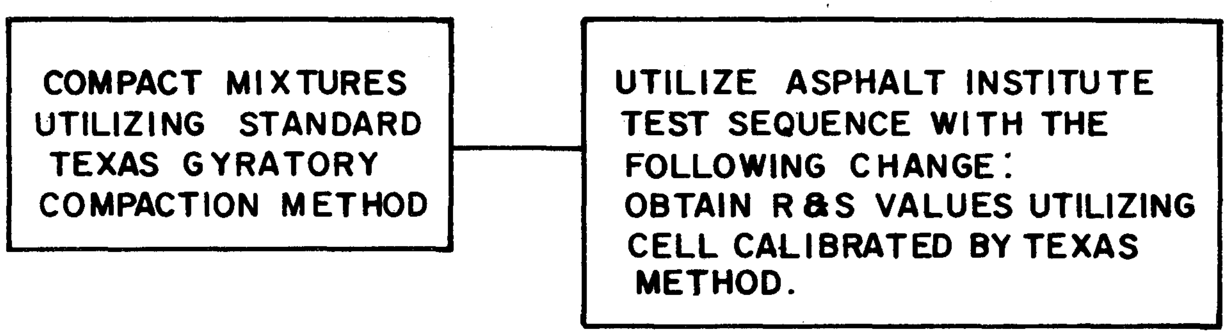


Figure 4b. Texas Compaction And Testing With Asphalt Institute Curing Sequence.

destructiveness of the stabilometer test. Therefore, in an effort to conserve samples this procedural alteration was made. Test sequences III and IV are standard Chevron and Asphalt Institute procedures except for Texas State Department of Highways and Public Transportation (SDHPT) compaction and Hveem cell lateral confinement modifications.

Figure 2 illustrates the Chevron mixture design test sequence (test sequence I). Data collection and analysis steps have been included where appropriate on this figure. Figure 3 depicts test sequence II on the Asphalt Institute method. Resilient moduli tests were added at points within the sequence most nearly approximating the location in the Chevron design sequence. The sequences shown in Figures 2 and 3 and as modified for Texas test methods (Figure 4) allow for the investigation of the variable discussed above.

LABORATORY RESULTS

Stability and Resistance Value

As discussed previously the Texas State Department of Highways and Public Transportation is one of several agencies which employs the gyratory compactor in lieu of the kneading type compactor used by the Asphalt Institute and Chevron. Also the stability tests(S test) is utilized in Texas for mixture stability determination but the resistance test(R test) is not used. Thus a correlation of S and R values obtained from the same design procedure was first attempted followed by an examination of the effect of substituting the Texas gyratory compactor for the kneading compactor.

Correlation coefficients determined by comparing resistance and stability values within each mix design procedure reveal that a correlation does exist. When S and R values were correlated after specimens were cured as prescribed in the Chevron curing procedure the linear correlation coefficient was 0.63. The same correlation after specimens underwent the Asphalt Institute curing procedure yielded a correlation coefficient of 0.84. The S vs. R linear correlation coefficients for the Chevron and Asphalt Institute procedures when the Texas gyratory compactor was substituted for the California kneading compactor were 0.86 and 0.79, respectively. Exponential models fitted to these data yielded a much improved correlation as is shown in Figures 5, 6, 7, and 8. These correlation coefficients improved from the values listed above to 0.70 for the Chevron curing scheme, 0.92 for the Asphalt Institute curing scheme, and to 0.94 and 0.88 respectively when the Texas gyratory compactor was substituted for kneading compaction in each scheme.

Although credible regression equations predicting R values on the basis of S values require more data, the possibility of such a relation

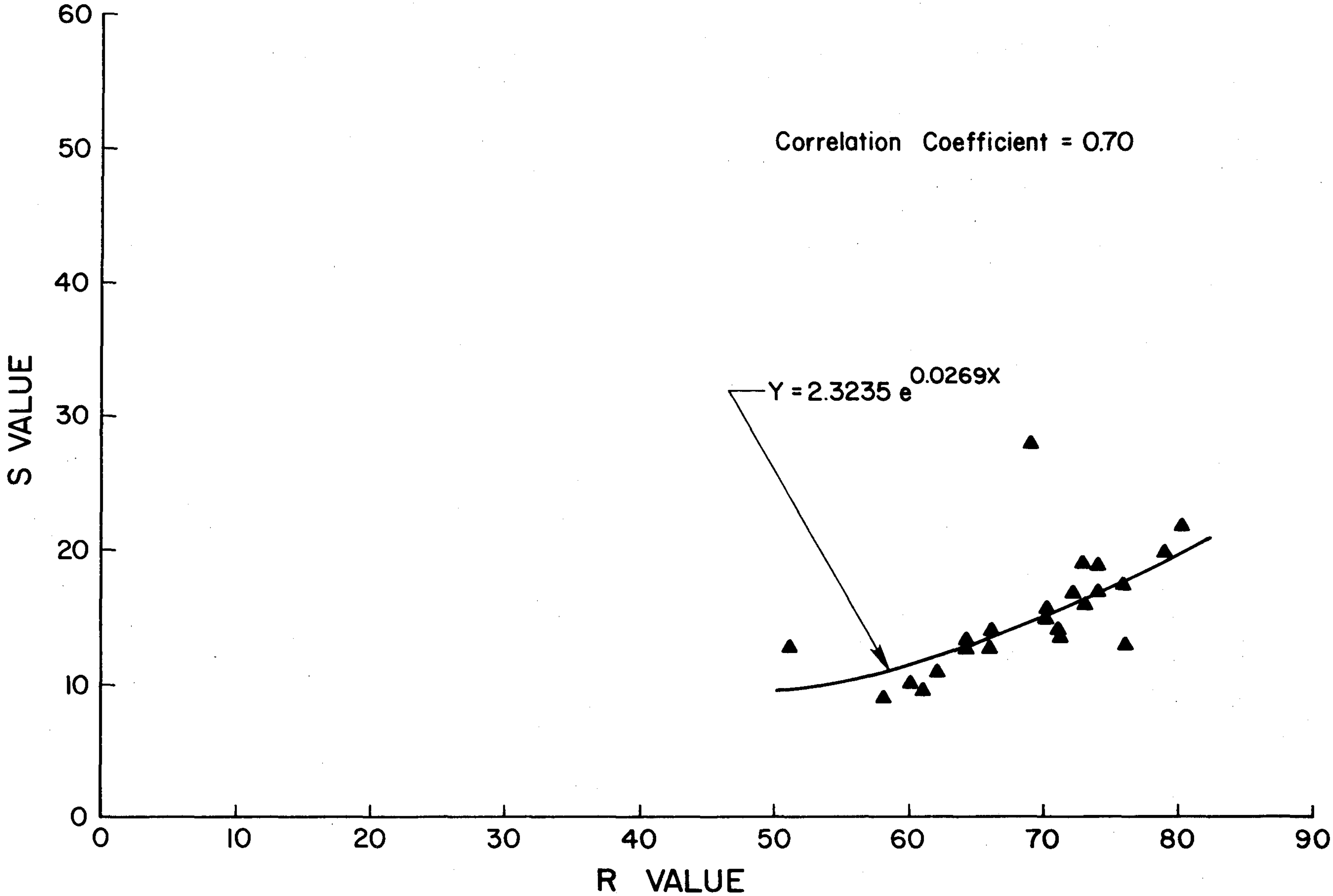


Figure 5. Comparison of R and S Values Obtained After the Chevron Curing Scheme.

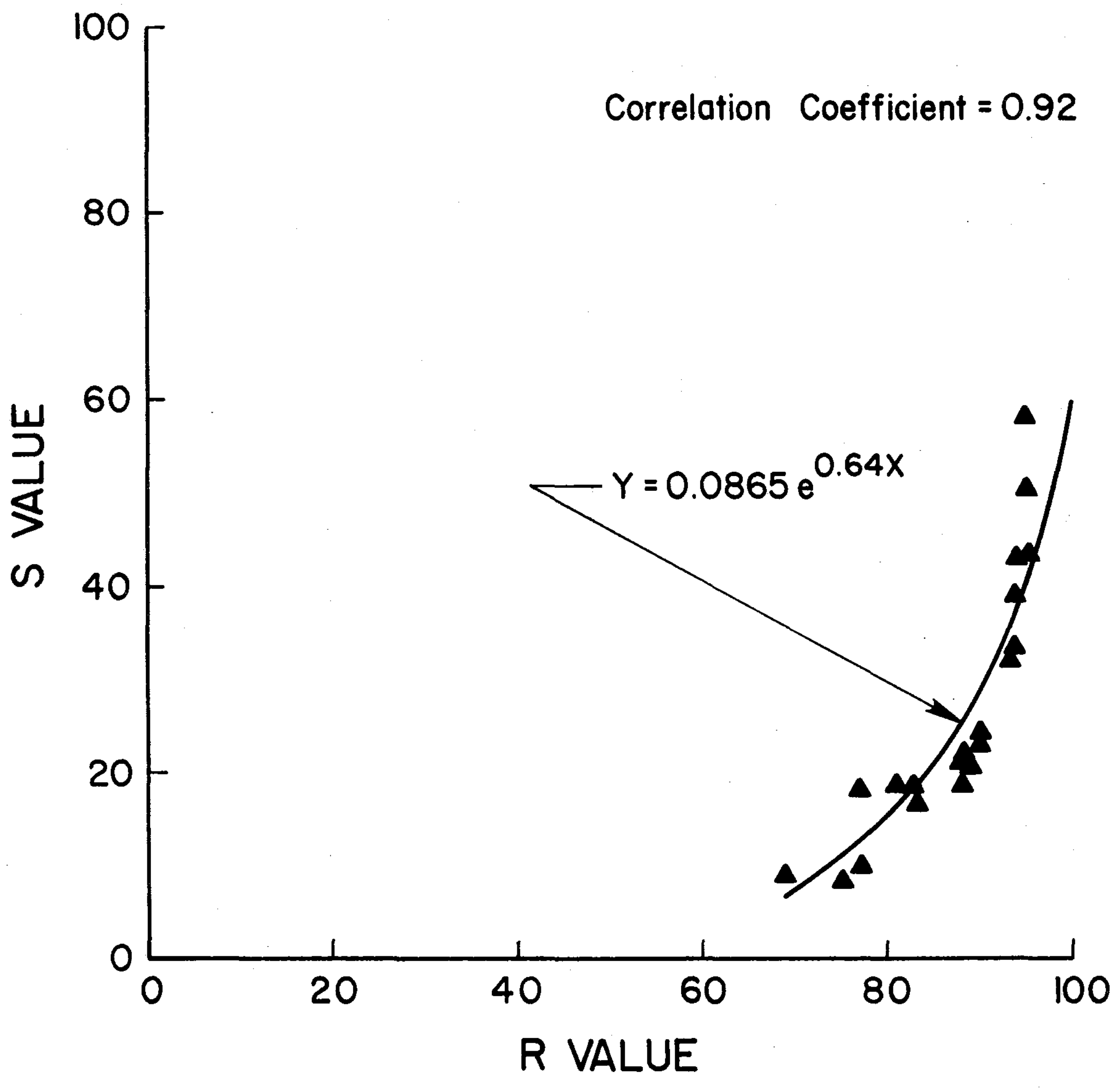


Figure 6. Comparison of R and S Values Obtained After the Asphalt Institute Curing Scheme.

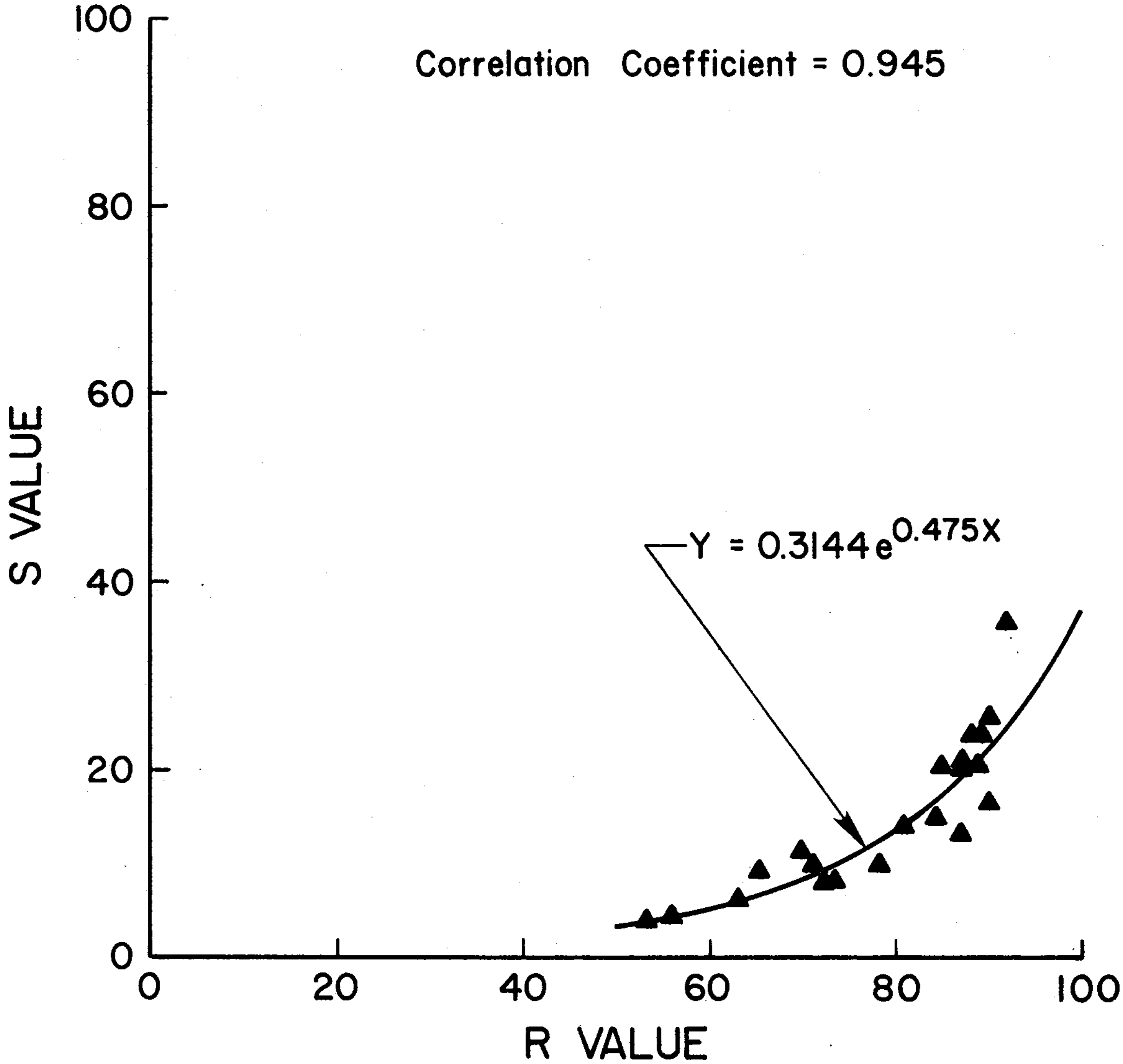


Figure 7. Comparison of R and S Values Obtained After the Chevron Curing Scheme with the Texas Gyratory Compactor Used in Lieu of the California Kneading Compactor.

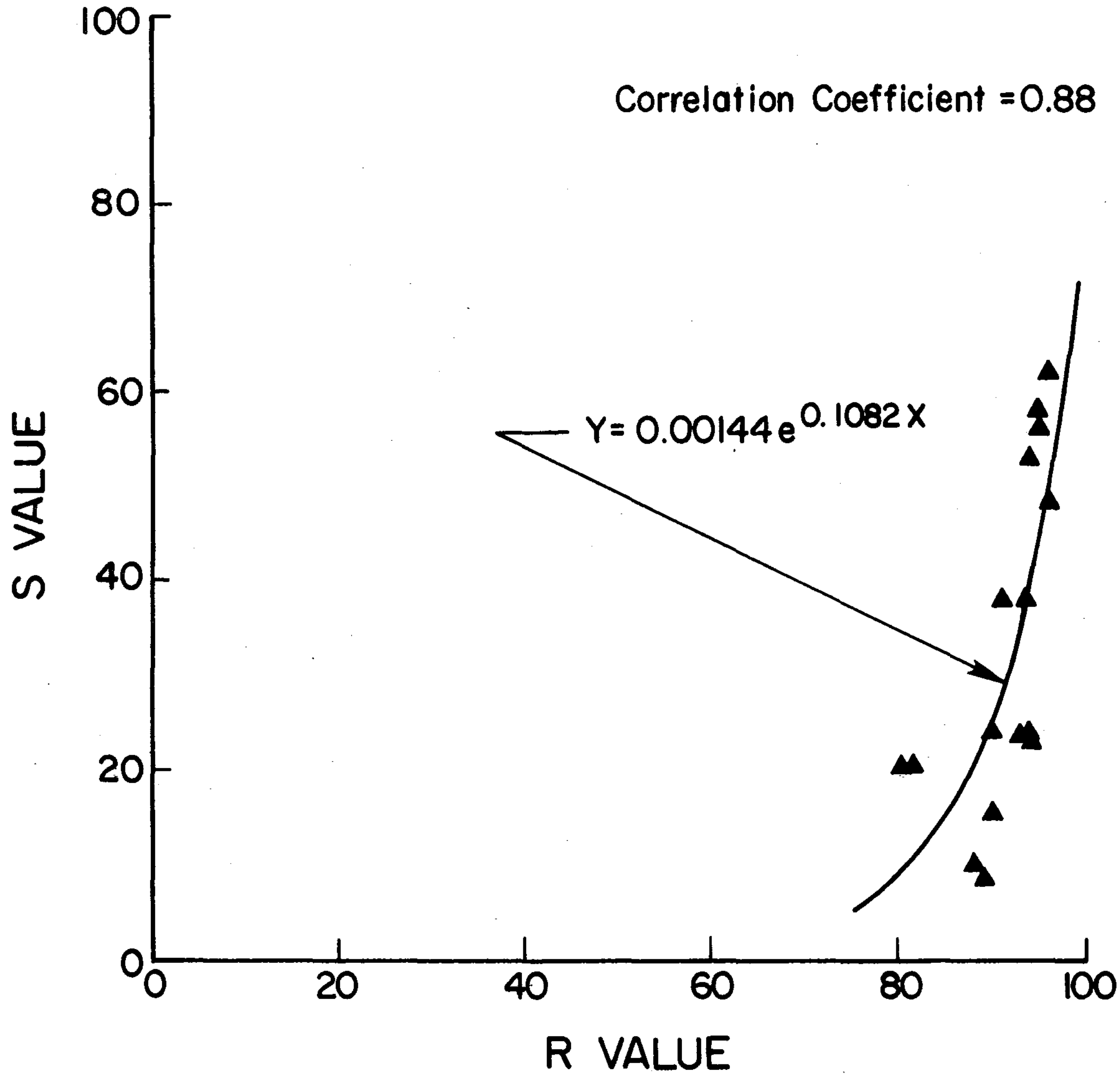


Figure 8. Comparison of S and R Values Obtained After The Asphalt Institute Curing Scheme With Texas Gyratron Compactor Used In Lieu Of The California Kneading Compactor.

and the resultant development of emulsified asphalt mix criteria on the basis of the S value is promising.

It must be noted here that the stabilometer values in the Asphalt Institute procedure are measured immediately after vacuum saturation and are not proceeded by dry back to constant weight as was done here. However, the vacuum saturation procedure should only lower the stabilometer values. One would expect a good correlation to prevail.

In order to more carefully investigate the effect of compaction technique on the S and R values of the Hveem test, R values obtained from schemes employing kneading compaction were compared directly with R values obtained from schemes where the gyratory compactor was used. Exactly the same comparison was made for S values.

Substitution of the Texas gyratory compactor for the California kneading compactor appears to be feasible. The resistance values (R values) obtained when gyratory compaction was used in lieu of kneading compaction after the Chevron curing scheme was followed are slightly conservative at low resistance values, Figure 9, but are approximately equivalent to R values obtained after kneading compaction where resistance approaches the maximum value. Largely the data in Figure 9 are below the minimum R values specified by Chevron. These low values may be due primarily to the vacuum saturation accomplished immediately before resistance testing. As these materials are highly moisture susceptible, one would expect the correlation to increase if the vacuum saturation step is omitted. This is substantiated by Figure 10 where the modified Asphalt Institute curing scheme, yields a good correlation between the two compaction procedures. On the basis of range of R values in Figures 9 and 10, the R value criteria

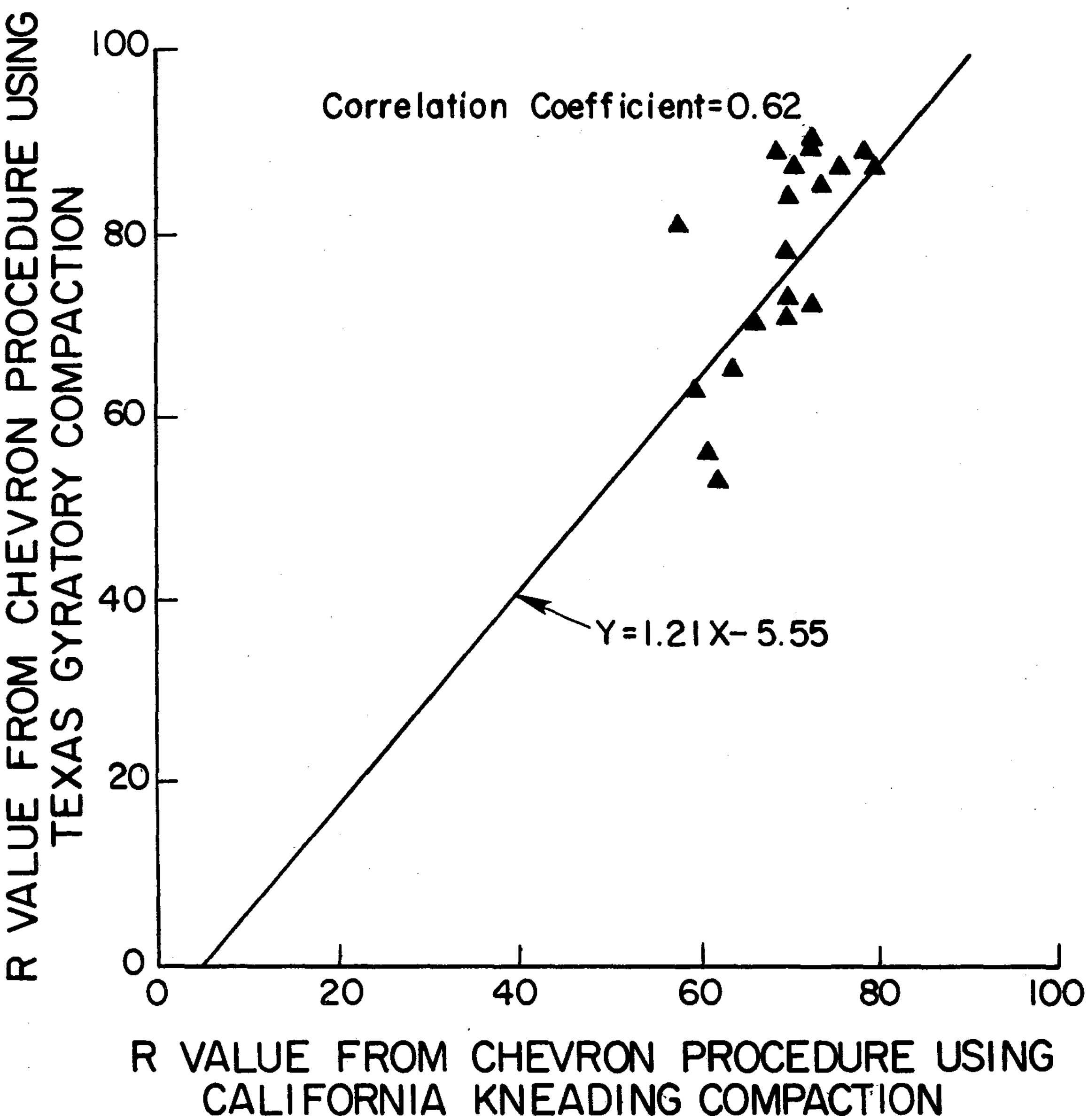


Figure 9 Effect of Compaction Technique On The R Value.

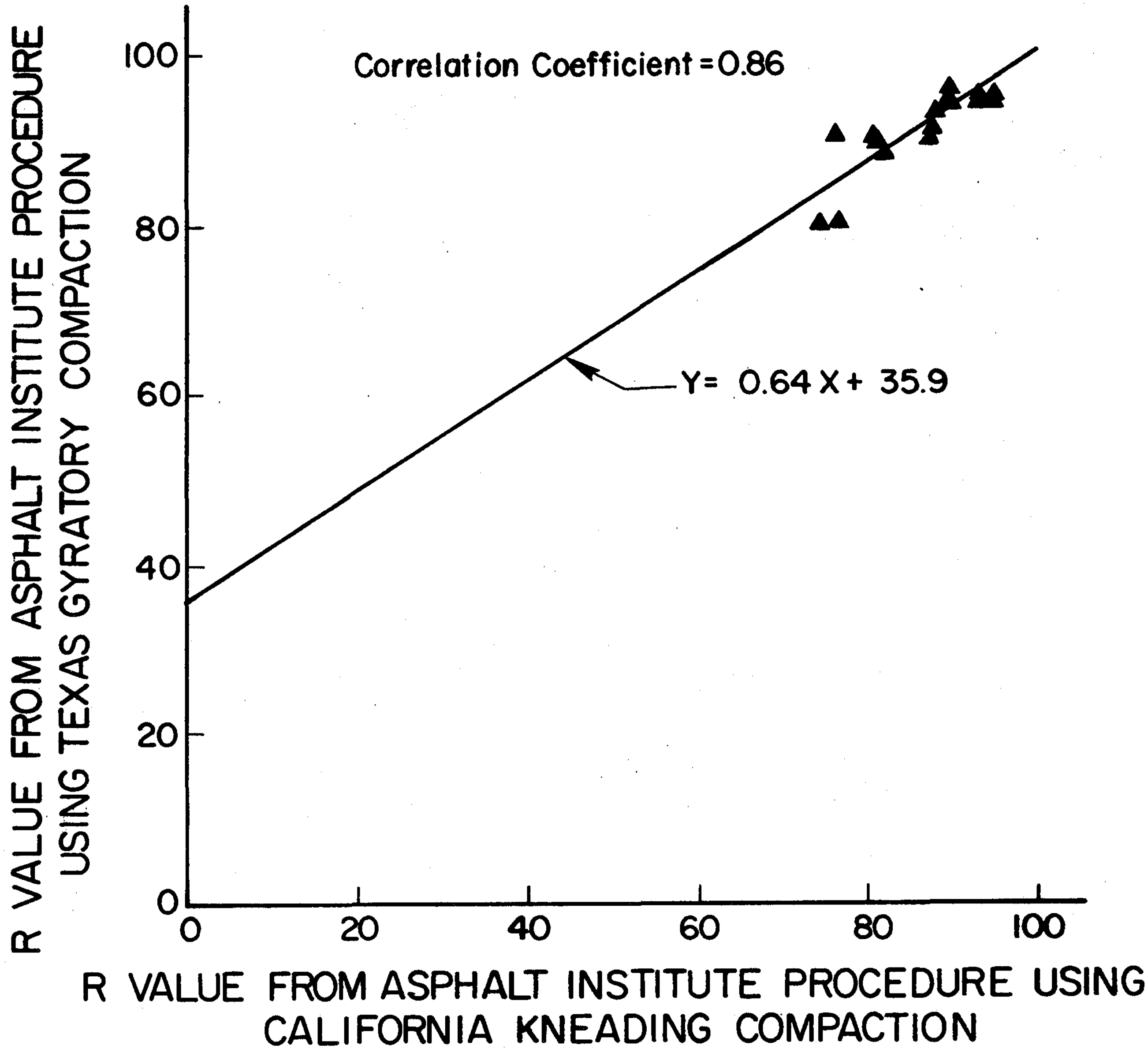


Figure 10. Effect Of Compaction Technique On The R Value.

specified by the Asphalt Institute (3) appears applicable when Texas gyratory compaction is substituted for California kneading compaction.

Although the correlation developed in Figures 9 and 10 definitely show promise in substituting the gyratory compactor for the kneading compactor, a wider range of R values are obviously required to establish a valid regression analysis.

Figures 11 and 12 show the effect of altering the type of compaction on the stability or S value. Figure 12 shows the correlation between S values obtained after kneading compaction and S values obtained after gyratory compaction. Here specimen were cured as prescribed by the modified Asphalt Institute sequence shown in Figure 3. However, the correlation, Figure 11, is poor when the same comparison is made following the Chevron curing procedure.

Gyratory compaction studies by George (13) reveal that moisture contents 2 to 3 percent above optimum and reasonable mixing time are required to yield uniform moisture distribution. Since moisture contents dictated by the Asphalt Institute and Chevron procedures are most probably lower than this, the correlations between gyratory and kneading compaction techniques could be improved by using the higher mixing moisture contents for the specimens compacted by gyratory means.

Once again, the vacuum saturation of the emulsified asphalt mixed after the Chevron curing scheme affects the correlation. Previous research (22) indicates that the vacuum saturation procedure is a severe test. With these data it is impossible to identify the effect of vacuum saturation on these tests other than to note its effect of scattering the data and possibly preventing an acceptable correlation.

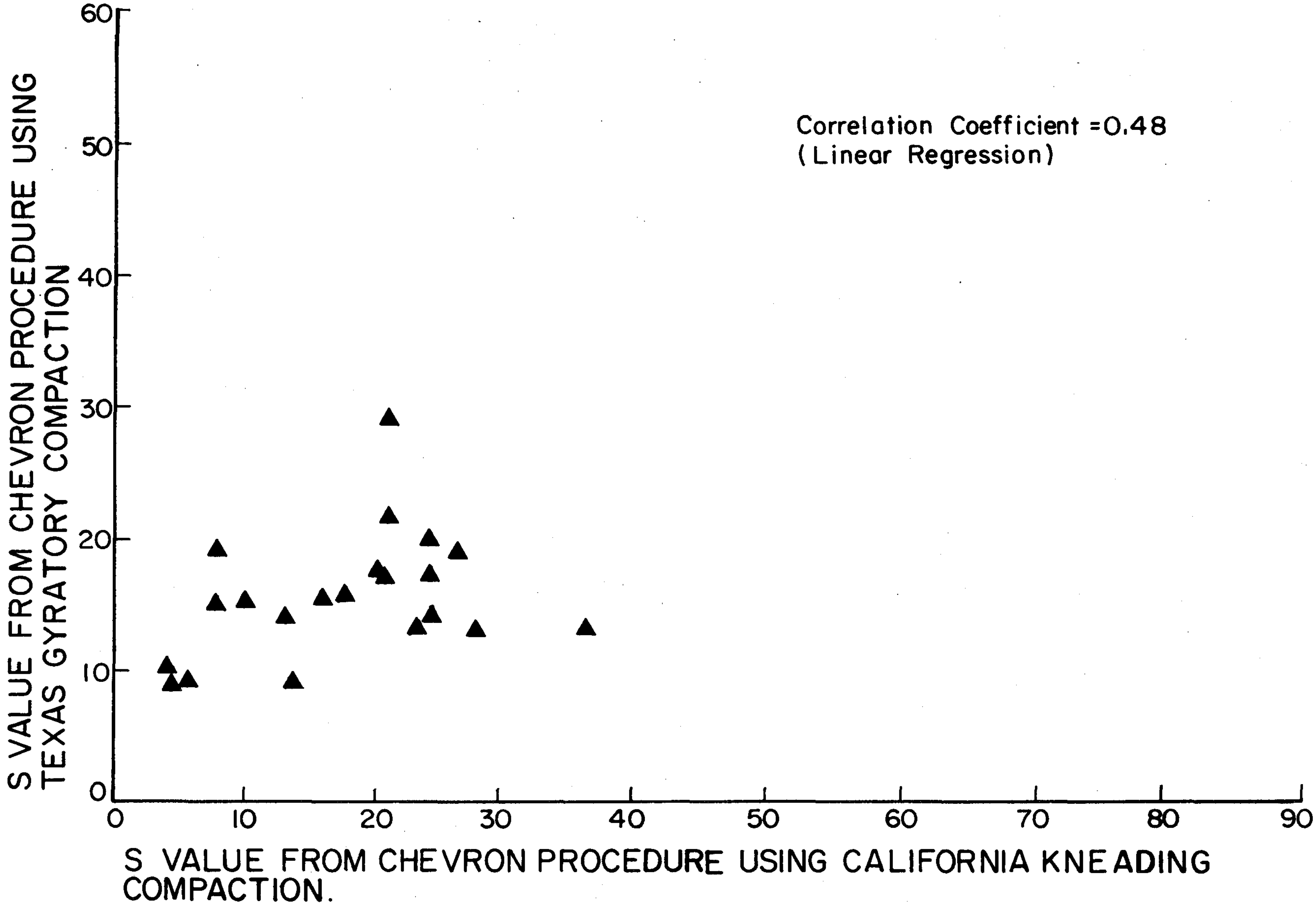


Figure 11. Effect Of Compaction Technique On S Value.

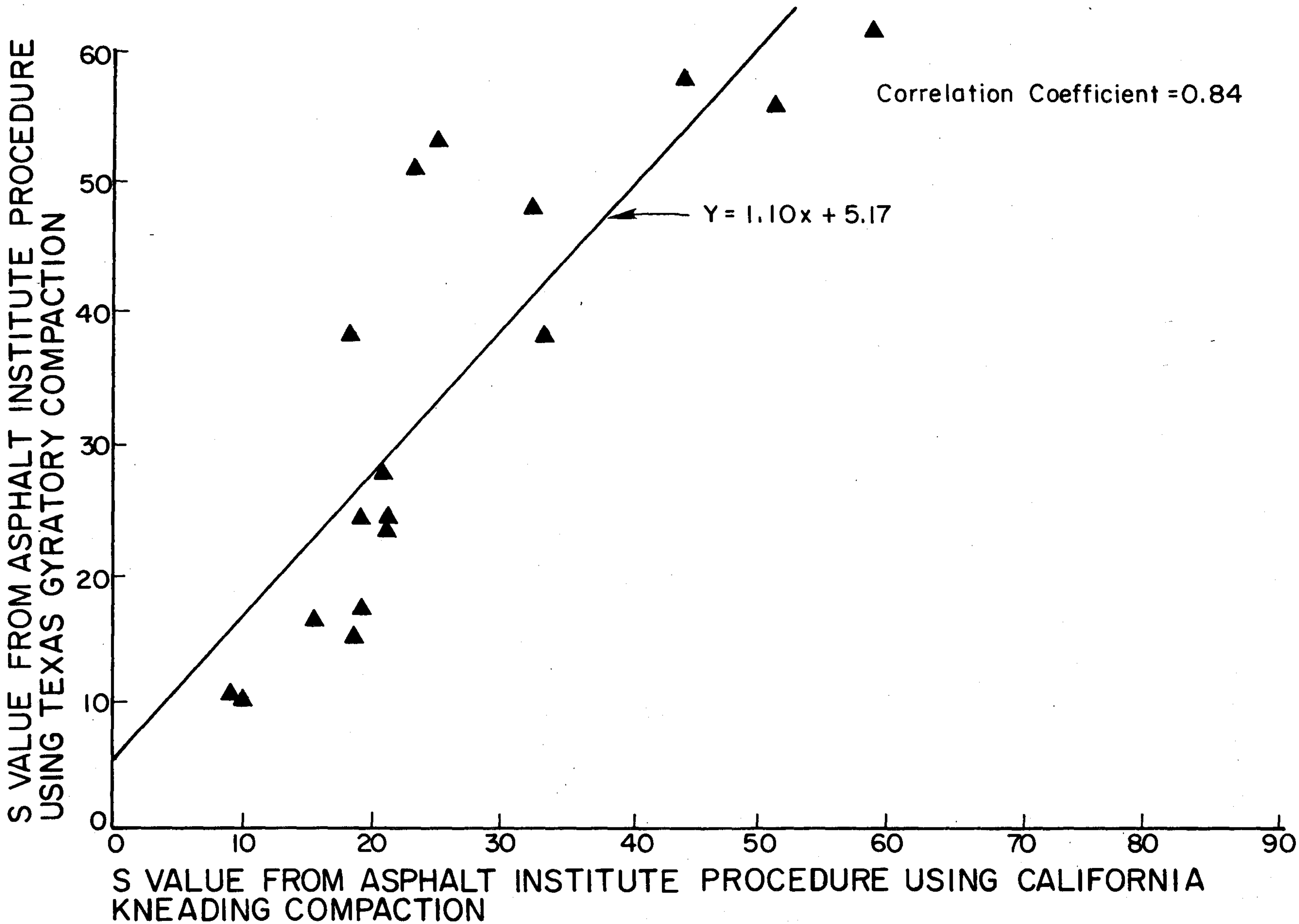


Figure 12. Effect Of Compaction Technique Of S Values.

Figure 13 and 14 indicate little promise of interchanging either S values or R values between Chevron and Asphalt Institute schemes. Here again, the vacuum saturation procedure followed at the end of the Chevron scheme coupled with the differences in curing between the two schemes appears to be the cause of data scatter.

It should be noted that the above discussion is concerned with the prediction of S or R values utilizing different compaction and curing techniques. However, reference to Table 1 indicates that the selection of the emulsion content is based on the factor R_t for base course stabilization. R_t is obtained by combining the results of stability tests and cohesiometer tests according to the following equation:

$$R_t = R + 0.05C$$

where;

R_t = Resistance (total)

R = Resistance value

C = Cohesiometer value

Cohesiometer testing was not included in this study as recent literature has indicated that criteria based on R value can be predicted from R_t (22).

If resistance, R_t, can be calculated without determining the cohesiometer value, the R value can be compared directly to design criteria, thus saving laboratory time and money. Figure 15 shows the correlation for a linear regression between R_t and R value. The dotted line represents the regression line developed at the Air Force Academy on 24 different mixes while the solid line represents a linear regression performed at Texas A&M on test results supplied by Chevron on 315 different mixes (23). Although the regression lines are different, there is enough similarity to recognize that R_t can be predicted from R. Thus when cohesiometer equipment is not available such a correlation appears useful.

Table 4. Suitability of Mixtures

Aggregate	Test	Chevron Mixture Design Criteria — Material Use: Base, Densely Graded	Temporary Surface, Densely Graded	Permanent Surface, Densely Graded	Average Test Values
Jefferson County	Rt (1)				86
	S (2)				28
	ΔW(3)	Marginal	Marginal		5.8
Newton County	Rt				89
	S				22
	ΔW	Marginal	Marginal		7
Wheeler County	Rt				78
	S				14
	ΔW				13
Padre Island	Rt				68
	S				13
	ΔW				No Data
Angelina County	Rt				81
	S				17
	ΔW	Marginal	Marginal		6
Trinity County	Rt				80
	S				20
	ΔW	Marginal	Marginal		6
Gibson County	Rt				78
	S				16
	ΔW				16
Lamb County	Rt				61
	S				10
	ΔW				15

(1) All Rt values represent full cure (72 hours in mold @ 73 ± 5°F) plus vacuum saturation. R_t values obtained from R values and Figure 15.

(2) All S values represent full cure (72 hours in mold @ 73 ± 5°F) plus vacuum saturation. S tests were run at 140 5°F.

(3) Moisture pick up in percent on vacuum soak procedure. Applicable to Asphalt Institute procedure only.

Legend: Meets criteria: Fails to Meet Criteria Not Applicable

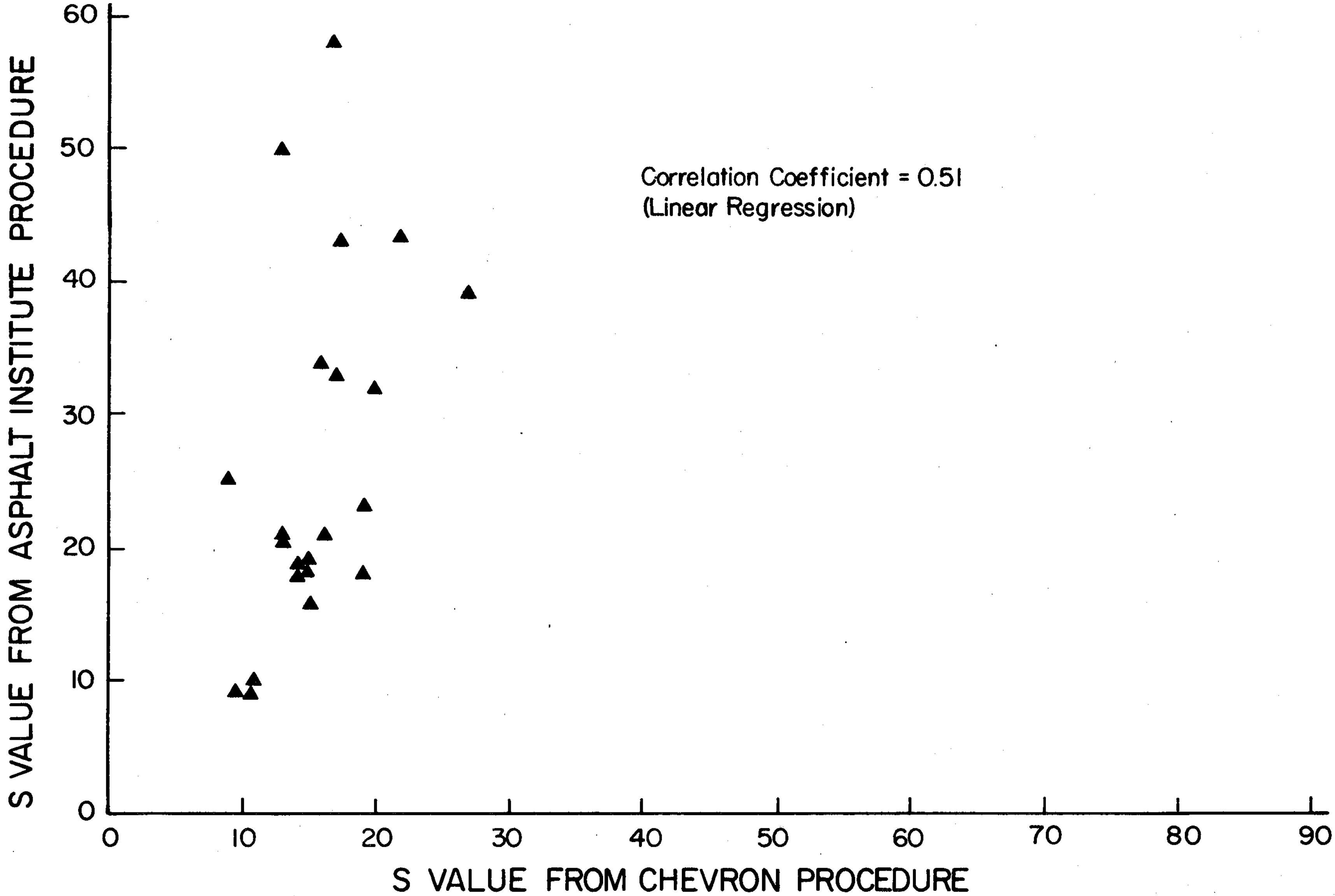


Figure 13. Comparison Of S Values Obtained From Chevron And Asphalt Institute Procedures.

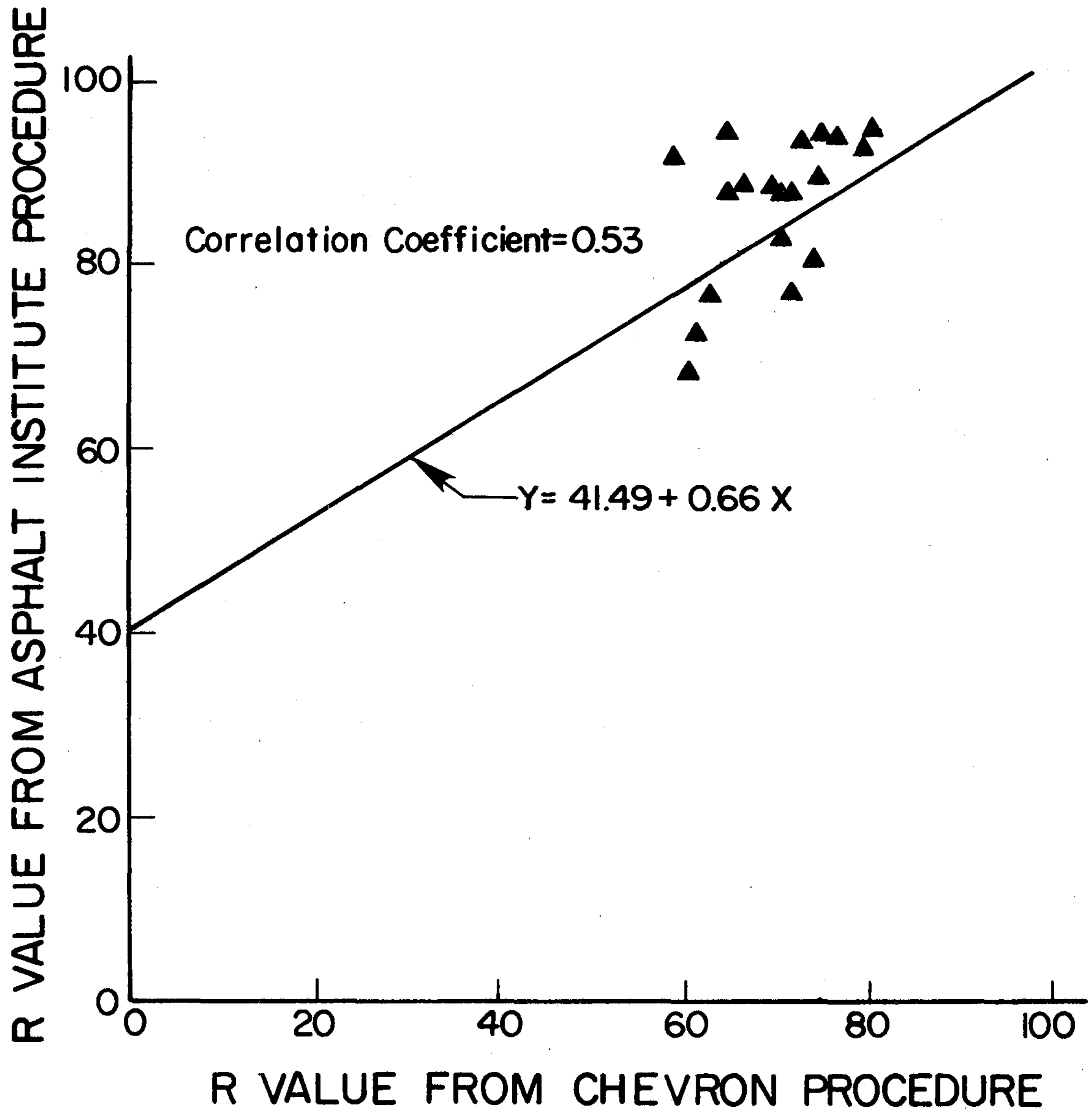


Figure 14 Comparison Of R Values Obtained From Chevron And Asphalt Institute Procedures.

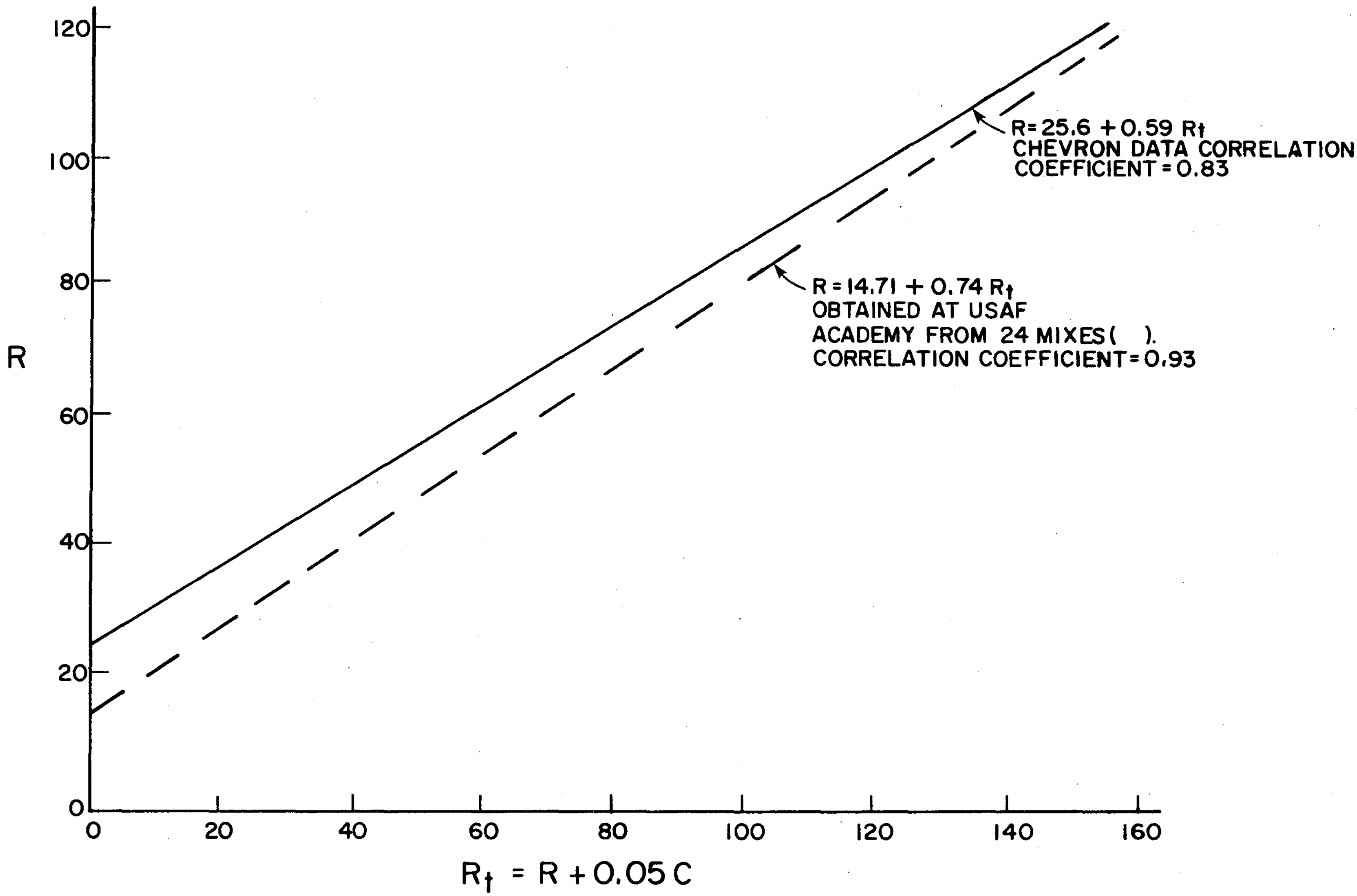


Figure 15. Relationship Between R And R_t, Linear Regression.

Resilient Modulus

The strength of emulsified asphalt mixes at different curing conditions is measured in the Chevron procedure by running an initial resilient modulus on the compacted specimen (M_i) after a total of two days air cure. The final modulus (M_f) is run at two temperatures, 73 and 100°F after one day of additional air curing plus 4 days of curing at 73°F with vacuum desiccation. These data may be used in conjunction with the specimen density, volume percent of asphalt, and volume percent of air in determining the structural section thickness requirements (2, 5, 24). The rate at which emulsified asphalt mixes cure or develop tensile strength is important. Several factors including aggregate gradation, type and amount of emulsion, type and amount of additive, construction, and climatic condition must be assessed by the engineer in determining the rate of tensile strength development (24).

The major factors influencing the modulus of the treated layer are temperature and, in the case of emulsified asphalt mixes, the early cure condition. The diametral M_R is employed in the Chevron procedure to measure the effect of these variables on the strength of a treated mix. The two day air cure represents the initial cure condition of the emulsified asphalt mix in the field shortly after construction. The air cure plus vacuum desiccation treatment represents conditions required to reach the final strength attained by the emulsified asphalt mix in the field. The magnitude of the final M_R in the field and the time required for an emulsified asphalt mix to attain this value are critical in determining pavement design thickness.

In the Chevron procedure, Figure 2, one additional modulus reading, (M_s) was measured after the specimen was vacuum saturated. In the Asphalt

Institute procedure only two resilient moduli were measured. The first, M_i, was measured after cure and vacuum saturation in the mold. The second, M_f, was measured after drying to a constant weight.

To determine whether or not there is a correlation between the resilient moduli measured under the respective test procedures, the initial (M_i) and final (M_f) values were compared (Figure 16, 17 and 18). In addition, the M_s value obtained after vacuum saturation in the Chevron procedure was compared with M_i of the Asphalt Institute procedure. The effect of substitution of gyratory compaction for California kneading compaction on the respective M_R values was also investigated and is presented in Figures 19 and 20.

The correlation coefficients were very low for each comparison explained above. Therefore, on the basis of these data it would be invalid to use the Chevron pavement thickness design procedures based on M_R values obtained from the Asphalt Institute's test procedure. Furthermore, the substitution of the Texas gyratory compactor for the California kneading compactor minimizes the reproducibility of M_R data.

The M_i data show that the Asphalt Institute's curing scheme does not allow enough cure for sufficient stiffness development. Figure 16 shows that the M_i values obtained from the Asphalt Institute procedure are far below (approximately one order of magnitude below) those M_i values obtained from the Chevron procedure.

The locations in the test sequences of the final resilient modulus values are shown in Figure 2 and 3. These M_f values do not correlate when compared to test procedures at either the 73°F test temperature or the 100°F test temperature, Figures 17 and 18. However, this time there is no obvious effect of curing procedure. No trend exists which would

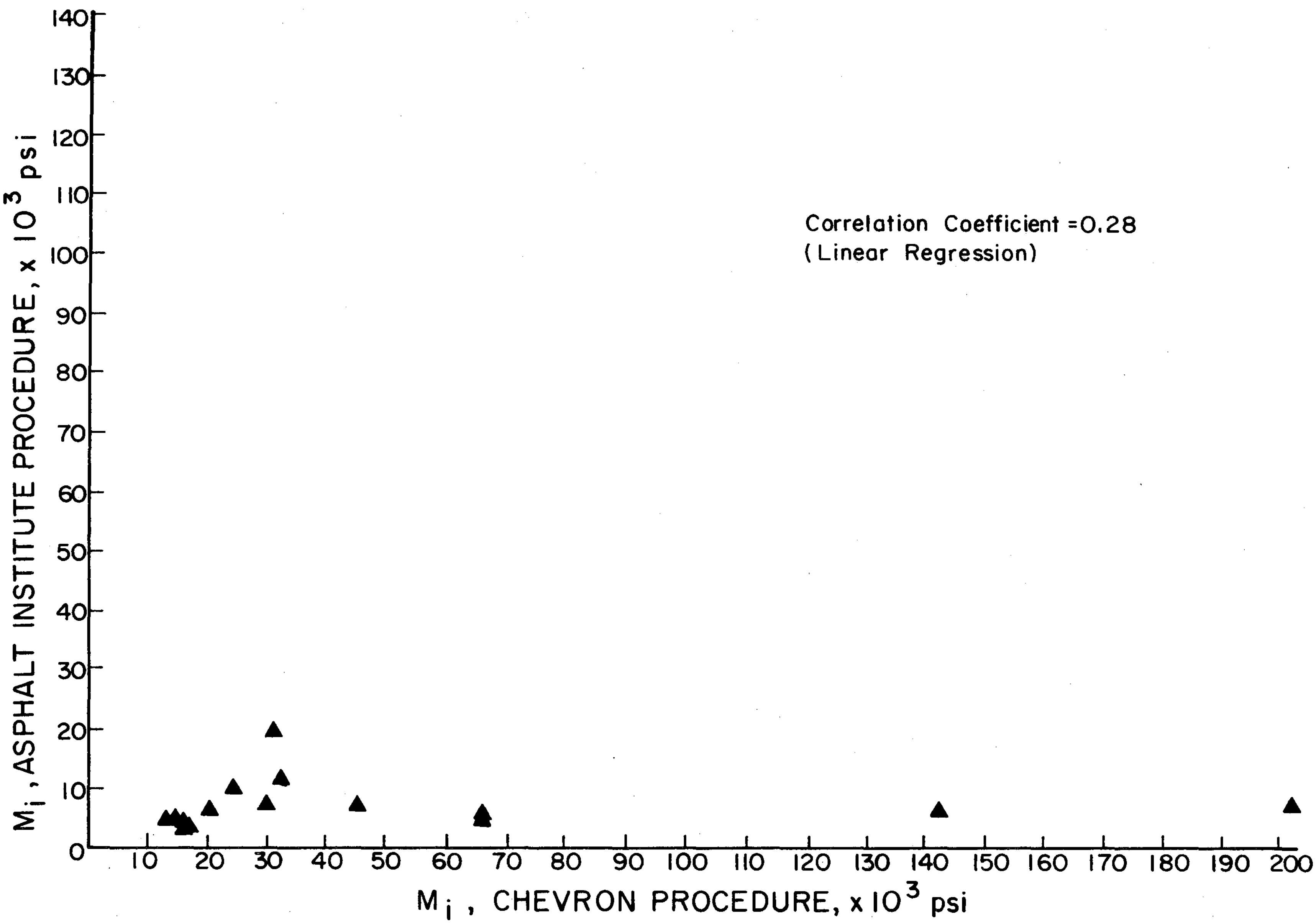


Figure 16. Comparison Of Initial Resilient Modulus Values Obtained From The Chevron And Asphalt Institute Procedures.

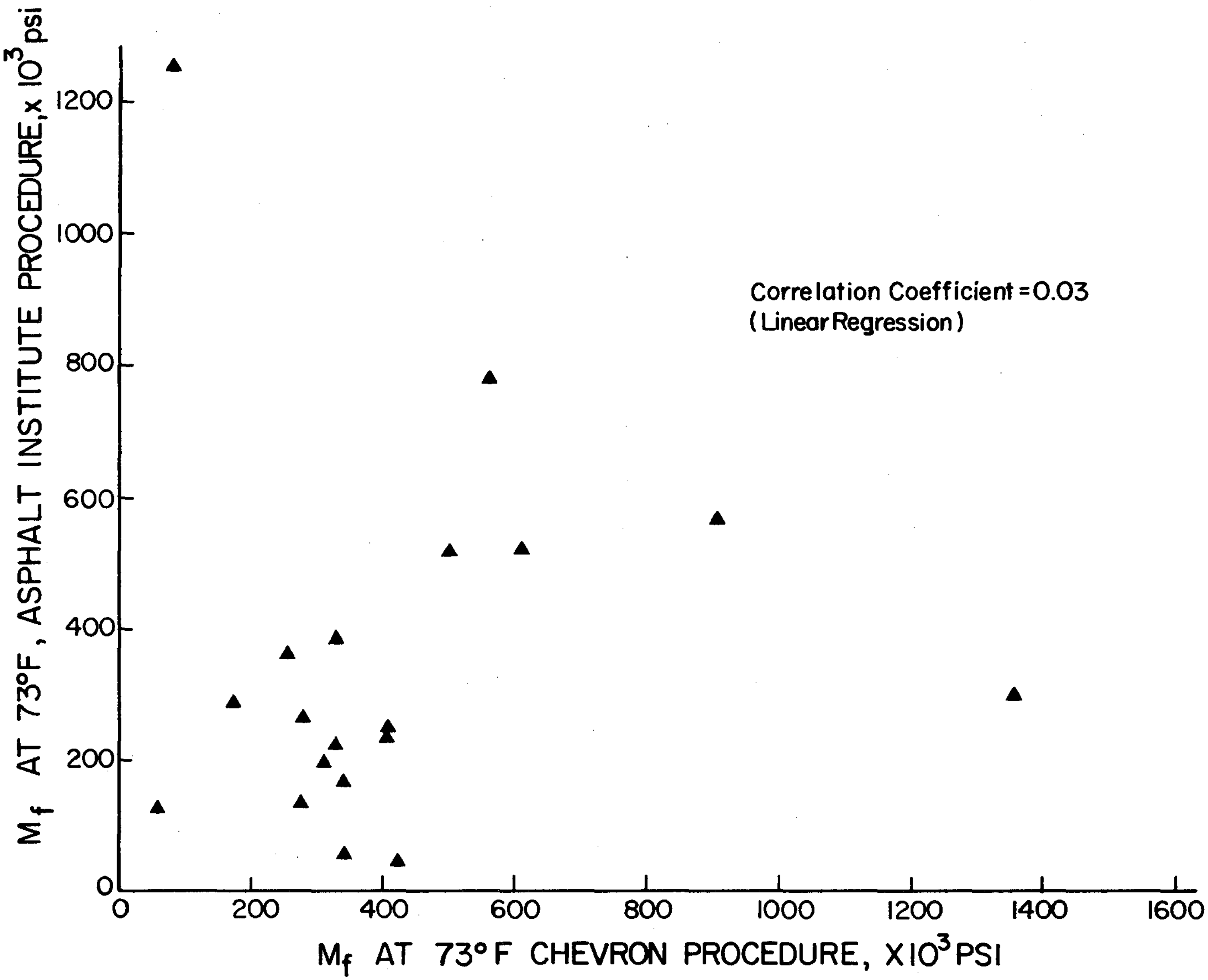


Figure 17. Comparison Of Final Resilient Modulus Values Obtained From The Chevron And Asphalt Instititute Procedures.

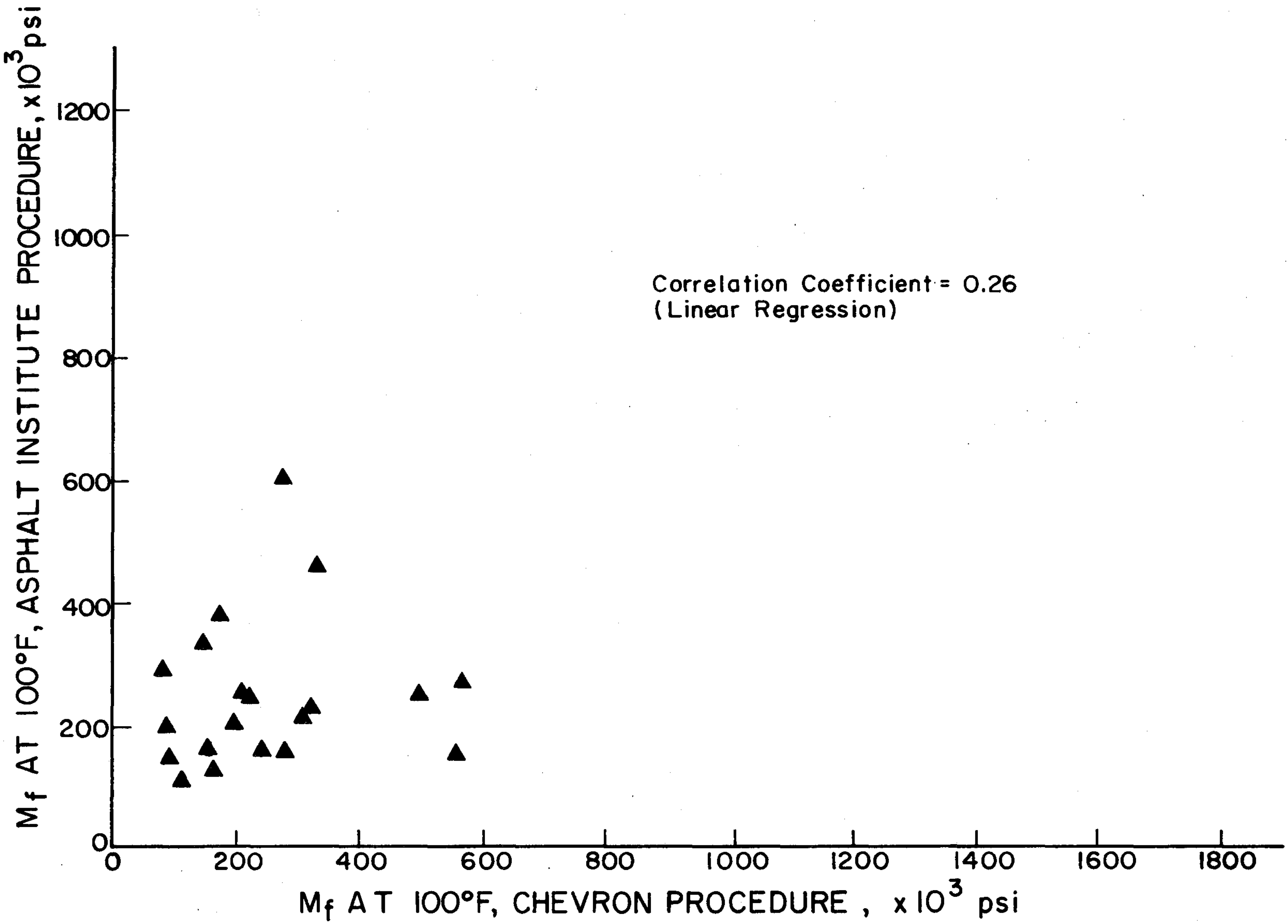


Figure 18. Comparison Of Final Resilient Modulus Values Obtained From The Chevron And Asphalt Institute Procedure.

indicate either more or less cure occurring in a given procedure. In fact, the mean M_f values for both 73°F and 100°F testing obtained from the Chevron procedure compare favorably with those obtained from the Asphalt Institute procedure.

On the basis of these results, it seems that resilient moduli are either 1) not reproducible, 2) are highly sensitive to the slightest variation in environmental conditions occurring during the test, 3) are highly sensitive to the variation in the properties of the aggregates intensifying the effects of the other variables, or 4) maybe all three statements apply. Let's briefly consider the above hypotheses.

A recent reproduceability analysis (25) of the resilient modulus test showed excellent reproduceability characteristics of the test under constant environmental and operator conditions. The study also revealed, as suspected, that the test is extremely sensitive to any variation in the testing environment. Therefore, when any single variable in the resilient modulus test is altered, as was the case in the above correlations, the test becomes all the more sensitive to random error, environmental variation or material property variation. This sensitivity may prevent a good regression correlation yet the magnitudes of the resilient moduli being compared may be within a reasonable range of each other as far as meeting design criteria is concerned. The data were again reviewed with this in mind.

Once again the vastly different curing sequences between the Asphalt Institute procedure and Chevron procedure rejects even a broad relation between resilient moduli magnitude and criteria. However, the important relationship is that between gyratory compaction and kneading compaction within the Chevron test procedure as we try to determine if substitution of gyratory compaction for kneading compaction in the Chevron procedure is valid. Figures 19 and 20 show that the gyratory compaction yields significantly lower resilient moduli for M_i and M_f. In fact, the magnitudes are so different that use of the Chevron criteria with substitution of gyratory compaction is invalid.

Indirect Tension

The indirect tension test or splitting tensile test involves loading a 4-inch diameter by 2-inch height specimen in diametral compression. The specimen are failed at a uniform stress rate of 2.0 inches per minute and a temperature of 73°F. Horizontal deformation is measured by two cantilever strain gage transducers, and deflections of these transducers as well as the applied load are recorded. The modulus of elasticity of the specimen is then defined as the ratio of horizontal stress normal to the axis of loading and the strain across the specimen.

Figure 22 illustrates the effect of vacuum saturation on the modulus of elasticity of the specimen cured under the Chevron procedure and then vacuum saturated. Although the specimens cured under the Asphalt Institute procedure were subjected to vacuum saturation, this saturation occurred while the sample remained in the mold more. The vacuum saturation procedure used after the Chevron cure sequence allowed the specimen to absorb water while under a vacuum of 2 psi. This is an extremely severe test and maybe is too detrimental to the specimen as is reflected in the extremely low elastic moduli values shown in Figure 21.

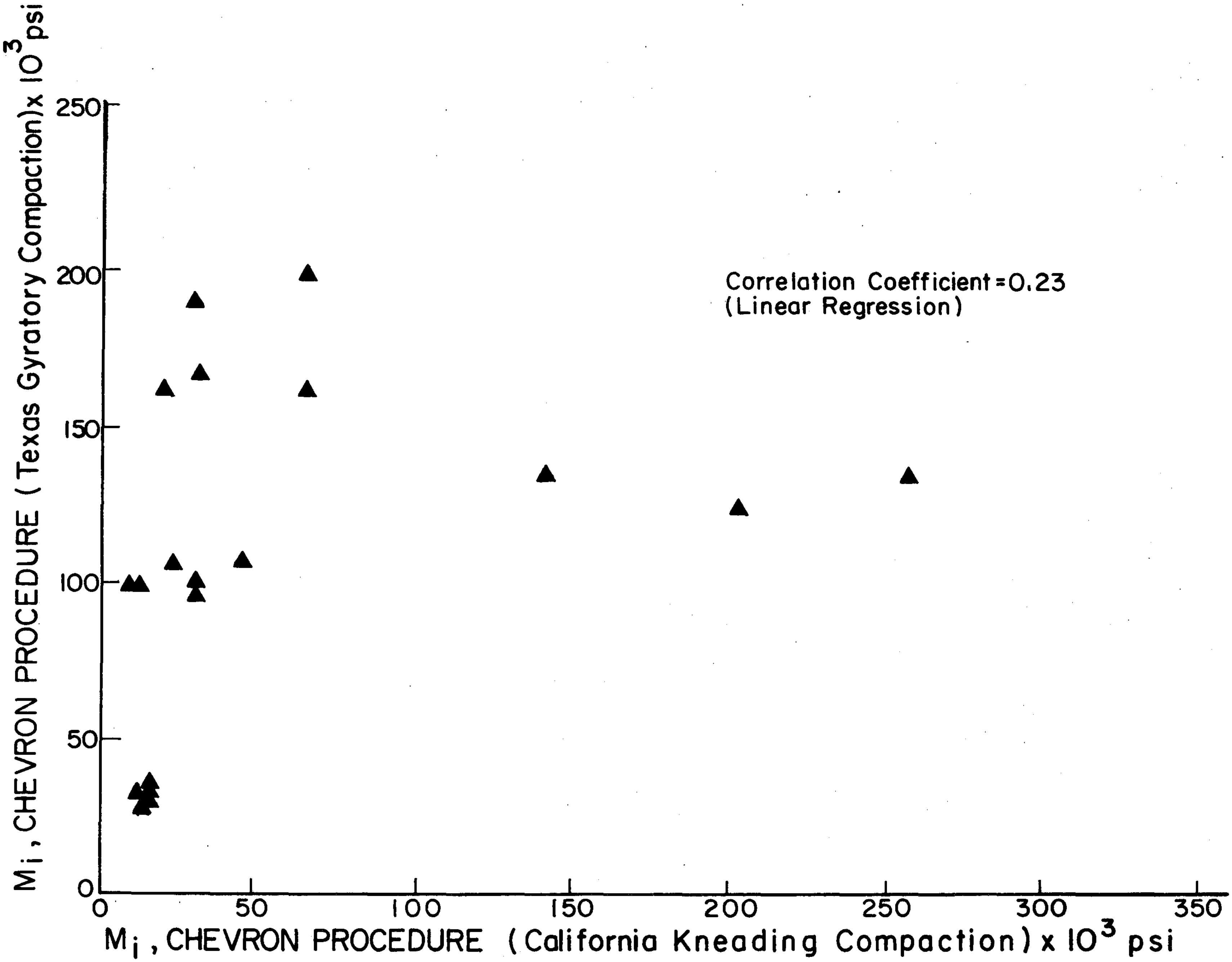


Figure 19. Comparison Of M_i Values Obtained From The Chevron Procedure Using California Kneading Compaction And Texas Gyratory Compaction.

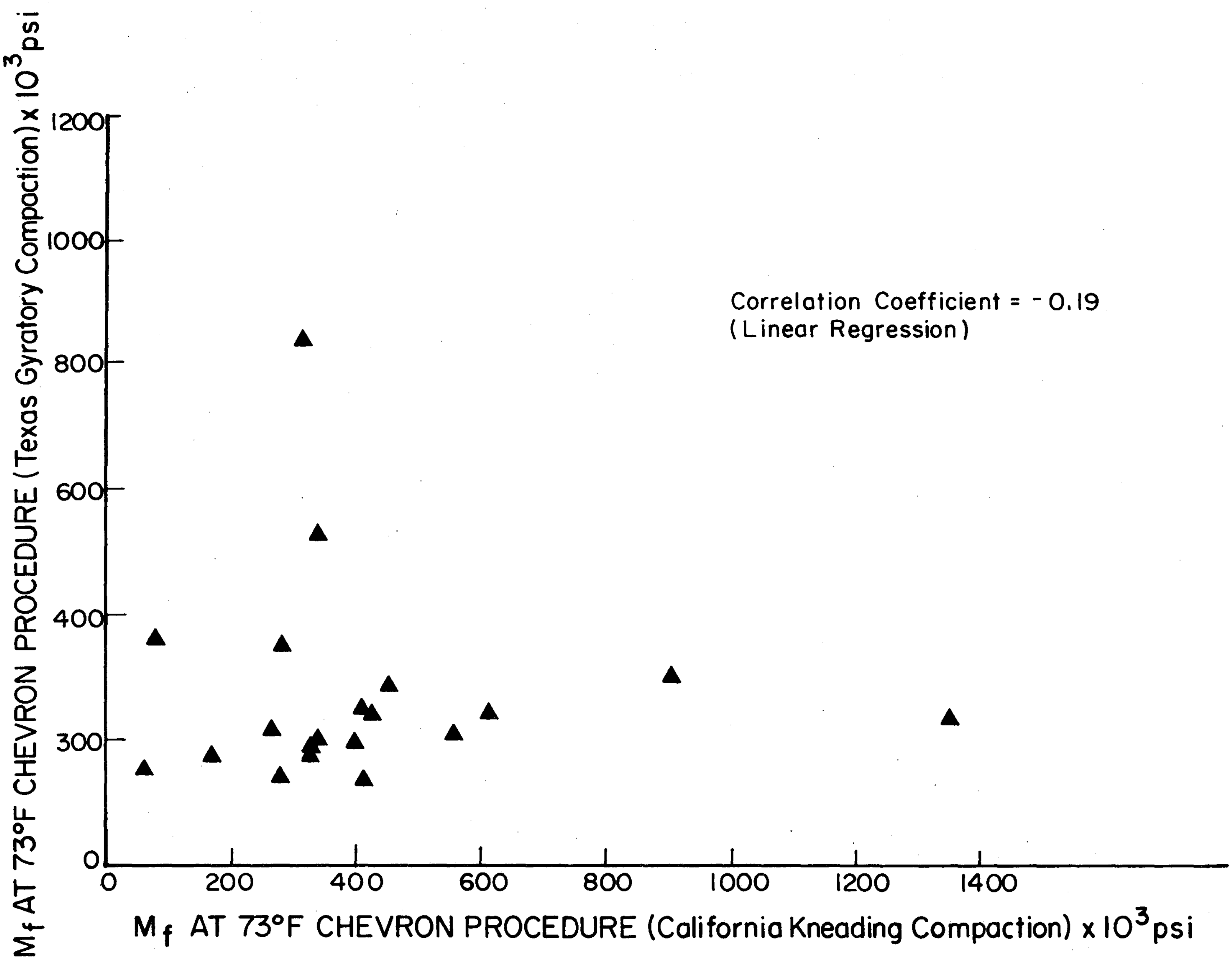


Figure 20. Comparison Of M Values Obtained From The Chevron Procedure Using California Kneading Compaction And Texas Gyratory Compaction.

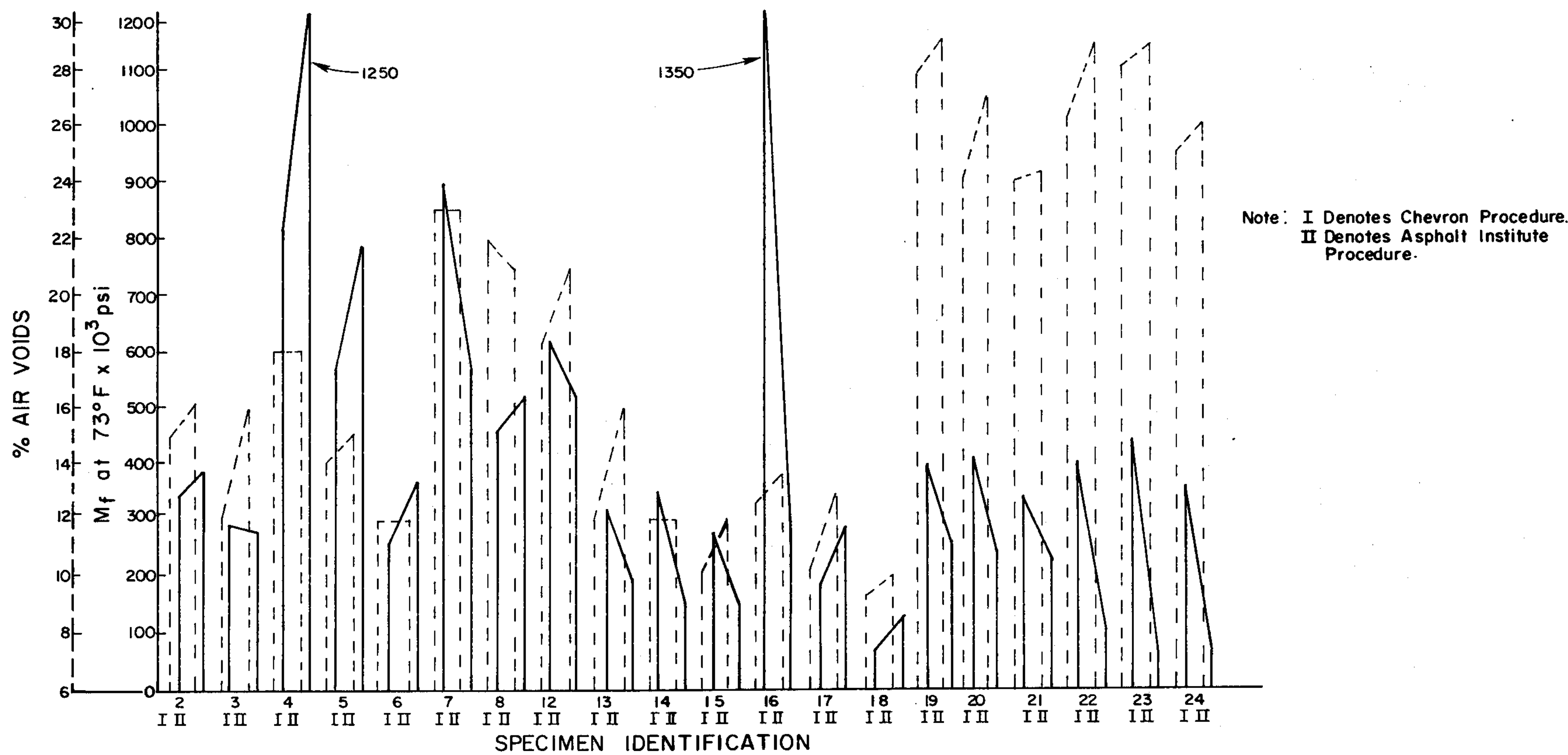


Figure 21. Effect Of Per cent Air Voids On The Final Resilient Modulus Value.

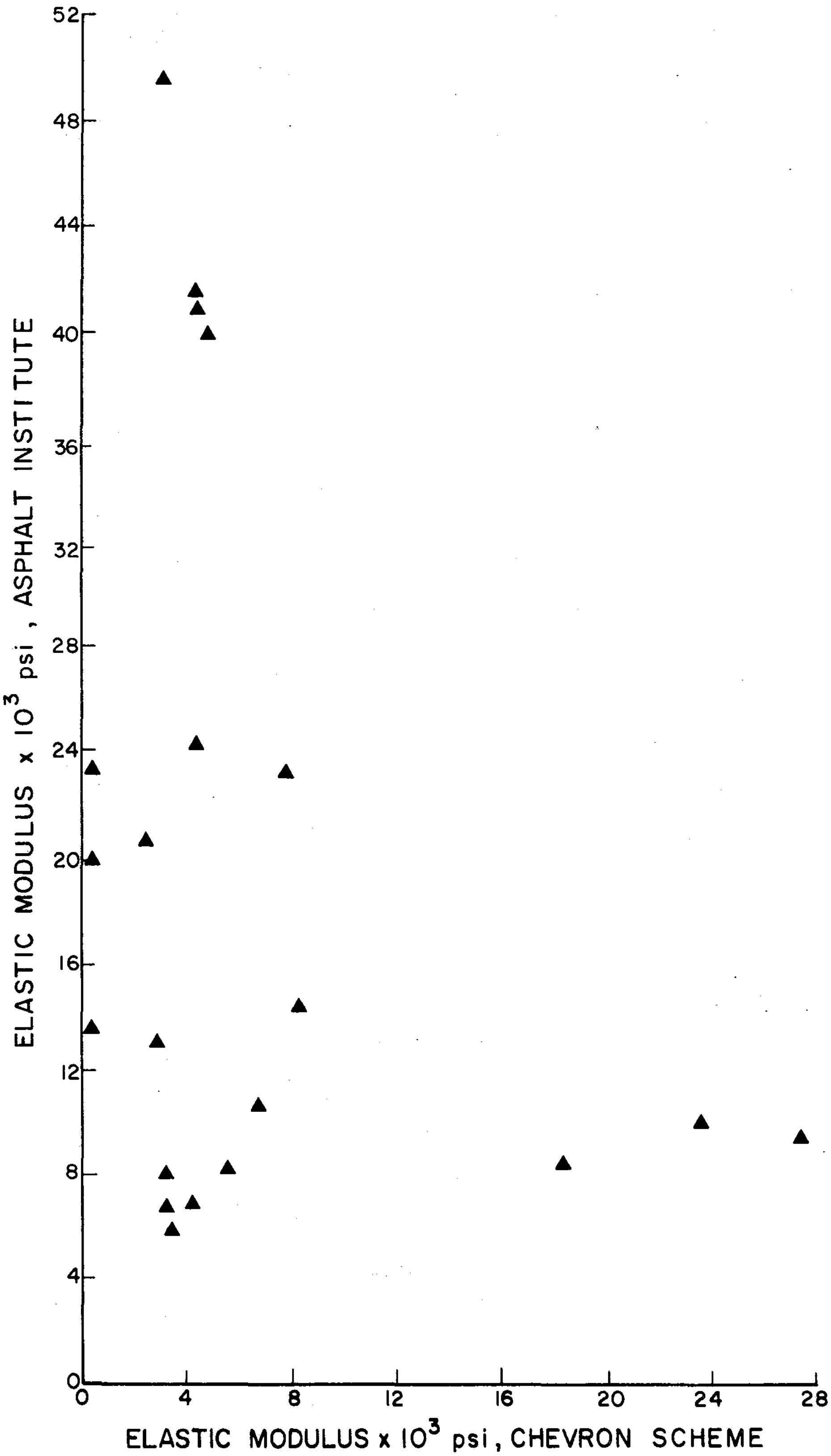


Figure 22. Comparison Of Elastic Module Obtained After Chevron And Asphalt Institute Curing Schemes.

SUITABILITY OF MATERIALS

Table 1 shows that the criteria used by Chevron and the Asphalt Institute to determine the adequacy of mixtures for use in pavement structural systems are identified in terms of values R_t and S. However, the R_t and S values obtained from these two different curing schemes are different. The magnitudes of these differences are not established by the data in this report. However, this information should be of value in confirming the two procedures.

A comparison of the R_t values derived from the Chevron test procedure with the Chevron criteria in Table 1 will give us an idea of the suitability of the materials tested in terms of stability and durability. From Table 4 we see that six of the eight mixtures tested can be considered suitable for use as bases or temporary surfaces in terms of R_t. The suitable aggregates are from Jefferson, Newton, Wheeler, Angelina, and Trinity Counties. This R_t criterion is established for specimens after final cure and vacuum saturation and, therefore, is an evaluation of the resistance of the mixture to moisture effects.

The Chevron thickness design procedure uses the resilient modulus to determine base thickness where emulsions are used as the binder. The design depends not only on M_R but also on other factors such as design traffic number, subgrade strength and type and thickness of surfacing. No numerical criterion is available upon which to evaluate resilient moduli alone. However, the magnitudes of the final resilient moduli shown in Appendix A are well within the range of other successful base materials. In fact, most of the final resilient moduli in Appendix A are of an order of magnitude that suggests a reduced surface thickness using the Chevron procedure (2).

It becomes evident from the R_t values and the final resilient modulus values that the mixtures tested would probably perform well within the pavement system if not subjected to excessive moisture intrusion. However, the mixtures appear highly susceptible to moisture degradation.

On the basis of the Asphalt Institute moisture pick up criteria (i.e., a maximum of 5 percent after vacuum saturation) none of the mixes can be considered suitable. However, Jefferson, Newton, Angelina and Trinity are marginal. This further substantiates the sensitivity of these materials to moisture.

CONCLUSIONS

1. A significant difference in curing schemes exists between the Chevron procedure and the Asphalt Institute procedure. This difference affects stability, resistance and resilient modulus values.

2. Since the Asphalt Institute procedure was modified by drying the specimens to constant weight prior to stability testing a conclusive evaluation as to the effect of the variation in curing sequence between the two procedures cannot be made. However, the available data indicate that these differences have a significant effect on resistance values. For instance, correlations between R values obtained from the Chevron procedure and R values from the Asphalt Institute procedure were very poor. Likewise, S value correlations between procedures were poor.

3. No correlations exist between resilient moduli between the Chevron and Asphalt Institute procedures. This gives further evidence that the difference in curing schemes between the two procedures is significant in its effect since moduli were evaluated in each procedure at as nearly the same point as possible.

4. The effect of the variation in lateral confinement conditions between the test apparati was evaluated by comparing R and S within each of the test procedures. The S values represent the type of values obtained from the Texas Hveem stability test. The R value is the value required by both the Chevron and Asphalt Institute procedures. Exponential models fitting these data yielded highly acceptable correlations. It is possible to predict R values from S values. However, more data are required in order to develop a viable model.

5. The rational pavement design procedure incorporated in the Chevron procedure is a valuable concept. However, on the basis of present data in order to use the Chevron empirical criteria, the kneading compactor should be used to prepare specimens. Additional research over a broader range of mixtures is needed to further evaluate possible substitution of the gyratory compactor.

6. Of the mixtures tested six, Jefferson, Newton, Wheeler, Angelina, Trinity and Lufkin, met Chevron criteria, Table 1, for a base or temporary surface material. However, even these mixtures had excessive moisture pick up after vacuum saturation according to Asphalt Institute criteria. However, all mixtures appeared suitable for incorporation in pavement systems on the basis of final resilient moduli obtained after vacuum dessication.

7. No correlation was found between elastic moduli obtained after Chevron curing and those obtained after Asphalt Institute curing. This is probably due to the variation in curing between the two procedures.

RECOMMENDATIONS

1. Use the Chevron design procedure which is based on field performance dating back to 1965.

2. Use the R_t value to determine whether or not stability criterion is met. If only the Texas Hveem stabilometer is available, predict an R value on the basis of the regression relation shown in Figure 7.

3. If no cohesiometer is available, comput R_t on the basis the R value and the linear regression shown in Figure 15.

4. Substitution of the gyratory compactor for the kneading compactor appears feasible when determining resistance values (R values). Correlations between R values obtained after gyratory compaction and those obtained after kneading compaction were good for both procedures. Similar correlations based on S values were not as good.

5. Although the gyratory compactor may be substituted for the kneading compactor with success in determining resistance values, substitution of gyratory compaction for kneading compaction greatly affects the magnitude of resulting resilient moduli. If Chevron pavement thickness design criteria are used such a substitution appears invalid. Further data collection and analysis in this area is suggested.

REFERENCES

1. McKessen, C. L., "Soil Stabilization with Emulsified Asphalt," HRB Proceedings, 1935.

2. "Bituminous Mix Manual," Asphalt Division, Chevron U.S.A., Inc., 1977.

3. Epps, J. A. and Gallaway, B. M., "Design and Economics of Bituminous Treated Bases in Texas," Research Report 14-1F, Texas Transportation Institute, July 1974.

4. Kari, W. J., "Design of Emulsified Asphalt Treated Base Courses," paper presented at First Conference on Asphalt Pavements for South Africa, Durban, South Africa, July 1969.

5. Santucci, L. E., Thickness Design Procedure for Asphalt and Emulsified Asphalt Mixes, presented at meeting of Committee A2B02-Flexible Pavement Design, Washington, D. C., January 1975.

6. Dybalski, J., "Marshall Stability," Internal test methods, ARMSK, Company.

7. Mix Design Methods for Liquid Asphalt Mixtures, MISC-74-2, Asphalt Institute, College Park, Maryland, February 1974.

8. Darter, M. I., Wilkey, P. L. and S. L. Ahlfield, "Development of Mixtures Design Procedures for Emulsified Asphalt-Aggregates Cold Mixtures," Research Report 505-1, University of Illinois, 1977.

9. Herrin, M., Darter, M. I. and Ishai, I., "Determination of Feasible Testing Methods for Asphalt-Aggregate Cold Mix Bases," Research Report 505-2, University of Illinois, March 1974.

10. Gadallah, A. A., Wood, L. E. and Yoder, E.J., "A Suggested Method for the Preparation and Testing of Asphalt Emulsion Treated Mixtures Using Marshall Equipment," Proceedings Association of Asphalt Paving Technologists, 1977.

11. Gadallah, A. A., Wood, L. E. and Yoder E. J., "Evaluation of Asphalt Emulsion Treated Mixture Properties Using Marshall Concepts," paper prepared for 1979 Annual meeting of Transportation Research Board.

12. George, K. P., "Criteria for Emulsified Asphalt Stabilization of Sandy Soils in Mississippi," Interim Report prepared for Mississippi State Highway Department by University of Mississippi Civil Engineering Department, January 1977.

13. George, K. P., "Stabilization of Sands by Asphalt Emulsion," Record 593, Transportation Research Board, 1976.

14. Dunlap, Wayne A., Epps, Jon A. and Gallaway, Bob M., "U. S. Air Force Soil Stabilization Index System - A Validation," Texas A&M Research Foundation, May 1973.

15. Smith, A. W., "Asphalt Stabilization Research," Report on Project 3-05-70-023, Materials and Test Division, Texas State Department of Highways and Public Transportation, September 1975.

16. Currin, D. D., Allen, J. J. and Little, D. N., "Soil Stabilization Index System for Bituminous Stabilization," presented to Transportation Research Board, Stabilization with Asphalt Emulsion Committee, January 1976.

17. Richardson, E. S. and Liddle, W. A., "Experience in the Pacific Northwest," Implementation Package 74-3, Federal Highway Administration, July 1974.

18. Williamson, R., "Status Report on Emulsified Asphalt Pavements in Region 6," 1976.

19. FHWA Notice N505024, "National Experimental and Evaluation Program," (NEEP), Project No. 19, Used Emulsified Asphalts in Base Course Mixtures, November 12, 1974.

20. "Bituminous Emulsions for Highway Pavements," NCHRP Synthesis of Highway Practice 30, 1975.

21. "Manual of Testing Procedures," Volume 1, Texas Department of Highways and Public Transportation.

22. Currin, D. D., Little, D. N., Allen, J. J., Validation of Soil Stabilization Index System with Manual Development, FJSL-TR-76-0006, Air Force System Command, U. S. Air Force Academy, Co., February 1976.

23. Epps, J. A., "Personal correspondence with G. G. Sapp," Chevron Asphalt Company, May 9, 1977.

24. "Interim Guide to Full-Depth Asphalt Paving Using Various Asphalt Mixes," PCD-1, Pacific Coast Division, The Asphalt Institute, January 1976.

25. Button, Joe W., Mahoney, Joe P., "Statistical Summary of Resilient Modulus Measurements," Texas Transportation Institute, Texas A&M University, 1977.

APPENDIX A

Table A-1. Laboratory Data - Sequence I

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI x 10^6				Indirect Tension		
					M_i 73°F*	M_f 73°F**	M_f 73°F**	M_s 73°F***	E, PSI	σ_f, PSI	ε_f
Jefferson	1.1 A	7.6	70	29	0.119		0.214	0.0131	1286	4.75	.00369
	1.1 B	7.6	69	27	0.138		0.216	0.0137	3567	9.38	.00263
	1.1 C	7.6	69.25	29	0.168		0.247	0.0163	1387	8.64	.00623
	Average	7.6	69.4	28	0.142		0.226	0.0144	2080		
Jefferson	1.4 A	10.1	76.5	17	0.263	0.3023	0.204	0.0873	3381	17.04	.00504
	1.4 B	10.1	76.5	17.5	0.246	0.3353	0.218	0.0827	3142	14.32	.00456
	1.4 C	10.1	76.5	18	0.264	0.3533	0.217	0.0801	5973	29.21	.00489
	Average	10.1	76.5	17.5	0.258	0.3303	0.213	0.0834	4165		
Jefferson	1.7 A	12.2	71.5	15	0.196	0.2788	0.0934	0.0718	3886	17.96	.00462
	1.7 B	12.2	73	16.25	0.212	0.2697	0.0888	0.0821	3315	17.78	.00536
	1.7 C	12.2	75.5	16		0.2944	.0873	0.0681	6902	36.06	.00522
	Average	12.2	73.3	15.8		0.2810	0.0898	0.0740	4701		
Newton	1.1 A	9.0	78	20		0.709	0.2456	0.0989	4856	16.59	.00342
	1.1 B	9.0	78.5	21.6	0.0644	0.770	0.2511	0.1066	4034	15.67	.00388
	1.1 C	9.0	82	23.5	0.0672	0.981	0.3342	0.2622	7834	32.41	.00414
	Average	9.0	79.5	21.7	0.0659	0.820	0.2770	0.1559	5575		
Newton	1.4 A	12.5	72.3	16.5	0.0472	0.436	0.1192	0.0846	2778	20.47	.00737
	1.4 B	12.5	73.5	17.5	0.0456	0.402	0.1150	0.0676	4045	17.21	.00425
	1.4 C	12.5	70.5	16	0.0416	0.839	0.2951	0.0708	3356	15.85	.00472
	Average	12.5	72.1	16.7	0.448	0.559	0.1764	0.0743	3393		
Newton	1.7 A	15.1	68	15.6	0.0311	0.292	0.0596	0.0451	3799	17.94	.00472
	1.7 B	15.1	71.5	15.5	0.0293	0.270	0.0622	0.0848	2968	24.75	.00834
	1.7 C	15.1	70	15.6	0.0330	0.203	0.0472	0.0466	2588	24.17	.00674
	Average	15.1	69.8	15.6	0.0311	0.255	0.0563	0.0588	3118		
Wheeler	1.1 A	6.5	62.5	10.75	0.0175	0.909	0.490	Broke	318	1.72	.00541
	1.1 B	6.5	66.5	15.5	0.0164	0.879	0.520	0.0021	490	1.84	.00376
	1.1 C	6.5	62.5	12.75	0.0172	0.923	0.498	0.0049	415	1.72	.00414
	Average	6.5	63.8	13.0	0.0170	0.904	0.503	0.0035	408		
Wheeler	1.4 A	8.2	71	14	0.0160	0.406	0.168	0.0107	522	2.55	.00489
	1.4 B	8.2	71	14	0.0161	0.382	0.149	0.0106	600	2.37	.00395
	1.4 C	8.2	72	13.5	0.0169	0.564	0.272	Broke	307	1.69	.00550
	Average	8.2	71	14	0.0163	0.451	0.196	0.0107	476		
Wheeler	1.7 A	3.9	66	13	0.0159	0.518	0.225	0.0064	448	2.32	.00518
	1.7 B	3.9	66	12.75	0.0170	0.669	0.242	0.0051	446	2.37	.00531
	1.7 C	3.9	66	12	0.0169	0.644	0.260	0.0055	413	2.29	.00554
	Average	3.9	66	12.6	0.0166	0.610	0.242	0.0057	436		

* After Initial Cure

** After Final Cure

*** After Vacuum Saturation

Table A-2. **Laboratory Data - Sequence I**

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI x 10^6 M_i 73°F*	M_f 73°F**	M_f 100°F**	M_s 73°F***	Indirect Tension E, PSI	σ_f, PSI	ε_f
	1.1 A	8.7	76.5	13	0.0039	0.0047		0.0101	100.30	1.67	0.01655
Padre	1.1 B	8.7	Broke	Broke	0.0040	Broke	Broke	Broke			
Island	1.1 C	8.7	Broke	Broke	0.0048	Broke	Broke	Broke			
	Average	8.7	76.5	13	0.0042	0.0047		0.0101	100		
	1.4 A	10.6	61	13	0.0032	0.0274	0.0137	0.0076	169.64	2.07	0.01220
Padre	1.4 B	10.6	65	13	0.0042	0.0212	0.0046	0.0072	126.18	1.81	0.01434
Island	1.4 C	10.6	71	16	0.0035	0.0139	0.0060	0.0061	76.53	1.45	0.01895
	Average	10.6	65.7	14	0.0036	0.0208		0.0070	124		
	1.7 A	12	49.5	14	0.0035			0.0342	447.69	3.49	0.00780
Padre	1.7 B	12	53	13	0.0037			0.0316	299.50	3.33	0.01112
Island	1.7 C	12	52.5	13	0.0032			0.0226	274.03	2.84	0.01036
	Average	12	51.7	13	0.0035			0.0295	341		
	1.1 A	9.8	73	20	0.0725	0.332	0.3675	0.0255	1494	20.62	
Angelina	1.1 B	9.8	77.25	14	0.0725	0.302	0.3185	0.0275	4297	16.48	.01380
	1.1 C	9.8	73	16.75	0.0520	0.295	0.3060	0.0235	3190	14.26	.00384
	Average	9.8	74.4	16.9	0.0657	0.310	0.3307	0.0255	2994		.00447
	1.4 A	12.5	65	13	0.0235	0.273	0.2365	0.0220	2914	18.74	.00643
Angelina	1.4 B	12.5	65.7	17	0.0255	0.264	0.2150	0.0240	3553	20.07	.00568
	1.4 C	12.5	60	10	0.0240	0.484	0.5070	0.0590	6060	22.84	.00377
	Average	12.5	63.6	13.3	0.0243	0.340	0.3195	0.0350	4169		
	1.7 A	15.1	58	8	0.0275	0.266	0.1750	0.0215	4955	17.19	.00347
Angelina	1.7 B	15.1	58	10	0.0305	0.2675	0.1650	0.0220	4796	24.18	.00504
	1.7 C	15.1	59	9	0.0345	0.2945	0.1970	0.0440	6284	28.74	.00457
	Average	15.1	58.3	9	0.0308	0.2760	0.1790	0.0292	5345		
	1.1 A	7.5	79	21	0.0299	1.137	0.676	0.169	4721	14.64	.00310
Trinity	1.1 B	7.5	79.5	20.5	0.0345	1.452	0.391	0.152	7866	26.48	.00337
	1.1 C	7.5	79.5	19.5	0.0310	1.472	0.668	0.187	10753	32.79	.00305
	Average	7.5	79.3	20.3	0.0318	1.354	0.578	0.169	7780		
	1.4 A	9.5	73	18	0.0259	0.176	0.315	0.0315	8624	32.79	.00380
Trinity	1.4 B	9.5	76	19.25	0.0329	0.178	0.355	0.042	7519	33.51	.00446
	1.4 C	9.5	73	20	0.0295	0.166	0.275	0.0355	8439	30.97	.00367
	Average	9.5	74	19.08	0.0295	0.173	0.315	0.0363	8194		
	1.7 A	11.6	73	15.5	0.0205	0.0645	0.009	0.0125	3971	26.07	.00657
Trinity	1.7 B	11.6	68	12.5	0.0205	0.061	0.0085	0.0115	3336	25.71	.00771
	1.7 C	11.6	73	13.5	0.0205	0.061	0.010	0.012	4983	31.38	.00630
	Average	11.6	71.33	13.8	0.0205	0.0622	0.0092	0.120	4097		

* After Initial Cure

** After Final Cure

*** After Vacuum Saturation

Table A-3. Laboratory Data - Sequence I

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI x 10^6				Indirect Tension		
					M_i 73°F*	M_f 73°F**	M_f 100°F**	M_s 73°F***	E, PSI	σ_f, PSI	ε_f
Lufkin	1.1 A	7.2	72	18	0.013	0.431	0.120	0.035	18232	4.52	0.00025
	1.1 B	7.2	72	18.25	0.013	0.3825	0.1625	0.0375	19888	5.13	0.00026
	1.1 C	7.2	76	21.5	0.0145	0.412	0.1925	0.035	17092	4.19	0.00025
	Average	7.2	73.3	19.25	0.0135	0.4085	0.158	0.036	18404		
Lufkin	1.4 A	9.2	70	14.75	0.015	0.428	0.183	0.031	24668	6.87	0.00028
	1.4 B	9.2	67	13.75	0.015	0.408	0.1445	0.023	21467	6.20	0.00029
	1.4 C	9.2	72	15.75	0.014	0.382	0.164	0.043	24803	7.03	0.00028
	Average	9.2	69.7	14.75	0.0147	0.406	0.164	0.032	23646		
Lufkin	1.7 A	11.2	68	14.5	0.014	0.3365	0.096	0.0315	23362	8.77	0.00038
	1.7 B	11.2	69	15.5	0.013	0.328	0.1095	0.032	30139	7.54	0.00025
	1.7 C	11.2	72	16	0.0135	0.3325	0.135	0.036	28867	9.73	0.00034
	Average	11.2	69.7	15.3	0.0135	0.3323	0.1135	0.033	27456		
Lamb	1.1 A	6.5	62	11.5	0.0125	0.394	0.146	0.007	1924	1.42	0.00074
	1.1 B	6.5	61.5	11	0.010	0.414	0.1475	0.015	3997	1.60	0.00040
	1.1 C	6.5	63	11	0.0115	0.4045	0.155	0.021	11276	2.56	0.00023
	Average	6.5	62.2	11.2	0.0113	0.4042	0.1495	0.014	5732		
Lamb	1.4 A	8.2	61	9	0.012	0.442	0.1445	0.0065	2892	1.30	0.00045
	1.4 B	8.2	60.5	9	0.012	0.4145	0.068	0.007	2595	1.28	0.00049
	1.4 C	8.2	61.5	10.6	0.0125	0.4125	0.0465	0.0075	2883	1.42	0.00049
	Average	8.2	61	9.5	0.0122	0.423	0.086	0.007	2790		
Lamb	1.7 A	10.0	60	10	0.0125	0.346	0.042	0.005	2850	1.83	0.00064
	1.7 B	10.0	59	10.75	0.011	0.356	0.127	0.0085	3180	1.80	0.00057
	1.7 C	10.0	62.2	10.25	0.008	0.324	0.118	0.0065	3244	1.89	0.00058
	Average	10.0	60.4	10.3	0.0105	0.342	0.096	0.007	3091		
	1.1 A										
	1.1 B										
	1.1 C										
	Average										
	1.4 A										
	1.4 B										
	1.4 C										
	Average										
	1.7 A										
	1.7 B										
	1.7 C										
	Average										

* After Initial Cure

** After Final Cure

*** After Vacuum Saturation

Table A-4. Laboratory Data - Sequence I

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up By Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Jefferson	1.1 A	7.6	4.8		2.017	2.440	17.0	83.0
	1.1 B	7.6	4.8		2.018	2.418	16.9	83.1
	1.1 C	7.6	4.8		2.022	3.853	16.8	83.2
	Avg.	7.6	4.8	8.2	2.019	2.429	16.9	83.1
Jefferson	1.4 A	10.1	4.3		2.669	2.42	14.5	85.5
	1.4 B	10.1	4.3		2.062	2.41	14.8	85.2
	1.4 C	10.1	4.3		2.063	2.42	14.8	85.2
	Avg.	10.1	4.3	5.9	2.065	2.42	14.7	85.3
Jefferson	1.7 A	12.2	3.7		2.069	2.37	12.3	87.7
	1.7 B	12.2	3.7		2.076	2.37	12.0	88.0
	1.7 C	12.2	3.7		2.076	2.35	12.0	88.0
	Avg.	12.2	3.7	4.8	2.074	2.36	12.1	87.9
Newton	1.1	9.8	5.0		1.989	2.43	18.1	81.9
	1.1	9.8	5.0		1.996	2.44	17.8	82.1
	1.1	9.8	5.0		1.989	2.41	18.1	81.9
	Avg.	9.8	5.0	*	1.991	2.43	18.1	81.9
Newton	1.4	12.5	4.2		2.035	2.37	14.1	85.9
	1.4	12.5	4.2		2.037	2.36	14.1	85.9
	1.4	12.5	4.2		2.027	2.38	14.5	85.5
	Avg.	12.5	4.2	*	2.033	2.37	14.2	85.8
Newton	1.7	15.1	3.3		2.044	2.32	11.9	88.1
	1.7	15.1	3.3		2.058	2.32	11.3	88.7
	1.7	15.1	3.3		2.037	2.31	12.2	87.8
	Avg.	15.1	3.3	*	2.046	2.32	11.8	88.2
Wheeler	1.1	6.5	5.0		1.889	2.459	23.3	76.7
	1.1	6.5	5.0		1.887	2.471	23.3	76.7
	1.1	6.5	5.0		1.883	2.455	23.5	76.5
	Avg.	6.5	5.0	12.8	1.886	2.462	23.4	76.6
Wheeler	1.4	8.2	4.5		1.908	2.433	22.0	78.0
	1.4	8.2	4.5		1.907	2.451	22.1	77.9
	1.4	8.2	4.5		1.906	2.459	22.1	77.9
	Avg.	8.2	4.5	11.4	1.907	2.448	22.1	77.9
Wheeler	1.7	3.9	3.9		1.923	2.400	19.9	80.1
	1.7	3.9	3.9		1.923	2.406	19.9	80.1
	1.7	3.9	3.9		1.923	2.396	19.9	80.1
	Avg.	3.9	3.9	10.2	1.923	2.401	19.9	80.1

*No Date

Table A-5. Laboratory Data - Sequence I

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up By Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Padre Island	1.1	8.7	10.7			2.48		
	1.1	8.7	10.7			2.46		
	1.1	8.7	10.7					
	Avg.	8.7		14.8		2.47		
Padre Island	1.4	10.6	9.1			2.381		
	1.4	10.6	9.1			2.407		
	1.4	10.6	9.1			2.398		
	Avg.	10.6	9.1	14.4	1.728	2.395	72.2	27.8
Padre Island	1.7	12	6.8		1.640	2.392	68.7	31.3
	1.7	12	6.8		1.639	2.381	68.6	31.4
	1.7	12	6.8		1.644	2.389	68.9	31.1
	Avg.	12	6.8	14.4	1.641	2.387	68.7	31.3
Angelina	1.1	9.8	6		2.062	2.394	85.8	14.2
	1.1	9.8	6		2.074	2.393	86.3	13.7
	1.1	9.8	6		2.076	2.419	86.4	13.6
	Avg.	9.8	6	6.0	2.070	2.402	86.2	13.8
Angelina	1.4	12.5	5.1		2.072	2.344	88.4	11.6
	1.4	12.5	5.1		2.075	2.349	88.6	11.4
	1.4	12.5	5.1		2.052	2.336	87.6	12.4
	Avg.	12.5	5.1	5.1	2.066	2.343	88.2	11.8
Angelina	1.7	15.1	4.2		2.062	2.301	89.8	10.2
	1.7	15.1	4.2		2.069	2.297	90.1	9.9
	1.7	15.1	4.2		2.072	2.290	90.2	9.8
	Avg.	15.1	4.2	5.5	2.068	2.296	90.1	9.9
Trinity	1.1	7.5	3		2.141	2.457	87.1	12.9
	1.1	7.5	3		2.160	2.467	87.8	12.2
	1.1	7.5	3		2.151	2.454	87.5	12.5
	Avg.	7.5	3	4.8	2.151	2.459	87.5	12.5
Trinity	1.4	9.5	2		2.187	2.427	90.0	10.0
	1.4	9.5	2		2.188	2.433	90.0	10.0
	1.4	9.5	2		2.185	2.431	89.9	10.1
	Avg.	9.5	2	3.1	2.187	2.430	90.0	10.0
Trinity	1.7	11.6	1.7		2.169	2.373	91.2	8.8
	1.7	11.6	1.7		2.168	2.368	91.2	8.8
	1.7	11.6	1.7		2.165	2.390	91.1	8.9
	Avg.	11.6	1.7	2.8	2.167	2.377	91.2	8.8

Table A-6. Laboratory Data - Sequence I

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up By Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Lufkin	1.1	7.2	4.0		1.794	2.488	27.4	72.6
	1.1	7.2	4.0		1.762	2.459	28.7	71.3
	1.1	7.2	4.0		1.804	2.464	27.0	73.0
	Avg.		4.0	15.0	1.786	2.470	27.7	72.3
Lufkin	1.4	9.2	3.3		1.843	2.427	23.9	76.1
	1.4	9.2	3.3		1.823	2.419	24.7	75.3
	1.4	9.2	3.3	13.4	1.842	2.416	23.9	76.1
	Avg.		3.3		1.836	2.421	24.2	75.8
Lufkin	1.7	11.2	2.7		1.780	2.378	24.9	75.1
	1.7	11.2	2.7		1.831	2.350	22.7	77.3
	1.7	11.2	2.7		1.780	2.383	24.9	75.1
	Avg.		2.7	12.1	1.801	2.370	24.0	76.0
Lamb	1.1	6.5	4.0		1.765	2.462	26.2	73.8
	1.1	6.5	4.0		1.768	2.479	26.0	74.0
	1.1	6.5	4.0		1.766	2.230	26.1	73.9
	Avg.		4.0	14.4	1.766	2.390	26.1	73.9
Lamb	1.4	8.2	3.5		1.782	2.441	27.9	72.1
	1.4	8.2	3.5		1.786	2.518	27.8	72.2
	1.4	8.2	3.5		1.782	2.459	27.9	72.1
	Avg.		3.5	15.5	1.783	2.473	27.9	72.1
Lamb	1.7	10.0	2.9		1.808	2.421	25.2	74.8
	1.7	10.0	2.9		1.813	2.410	25.0	75.0
	1.7	10.0	2.9		1.804	2.419	25.4	74.6
	Avg.		2.9	13.5	1.808	2.417	25.2	74.8

Table A-7. Laboratory Data - Sequence II

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI x 10^6 M_i 73°F*	M_f 73°F**	M_f 100°F**	Indirect Tension E, PSI	σ_f, PSI	ε_f
	1.1 A	7.6	93	38.7	0.007	0.361	0.231	16895	66.53	0.00394
Jefferson	1.1 B	7.6	93.8	41.7		0.367	0.227	22504	79.94	.00355
	1.1 C	7.6	94	37	0.006	0.422	0.267	20979	70.99	.00338
	Average	7.6	93.6	39.1	0.0065	0.383	0.242	20126		
	1.4 A	10.1	94.2	46	0.0305	0.422	0.253	46170	124.51	0.00270
Jefferson	1.4 B	10.1	94	40.5	0.015	0.365	0.234	36400	106.72	.00293
	1.4 C	10.1	94.2	43	0.060	0.365	0.242	42198	125.87	.00298
	Average	10.1	94.1	43.2	0.0352	0.384	0.243	41589		
	1.7 A	12.2	94	36	0.005	0.275	0.215	46981	133.78	0.00285
Jefferson	1.7 B	12.2	93	31.25	0.0065	0.272	0.188	39755	138.48	0.00348
	1.7 C	12.2	94.5	33.5	0.0085	0.273	0.177	32996	149.82	.00454
	Average	12.2	93.8	33.6	0.0067	0.273	0.193	39911		
	1.1 A	9.8	95	53.2	0.0055	1.153	0.561	8243	13.3	0.00161
Newton	1.1 B	9.8	95	38.7	0.005	1.301	0.614	8955	12.28	0.00137
	1.1 C	9.8	95.5	38.5	0.0045	1.309	0.610	7535	12.28	0.00163
	Average	9.8	95.2	43.5	0.0050	1.254	0.595	8244		
	1.4 A	12.5	94.5	33.3	0.006	0.781	0.378	5395	12.06	0.00224
Newton	1.4 B	12.5	94	33	0.007	0.708	0.310	5515	12.22	0.00222
	1.4 C	12.5	94	32.5	0.0065	0.850	0.433	6565	12.71	0.00194
	Average	12.5	94.2	32.9	0.0065	0.780	0.374	5825		
	1.7 A	15.1	87.2	22.5	0.010	0.309	0.110	5552	12.45	0.00224
Newton	1.7 B	15.1	88.1	20.5	0.029	0.302	0.173	4818	12.82	0.00266
	1.7 C	15.1	89	19.0	0.018	0.461	0.159	6774	46.76	.00690
	Average	15.1	88.1	20.7	0.019	0.357	0.147	5715		
	1.1 A	6.5	86.2	20.4	0.0025	0.534	0.232	29966	57.73	0.00193
Wheeler	1.1 B	6.5	89.8	22	0.003	0.594	0.262	16952	53.94	0.00318
	1.1 C	6.5								
	Average	6.5	88.0	21.2	0.003	0.564	0.247	23459		
	1.4 A	8.2	89	21.3	0.0035	0.545	0.226	13701	61.97	0.00452
Wheeler	1.4 B	8.2	87	15.6	0.003	0.499	0.186	13876	66.27	0.00478
	1.4 C	8.2	88.2	19	0.003	0.503	0.187	13667	64.32	0.00471
	Average	8.2	88.1	18.6	0.003	0.516	0.200	13748		
	1.7 A	10.0	89.8	20.5	0.004	0.510	0.162	23893	71.45	0.00299
Wheeler	1.7 B	10.0	89	21.7	0.004	0.488	0.150	18262	74.95	0.00410
	1.7 C	10.0	87.5	19.3	0.004	0.549	0.158	17399	74.34	0.00427
	Average	10.0	88.8	20.5	0.004	0.516	0.157	19851		

* After Initial Cure

** After Final Cure

Table A-8. **Laboratory Data** - Sequence II

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI x 10^6 M_i 73°F*	M_f 73°F**	M_f 100°F**	Indirect Tension E, PSI	σ_f, PSI	ε_f
	1.1 A	8.7								
Padre	1.1 B	8.7			***	***	***	***	***	***
Island	1.1 C	8.7	***	***						
	Average	8.7								
					***	***	***	***	***	***
	1.4 A	10.6								
Padre	1.4 B	10.6								
Island	1.4 C	10.6	***	***						
	Average	10.6								
	1.7 A	12								
Padre	1.7 B	12								
Island	1.7 C	12	***	***	***	***	***	***	***	***
	Average	12								
	1.1 A	9.8	94.8	54.5	0.0065	0.207	0.4695	33059	120.65	.00365
Angelina	1.1 B	9.8	96	62	0.0015	0.182	0.434	66124	142.70	.00216
	1.1 C	9.8	Broke	Broke	Broke	Broke	Broke			
	Average	9.8	95.4	58.3	0.0040	0.1945	0.452	49592		
	1.4 A	12.5	95.7	54	0.0115	0.170	0.2155	46285	159.10	.00344
Angelina	1.4 B	12.5	94.8	45	0.007	0.151	0.2435	35598	157.46	.00442
	1.4 C	12.5	94.5	52.5	0.013	0.168	0.214	40834	159.76	.00391
	Average	12.5	95	50.5	0.0105	0.163	0.224	40906		
	1.7 A	15.1	90	16	0.014	0.137	0.149	18759	148.99	.00794
Angelina	1.7 B	15.1	94.5	44	0.135	0.140	0.169	28151	151.69	.00539
	1.7 C	15.1	87	14	0.0085	0.138	0.1375	26109	120.76	.00463
	Average	15.1	90.5	24.7	0.0525	0.138	0.152	24340		
	1.1 A	7.5	92.5	29.5	0.008	0.298	0.2595	22858	74.66	0.00327
Trinity	1.1 B	7.5	94.5	35.5	0.014	0.306	0.2705	24699	84.84	0.00343
	1.1 C	7.5	92.5	30.6	0.012	0.292	0.2545	22430	84.55	0.00377
	Average	7.5	93.2	31.9	0.011	0.299	0.2615	23329		
	1.4 A	9.5	87.5	21.5	0.006	0.293	0.172	13689	87.16	0.00637
Trinity	1.4 B	9.5	89	21.5	0.007	0.292	0.198	11748	78.73	0.00670
	1.4 C	9.5	92.5	26.5	0.007	0.276	0.245	17969	94.81	0.00528
	Average	9.5	89.7	23.2	0.007	0.287	0.205	14469		
	1.7 A	11.6	78.5	19.0	0.007	0.115	0.0235	7136	57.39	0.00804
Trinity	1.7 B	11.6	78.7	17.25	0.006	0.143	0.0355	6632	59.44	0.00896
	1.7 C	11.6	75.0	16.5	0.006	0.110	0.0235	6818	55.96	0.00821
	Average	11.6	77.4	17.6	0.006	0.123	0.0275	6862		

* After Initial Cure

** After Final Cure

*** Fell apart after vacuum saturation

Table A-9. Laboratory Data - Sequence II

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI, x 10^6 M_i 73°F*	M_f 73°F**	M_f 100°F**	Indirect Tension E,PSI	σ_f,PSI	ε_f
Lufkin	1.1 A	7.2				Broke	Broke			
	1.1 B	7.2	82	19		0.243	0.181	9314	47.59	0.00511
	1.1 C	7.2	80	18		0.257	0.1385	7651	40.76	0.00533
	Avg.	7.2	81	18.5		0.250	0.1598	8482		
Lufkin	1.4 A	9.2	77	19		0.205	0.0965	7839	45.30	0.00578
	1.4 B	9.2	86	19	0.0035	0.228	0.1285	10478	49.32	0.00471
	1.4 C	9.2	87	19	0.0055	0.270	0.150	11713	52.98	0.00452
	Avg.	9.2	83	19		0.234	0.125	10010		
Lufkin	1.7 A	11.2	84	17	0.004	0.235	0.0965	8296	54.90	0.00662
	1.7 B	11.2	82	16	0.005	0.2175	0.1235	10584	54.08	0.00511
	1.7 C	11.2								
	Avg.	11.2	83	16.5	0.0045	0.2263	0.110	9420		
Lamb	1.1 A	6.5	77	10		0.091	0.3315			
	1.1 B	6.5		K				10640	40.30	.00379
	1.1 C	6.5		K						
	Avg.	6.5	77	10	***			10640		
Lamb	1.4 A	8.2								
	1.4 B	8.2	75	9		0.051	0.2945	9308	41.62	.00447
	1.4 C	8.2				0.033	0.275	16452	44.24	.00269
	Avg.	8.2	75	9	***			12880		
Lamb	1.7 A	10.0	69	7		0.057	0.138	6654	40.70	.00612
	1.7 B	10.0	69	11		0.061		7928	38.02	.00480
	1.7 C	10.0	70	8		0.050	0.1485	9456	41.15	.00435
	Avg.	10.0	69	9	***			8013		

*After initial cure
**After final cure
***Speciman too tender to test

Table A-10. Laboratory Data - Sequence II

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up By Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Jefferson	1.1	7.6	4.8		1.955	2.457	20.5	79.5
	1.1	7.6	4.8		1.966	2.453	20.0	80.0
	1.1	7.6	4.8		1.959	2.463	20.3	79.7
	Avg.	7.6		6.7	1.960	2.458	20.3	79.7
Jefferson	1.4	10.1	4.3		2.017	2.398	16.0	84.0
	1.4	10.1	4.3		2.006	2.389	16.4	83.6
	1.4	10.1	4.3		2.006	2.414	16.4	83.6
	Avg.	10.1	4.3	5.8	2.010	2.400	16.2	83.8
Jefferson	1.7	12.2	3.7		1.995	2.370	15.9	84.1
	1.7	12.2	3.7		1.992	2.366	16.1	83.9
	1.7	12.2	3.7		1.986	2.387	16.3	83.7
	Avg.	12.2	3.7	8.02	1.991	2.374	16.1	83.9
Newton	1.1	9.8	5		1.978	2.417	17.7	82.3
	1.1	9.8	5		1.980	2.410	17.6	82.4
	1.1	9.8	5		1.982	2.381	17.5	82.5
	Avg.	9.8	5	9.1	1.980	2.403	17.6	82.4
Newton	1.4	12.5	4.2		2.011	2.362	14.3	85.7
	1.4	12.5	4.2		1.981	2.349	15.6	84.4
	1.4	12.5	4.2		1.983	2.329	15.6	84.5
	Avg.	12.5	4.2	7.4	1.992	2.347	15.1	84.9
Newton	1.7	15.1	3.3		2.023	2.308	12.1	87.9
	1.7	15.1	3.3		2.026	2.302	12.0	88.0
	1.7	15.1	3.3		2.008	2.294	12.7	87.3
	Avg.	15.1	3.3	6.6	2.019	2.301	12.3	87.7
Wheeler	1.1	6.5	5		1.849	2.475	24.8	75.2
	1.1	6.5	5		1.851	2.461	24.7	75.3
	1.1	6.5	5		Broke	2.442		
	Avg.	6.5	5	13.3	1.850	2.459	24.8	75.2
Wheeler	1.4	8.2	4.5		1.872	2.449	23.2	76.8
	1.4	8.2	4.5		1.864	2.445	23.5	76.5
	1.4	8.2	4.5		1.863	2.414	23.5	76.5
	Avg.	8.2	4.5	12.6	1.866	2.436	23.4	76.6
Wheeler	1.7	10	3.9		1.895	2.411	21.2	78.8
	1.7	10	3.9		1.906	2.396	20.7	79.3
	1.7	10	3.9		1.900	2.406	21.0	79.0
	Avg.	10	3.9	10.9	1.900	2.404	21.0	79.0

Table A-11. Laboratory Data - Sequence II

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up By Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Padre Island	1.1	8.7	10.7					
	1.1	8.7	10.7					
	1.1	8.7	10.7					
	Avg.	8.7	10.7	*	*	*	*	*
Padre Island	1.4	10.6	9.1					
	1.4	10.6	9.1					
	1.4	10.6	9.1					
	Avg.	10.6	9.1	*	*	*	*	*
Padre Island	1.7	12	6.8					
	1.7	12	6.8					
	1.7	12	6.8					
	Avg.	12	6.8	*	*	*	*	*
Angelina	1.1	9.8	6		2.025	2.387	16.5	83.5
	1.1	9.8	6		2.048	2.463	15.6	84.4
	1.1	9.8	6		Broke	2.428		
	Avg.	9.8	6	8.9	2.037	2.426	16.0	84.0
Angelina	1.4	12.5	5.1		2.078	2.355	11.9	88.1
	1.4	12.5	5.1		2.053	2.341	12.9	87.1
	1.4	12.5	5.1		2.108	2.379	10.6	89.4
	Avg.	12.5	5.1	6.2	2.080	2.358	11.8	88.2
Angelina	1.7	15.1	4.2		2.048	2.304	11.0	89.0
	1.7	15.1	4.2		2.031	2.278	11.7	88.3
	1.7	15.1	4.2		1.976	2.318	14.1	85.9
	Avg.	15.1	4.2	5.1	2.018	2.300	12.3	87.7
Trinity	1.1	7.5	3		2.091	2.435	14.1	85.9
	1.1	7.5	3		2.096	2.455	13.7	86.3
	1.1	7.5	3		2.098		13.6	86.4
	Avg.	7.5	3	7.0	2.095	2.428	13.7	86.3
Trinity	1.4	9.5	2.3		2.113	2.419	12.6	87.4
	1.4	9.5	2.3		2.111	2.419	12.7	87.3
	1.4	9.5	2.3		2.119	2.417	12.3	87.7
	Avg.	9.5	2.3	6.3	2.114	2.418	12.6	87.4
Trinity	1.7	11.6	1.7		2.142	2.304	8.7	91.3
	1.7	11.6	1.7		2.115	2.358	10.3	89.7
	1.7	11.6	1.7		2.111	2.379	11.3	88.7
	Avg.	11.6	1.7	5.5	2.122	2.347	9.6	90.4

*Fell apart after vacuum saturation

Table A-12. Laboratory Data - Sequence II

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick up by Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Lufkin	1.1 A	7.2	4			2.451		
	1.1 B	7.2	4		1.748	2.441	28.9	71.1
	1.1 C	7.2	4		1.754	2.488	28.7	71.3
	Average	7.2	4		1.751	2.460	28.8	71.2
Lufkin	1.4 A	9.2	3.3		1.758	2.416	27.5	72.5
	1.4 B	9.2	3.3		1.776	2.412	26.4	73.6
	1.4 C	9.2	3.3		1.783	2.445	27.1	72.9
	Average	9.2	3.3	15.4	1.772	2.424	26.9	73.1
Lufkin	1.7 A	11.2	2.7		1.802	2.383	24.2	75.8
	1.7 B	11.2	2.7		1.798	2.342	24.4	75.6
	1.7 C	11.2	2.7			2.410		
	Average	11.2	2.7	17.0	1.800	2.378	24.3	75.7
Lamb	1.1 A	6.5	4.0		1.751	2.469	29.2	70.8
	1.1 B	6.5	4.0		Broke	2.445		
	1.1 C	6.5	4.0		Broke	2.505		
	Average	6.5	4.0		1.751	2.473	29.2	70.8
Lamb	1.4 A	8.2	3.5		Broke	2.443		
	1.4 B	8.2	3.5		1.747	2.400	28.25	71.75
	1.4 C	8.2	3.5		1.713	2.461	29.65	70.35
	Average	8.2	3.5	16.0	1.730	2.435	28.95	71.05
Lamb	1.7 A	10.0	2.9		1.785	2.381	25.63	74.38
	1.7 B	10.0	2.9		1.776	2.389	26.00	74.00
	1.7 C	10.0	2.9		1.786	2.429	25.58	74.42
	Average	10.0	2.9	14.5	1.782	2.400	25.74	74.27

Table A-13. Laboratory Data - Sequence III

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI x 10^6				Indirect Tension		
					M_i 73°F*	M_f 73°F**	M_f 100°F**	M_s 73°F***	E, PSI	σ_f, PSI	ε_f
	1.1 A	7.6	86	16	0.126	0.211	0.114	0.022	4912	15.53	.00316
Jefferson	1.1 B	7.6	90	22	0.131	0.235	0.124	0.012	5541	17.19	.00310
	1.1 C	7.6	90	25	0.145	0.224	0.124	0.021	5476	17.00	.00310
	Average	7.6	89	21	0.134	0.223	0.121	0.018	5310		
	1.4 A	10.1	84	18	0.134	0.182	0.073	0.028	8338	22.17	.00266
Jefferson	1.4 B	10.1	86	20	0.133	0.168	0.074	0.032	5531	21.57	.00390
	1.4 C	10.1	87	22	0.132	0.183	0.076	0.025	7484	22.78	.00304
	Average	10.1	87	20	0.133	0.178	0.074	0.028	7118		
	1.7 A	12.2	90	18	0.126	0.141	0.046	0.027	7358	24.35	.00331
Jefferson	1.7 B	12.2	89	16	0.116	0.133	0.043	0.029	5242	22.92	.00437
	1.7 C	12.2	89	18	0.129	0.139	0.046	0.037	3620	25.14	.00694
	Average	12.2	89.5	17	0.124	0.138	0.045	0.031	5407		
	1.1 A	9.8	88.5	19.5	0.192	0.393	0.0365	0.184	6774	24.13	0.00356
Newton	1.1 B	9.8	86.5	21.5	0.1975	0.3395	0.031	0.189	7164	23.93	0.00334
	1.1 C	9.8	87	22	0.2055	0.3465	0.035	0.2105	8266	26.92	0.00326
	Average	9.8	87.3	21.0	0.198	0.360	0.034	0.1945	7401		
	1.4 A	12.5	89	25	0.1165	0.214	0.0125	0.233	12191	47.64	0.00391
Newton	1.4 B	12.5	88	23	0.1005	0.1975	0.015	0.217	13135	55.82	0.00425
	1.4 C	12.5	88	23.5	0.102	0.208	0.015	0.226	10967	55.43	0.00505
	Average	12.5	88.3	23.8	0.106	0.2065	0.014	0.225	12098		
	1.7 A	15.1	79	6	0.0835	0.220	0.009	0.166	7917	50.87	0.00643
Newton	1.7 B	15.1	85	18.5	0.100	0.2115	0.010	0.173	10631	62.83	0.00591
	1.7 C	15.1	88	21.7	0.103	0.2095	0.0125	0.1795	10110	62.35	0.00617
	Average	15.1	84.0	15.4	0.0955	0.214	0.0105	0.173	9553		
	1.1 A	6.5	65	9.5	0.042	0.273	0.212	0.013	285.12	1.17	0.00410
Wheeler	1.1 B	6.5	63	9.25	0.031	0.2875	0.2755	0.0135	621.60	2.71	0.00436
	1.1 C	6.5	68	9.75	0.035	0.336	0.3125	0.015	475.81	2.23	0.00469
	Average	6.5	65.3	9.5	0.036	0.299	0.267	0.0138	461		
	1.4 A	8.2	68.5	9.0	0.0375	0.269	0.1795	0.029	1050.21	2.52	0.00240
Wheeler	1.4 B	8.2	75.5	13.5	0.0305	0.2975	0.1695	0.0255	596.05	2.52	0.00423
	1.4 C	8.2	70.5	8	0.034	0.274	0.1875	0.0285	796.71	3.22	0.00404
	Average	8.2	71.5	10.2	0.034	0.280	0.179	0.028	814		
	1.7 A	10.0	68	10.5	0.033	0.244	0.0845	0.0275	1085.92	4.01	0.00369
Wheeler	1.7 B	10.0	71.8	11.5	0.0275	0.224	0.0805	0.0215	810.88	3.19	0.00393
	1.7 C	10.0	70.5	10.75	0.026	0.247	0.0965	0.0285	618.78	2.54	0.00410
	Average	10.0	70.1	10.9	0.029	0.238	0.087	0.026	839		

* After Initial Cure

** After Final Cure

*** After Vacuum Saturation

Table A-14. Laboratory Data - Sequence III

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI, x 10^6 M_i 73°F*	M_f 73°F**	M_f 100°F***	M_s 73°F***	Indirect Tension E,PSI	σ_f	ε_f
Padre Island	1.1 A		****								
	1.1 B										
	1.1 C										
	Avg.										
Padre Island	1.4 A		****								
	1.4 B										
	1.4 C										
	Avg.										
Padre Island	1.7 A		****								
	1.7 B										
	1.7 C										
	Avg.										
Angelina	1.1 A	9.8	83.7	17	0.1645	0.849	0.3345	0.0985	2191	5.18	0.00236
	1.1 B	9.8	86.5	22	0.153	0.839	0.351	0.092	8337	18.57	0.00223
	1.1 C	9.8	85	22.5	0.170	0.8425	0.3575	0.094	7521	18.04	0.00240
	Avg.	9.8	85.1	20.5	0.1625	0.8435	0.348	0.095	6016		
Angelina	1.4 A	12.5	87.2	19.7	0.110	0.519	0.1945	0.125	5820	16.94	0.00291
	1.4 B	12.5	94.4	47.0	0.096	0.5385	0.226	0.245	10996	99.83	0.00908
	1.4 C	12.5	93.5	40.5	0.1135	0.546	0.202	0.245	19196	93.73	0.00488
	Avg.	12.5	91.7	35.7	0.1065	0.5345	0.2075	0.205	12004		
Angelina	1.7 A	15.1	79.2	10.5	0.0975	0.353	0.112	0.1185	16568	133.96	0.00869
	1.7 B	15.1	79.2	9.5	0.100	0.361	0.133	0.121	7309	32.55	0.00445
	1.7 C	15.1	84.0	23.0	0.098	0.324	0.0915	0.1715	8708	80.57	0.00925
	Avg.	15.1	80.8	14.3	0.0985	0.346	0.112	0.137	10867		
Trinity	1.1 A	7.5	90	26	0.198	0.225	0.018	0.127	11313.34	49.03	0.00433
	1.1 B	7.5	89	25	0.191	0.239	0.020	0.148	12694.19	20.68	0.00163
	1.1 C	7.5	88	21	0.113	0.240	0.020	0.090	7077.07	15.65	0.00221
	Avg.	7.5	89	24	0.167	0.235	0.019	0.123	10361		
Trinity	1.4 A	9.5	89	23	0.197	0.184	0.017	0.131	16247.02	45.93	0.00283
	1.4 B	9.5	89	28	0.169	0.175	0.014	0.154	17198.59	40.36	0.00235
	1.4 C	9.5	92	28	0.200	0.187	0.017	0.114			
	Avg.	9.5	90	26	0.189	0.182	0.016	0.133	16723		
Trinity	1.7 A	11.6	87	10	0.120	0.143	0.014	0.115	8873.97	57.47	0.00648
	1.7 B	11.6	86	11	0.140	0.146	0.011	0.090	9304.50	69.34	0.00745
	1.7 C	11.6	88	18	0.197	0.151	0.012	0.132			
	Avg.	11.6	87	13	0.152	0.147	0.012	0.112	9089		

*After initial cure
**After final cure
***After Vacuum Saturation
****Fell apart after Vacuum Saturation

Table A-15. Laboratory Data - Sequence III

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	M_i*	M_f 73°F**	M_f 100°F**	M_s*** 73°F	E,PSI	σ_f	ε_f,PSI
					Resilient Modulus, PSI, x 10^6				Indirect Tension		
Lufkin	1.1 A	7.2	72	7	0.027	0.221	0.433	0.050	1351	6.04	0.00447
	1.1 B	7.2	73	9	0.023	0.277	0.387	0.044	553	3.81	0.00689
	1.1 C	7.2	72	7	0.042	0.231	0.103	0.036	769	3.28	0.00427
	Avg.	7.2	72	8	0.031	0.243	0.308	0.043	891		
Lufkin	1.4 A	9.2	73	9	0.057	0.145	0.048	0.044	1347	5.31	0.00394
	1.4 B	9.2	75	8	0.058	0.141	0.059	0.051	1176	4.59	0.00390
	1.4 C	9.2	72	8	0.044	0.132	0.071	0.041	934	4.22	0.00452
	Avg.	9.2	73	8	0.053	0.139	0.059	0.045	1152		
Lufkin	1.7 A	11.2	79	10	0.027	0.190	0.083	0.056	922	4.19	0.00454
	1.7 B	11.2	78	11	0.028	0.194	0.077	0.068	1068	3.90	0.00365
	1.7 C	11.2	77	8	0.029	0.187	0.059	0.055	756	5.38	0.00712
	Avg.	11.2	78	10	0.028	0.190	0.073	0.060	915		
Lamb	1.1 A	6.5			0.129	0.168	0.050	0.002			
	1.1 B	6.5	49.5	3	0.092	0.217	0.153		279.69	1.15	0.00411
	1.1 C	6.5	56.0	5	0.075	0.217	0.131	0.004	215.77	.91	0.00422
	Avg.	6.5	52.75	4	0.099	0.201	0.111	0.003	248		
Lamb	1.4 A	8.2	57.0	4.5	0.129	0.229	0.203	0.007	353.72	1.58	0.00447
	1.4 B	8.2	53.0	3.5	0.092	0.263	0.396	0.008	370.25	1.57	0.00424
	1.4 C	8.2	59.0	5.5	0.075	0.239	0.291	0.009	333.46	1.43	0.00429
	Avg.	8.2	56.3	4.5	0.099	0.244	0.297	0.008	352		
Lamb	1.7 A	10.0	66.0	5.0	0.272	0.196	0.139	0.009	415.51	1.68	0.00404
	1.7 B	10.0	60.0	6.5	0.231	0.225	0.161	0.009	451.03	1.82	0.00404
	1.7 C	10.0	62.0	5.5	0.252	0.175	0.117	0.009	467.56	1.96	0.00419
	Avg.	10.0	62.7	5.7	0.252	0.199	0.139	0.009	445		

*After initial cure
**After final cure
***After Vacuum Saturation

Table A-16. Laboratory Data - Sequence III

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up After Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Jefferson	1.1 A	7.6	4.8		1.990	2.44	18.8	81.2
	1.1 B	7.6	4.8		1.995	2.45	18.6	81.4
	1.1 C	7.6	4.8		2.000	2.46	18.4	81.6
	Avg.	7.6	4.8	8.5	1.995	2.45	18.6	81.4
Jefferson	1.4 A	10.1	4.3		2.017	2.38	14.9	85.1
	1.4 B	10.1	4.3		2.027	2.38	14.5	85.5
	1.4 C	10.1	4.3		2.033	2.35	14.0	86.0
	Avg.	10.1	4.3	7.0	2.027	2.37	14.5	85.5
Jefferson	1.7 A	12.2	3.7		2.048	2.31	11.8	88.2
	1.7 B	12.2	3.7		2.050	2.31	11.6	88.4
	1.7 C	12.2	3.7		2.054	2.34	11.5	88.5
	Avg.	12.2	3.7	5.7	2.051	2.32	11.6	88.4
Newton	1.1 A	9.3	5.0		2.029	2.396	15.4	84.6
	1.1 B	9.3	5.0		2.052	2.383	14.5	85.5
	1.1 C	9.3	5.0		2.032	2.417	15.3	84.7
	Avg.	9.3	5.0	6.6	2.038	2.399	15.0	85.0
Newton	1.4 A	12.5	4.2		2.053	2.342	13.0	87.0
	1.4 B	12.5	4.2		2.063	2.353	12.6	87.4
	1.4 C	12.5	4.2		2.059	2.385	12.8	87.2
	Avg.	12.5	4.2	4.9	2.058	2.360	12.8	87.2
Newton	1.7 A	15.1	3.3		2.079	2.261	9.2	90.8
	1.7 B	15.1	3.3		2.070	2.299	9.6	90.4
	1.7 C	15.1	3.3		2.063	2.309	9.9	90.1
	Avg.	15.1	3.3	3.9	2.071	2.290	9.6	90.4
Wheeler	1.1 A	6.5	5		1.925	2.475	21.7	78.3
	1.1 B	6.5	5		1.934	2.459	21.3	78.7
	1.1 C	6.5	5		1.932	2.454	21.4	78.6
	Avg.	6.5	5	11.5	1.930	2.457	21.4	78.6
Wheeler	1.4 A	8.2	4.5		1.946	2.431	19.7	80.3
	1.4 B	8.2	4.5		1.944	2.475	19.8	80.2
	1.4 C	8.2	4.5		1.940	2.412	19.9	80.1
	Avg.	8.2	4.5	10.3	1.943	2.423	19.8	80.2
Wheeler	1.7 A	10.0	3.9		1.975	2.372	16.1	83.9
	1.7 B	10.0	3.9		1.965	2.354	16.5	83.5
	1.7 C	10.0	3.9		1.966	2.336	16.5	83.5
	Avg.	10.0	3.9	9.6	1.963	2.354	16.4	83.6

Table A-17. Laboratory Data - Sequence III

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up After Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Padre Island	1.1 A	*	*	*	*	*	*	*
	1.1 B							
	1.1 C							
	Avg.							
Padre Island	1.4 A	*	*	*	*	*	*	*
	1.4 B							
	1.4 C							
	Avg.							
Padre Island	1.7 A	*	*	*	*	*	*	*
	1.7 B							
	1.7 C							
	Avg.							
Angelina	1.1 A	9.8	6.0	5.4	2.108	2.400	12.9	87.1
	1.1 B	9.8	6.0		2.122	2.386	11.6	88.4
	1.1 C	9.8	6.0		2.111		12.0	88.0
	Avg.	9.8	6.0		2.114	2.399	12.2	87.8
Angelina	1.4 A	12.5	5.1	2.1	2.109	2.33	9.7	90.3
	1.4 B	12.5	5.1		2.088	2.32	10.6	89.4
	1.4 C	12.5	5.1		2.117		9.3	90.7
	Avg.	12.5	5.1		2.105	2.335	9.9	89.1
Angelina	1.7 A	15.1	4.2	2.8	2.107	2.288	6.1	93.9
	1.7 B	15.1	4.2		2.090	2.200	6.9	93.1
	1.7 C	15.1	4.2		2.101		6.4	93.6
	Avg.	15.1	4.2		2.099	2.244	6.5	93.5
Trinity	1.1 A	7.5	3.0	5.6	2.140	2.427	12.5	87.5
	1.1 B	7.5	3.0		2.163	2.471	11.6	88.4
	1.1 C	7.5	3.0		2.148		12.2	87.8
	Avg.	7.5	3.0		2.150	2.446	12.1	87.9
Trinity	1.4 A	9.5	2.3	4.1	2.173	2.398	10.6	89.4
	1.4 B	9.5	2.3		2.183	2.385	10.2	89.8
	1.4 C	9.5	2.3		2.192		9.8	90.2
	Avg.	9.5	2.3		2.183	2.431	10.2	89.8
Trinity	1.7 A	11.6	1.7	2.1	2.221	2.364	5.9	94.1
	1.7 B	11.6	1.7		2.223	2.353	5.8	94.2
	1.7 C	11.6	1.7		2.240		5.4	94.6
	Avg.	11.6	1.7		2.229	2.359	5.7	94.3

*Fell apart after Vacuum Saturation

Table A-18. Laboratory Data - Sequence III

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up After Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Lufkin	1.1 A	7.2	4.0	15.5	1.781	2.443	27.6	72.4
	1.1 B	7.2	4.0		1.783	2.479	27.5	72.5
	1.1 C	7.2	4.0		1.738		29.4	70.6
	Avg.	7.2	4.0		1.767	2.461		
Lufkin	1.4 A	9.2	3.3	14.8	1.809	2.425	25.1	74.9
	1.4 B	9.2	3.3		1.795	2.405	25.7	74.3
	1.4 C	9.2	3.3		1.748		26.1	73.9
	Avg.	9.2	3.3		1.784	2.415	25.6	74.4
Lufkin	1.7 A	11.2	2.7	12.3	1.840	2.396	22.9	77.1
	1.7 B	11.2	2.7		1.837	2.373	23.0	77.0
	1.7 C	11.2	2.7		1.806		24.3	75.7
	Avg.	11.2	2.7		1.828	2.385	23.4	76.6
Lamb	1.1 A	6.5	4.0	16.1	1.831	2.453	26.0	74.0
	1.1 B	6.5	4.0		1.810	2.496	26.9	73.1
	1.1 C	6.5	4.0		1.767		28.6	71.4
	Avg.	6.5	4.0		1.803	2.475	27.2	72.8
Lamb	1.4 A	8.2	3.5	13.8	1.821	2.443	24.8	75.2
	1.4 B	8.2	3.5		1.834	2.400	24.7	75.3
	1.4 C	8.2	3.5		1.844		23.9	76.1
	Avg.	8.2	3.5		1.833	2.422	24.5	75.5
Lamb	1.7 A	10.0	2.9	12.6	1.864	2.421	22.4	77.6
	1.7 B	10.0	2.9		1.863	2.385	22.5	77.5
	1.7 C	10.0	2.9		1.859		22.6	77.4
	Avg.	10.0	2.9		1.862	2.403	22.5	77.5

Table A-19. Laboratory Data Sequence IV

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI, x 10° M_i 73°F*	M_f 73°F**	M_f 100°F**	Indirect Tension E, PSI	σ_f, PSI	ε_f
Jefferson	1.1 A	***								
	1.1 B									
	1.1 C									
	Avg.									
Jefferson	1.4 A	***								
	1.4 B									
	1.4 C									
	Avg.									
Jefferson	1.7 A	***								
	1.7 B									
	1.7 C									
	Avg.									
Newton	1.1 A	9.8	94.0	51.2	0.0175	0.231	0.2275			
	1.1 B	9.8	96.0	62.0	0.0205	0.270	0.259	43048	124.64	0.00290
	1.1 C	9.8	96.0	61.5	0.021	0.2635	0.272	38443	109.99	0.00286
	Avg.	9.8	95.3	58.2	0.020	0.255	0.253			
Newton	1.4 A	12.5	94.0	34.0	0.008	0.134	0.066	19448	129.63	0.00667
	1.4 B	12.5	94.0	36.0	0.008	0.208	0.072	19743	129.21	0.00655
	1.4 C	12.5	95.0	44.0	0.007	0.156	0.089	21337	130.86	0.00613
	Avg.	12.5	94.3	38.0	0.008	0.166	0.076			
Newton	1.7 A	15.1	91.0	23.3	0.007	0.173	0.102	12046	115.57	0.00959
	1.7 B	15.1	88.5	21.7	0.0055	0.1945	0.100	10867	114.50	0.01054
	1.7 C	15.1	91.5	26.5	0.005	0.185	0.089	10779	115.79	0.01074
	Avg.	15.1	90.3	23.8	0.006	0.184	0.097			
Wheeler	1.1 A	6.5	92.0	19.5	0.002	0.275	0.149	11801	41.45	0.00351
	1.1 B	6.5	94.0	24.0		0.283	0.181	15963	47.31	0.00296
	1.1 C	6.5	93.0	24.5		0.239	0.1885	19796	55.96	0.00283
	Avg.	6.5	93.0	22.7	0.002	0.266	0.173			
Wheeler	1.4 A	8.2	93.0	20.0	0.0025	0.237	0.103	15261	56.74	0.00372
	1.4 B	8.2	93.5	27.6		0.154	0.123	16287	57.76	0.00355
	1.4 C	8.2	94.0	24.5	0.002	0.168	0.1155	16953	61.00	0.00360
	Avg.	8.2	93.5	24.0	0.002	0.186	0.114			
Wheeler	1.7 A	10.0	94.0	30.0	0.002	0.1295	0.875	21196	73.71	0.00348
	1.7 B	10.0	94.0	27.5	0.002	0.145	0.084	17130	73.95	0.00432
	1.7 C	10.0	93.5	24.9	0.002	0.148	0.114	19511	71.87	0.00368
	Avg.	10.0	93.8	27.5	0.002	0.141	0.095			

*After Initial Cure
**After Final Cure
***Not molded due to lack of material

Table A-20. Laboratory Data - Sequence IV

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI x 10^6 M_i 73°F	M_f 73°F*	M_s 100°F**	Indirect Tension E, PSI	σ_f, PSI	ε_f
Padre Island	1.1 A									
	1.1 B									
	1.1 C	***								
	Average									
Padre Island	1.4 A									
	1.4 B									
	1.4 C	***								
	Average									
Padre Island	1.7 A									
	1.7 A									
	1.7 C	***								
	Average									
Angelina	1.1 A	9.8	96	56	0.007	0.900	0.502			
	1.1 B	9.8	96	65	0.009	1.029	0.504	60892.59	141.82	0.00233
	1.1 C	9.8	96	65	0.007	0.790	0.365	52432.54	139.26	0.00266
	Average	9.8	96	62	0.008	0.906	0.457			
Angelina	1.4 A	12.5	96	62	0.012	0.652	0.206	21468.38	145.67	0.00679
	1.4 B	12.5	94	46	0.010	0.593	0.228	20498.23	133.80	0.00653
	1.4 C	12.5	94	59	0.013	0.623	0.284	22912.33	149.15	0.00651
	Average	12.5	95	56	0.012	0.623	0.239			
Angelina	1.7 A	15.1	94	50	0.020	0.445	0.120	14861.73	145.14	0.00977
	1.7 B	15.1	94	53	0.020	0.426	0.115	11767.31	143.14	0.01216
	1.7 C	15.1	94	55	0.018	0.408	0.113	13507.24	140.02	0.01037
	Average	15.1	94	53	0.019	0.426	0.116			
Trinity	1.1 A	7.5	97	45	0.010	1.034	0.408			
	1.1 B	7.5	97	47	0.013	1.010	0.429	24551.11	73.61	0.00300
	1.1 C	7.5	95	52	0.012	1.217	0.661	34485.43	93.61	0.00264
	Average	7.5	96	48	0.012	1.087	0.499			
Trinity	1.4 A	9.5	97	50	0.017	0.409	0.107	20175.12	101.30	0.00502
	1.4 B	9.5	96	54	0.012	0.481	0.171	23114.38	115.64	0.00500
	1.4 C	9.5	96	49	0.019	0.372	0.059	18180.57	120.21	0.00661
	Average	9.5	96	51	0.016	0.421	0.112			
Trinity	1.7 A	11.6	93	44	0.005	0.297	0.146	11022.07	73.27	0.00665
	1.7 B	11.6	92	34	0.006	0.300	0.151	14559.92	69.83	0.00480
	1.7 C	11.6	88	36	0.005	0.274	0.160	9436.97	69.02	0.00731
	Average	11.6	91	38	0.005	0.290	0.152			

* After Initial Cure
** After Final Cure
*** Not molded due to lack of material

Table A-21. Laboratory Data - Sequence IV

Aggregate Source	Sample Designation	Percent Emulsion	R Value	S Value	Resilient Modulus, PSI x 10^6 M_i 73°F*	M_f 73°F**	M_f 100°F**	Indirect Tension E, PSI	σ_f, PSI	ε_f
	1.1 A	7.2	89	14	0.007	0.178	0.046	11726	47.19	0.00402
Lufkin	1.1 B	7.2	92	15	0.009	0.171	0.044	11750	48.70	0.00414
	1.1 C	7.2	90	16	0.012	0.175	0.047	16763	51.72	0.00309
	Average	7.2	90	15	0.009	0.175	0.046			
	1.4 A	9.2	88	15	0.010	0.160	0.024	8873	53.36	0.00601
Lufkin	1.4 B	9.2	89	18	0.012	0.168	0.030	9098	62.03	0.00682
	1.4 C	9.2	91	19	0.010	0.168	0.030	9097	61.57	0.00677
	Average	9.2	89	17	0.011	0.165	0.028			
	1.7 A	11.2	90	17	0.007	0.162	0.211	13527	69.06	0.00511
Lufkin	1.7 B	11.2	87	14	0.006	0.157	0.182	14202	61.80	0.00435
	1.7 C	11.2	87	18	0.012	0.166	0.177	15119	69.42	0.00459
	Average	11.2	88	16	0.008	0.162	0.190			
	1.1 A	6.5	81.0	7.7	0.004	0.196	0.040	19816	45.49	0.00230
Lamb	1.1 B	6.5	82.0	13.3	0.001	0.266	0.046	15936	43.81	0.00275
	1.1 C	6.5	76.0	9.0	0.001	0.201	0.042	19593	37.58	0.00192
	Average	6.5	79.7	10.0	0.002	0.221	0.043			
	1.4 A	8.2	76.5	9.0	0.002	0.223	0.055	17361	55.91	0.00322
Lamb	1.4 B	8.2	83.0	11.6	0.002	0.208	0.105	18852	58.16	0.00309
	1.4 C	8.2	82.0	11.0	0.004	0.250	0.065	14677	52.29	0.00356
	Average	8.2	80.5	10.5	0.003	0.227	0.075			
	1.7 A	10.0								
Lamb	1.7 B	10.0								
	1.7 C	10.0								
	Average	10.0								
	1.1 A									
	1.1 B									
	1.1 C									
	Average									
	1.4 A									
	1.4 B									
	1.4 C									
	Average									
	1.7 A									
	1.7 B									
	1.7 C									
	Average									

* After Initial Cure
** After Final Cure

Table A-22. Laboratory Data - Sequence IV

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up After Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Padre Island	1.1 A	*	*	*	*	*	*	*
	1.1 B							
	1.1 C							
	Avg.							
Padre Island	1.4 A	*	*	*	*	*	*	*
	1.4 B							
	1.4 C							
	Avg.							
Padre Island	1.7 A	*	*	*	*	*	*	*
	1.7 B							
	1.7 C							
	Avg.							
Angelina	1.1 A	9.8	6.0		2.067	2.377	12.5	87.5
	1.1 B	9.8	6.0		2.097	2.321	11.2	88.8
	1.1 C	9.8	6.0		2.117	2.388	10.4	89.6
	Avg.	9.8	6.0	6.8	2.094	2.3621	11.4	88.6
Angelina	1.4 A	12.5	5.1		2.123	2.33	11.4	88.6
	1.4 B	12.5	5.1		2.100	2.46	12.3	87.7
	1.4 C	12.5	5.1		2.119		11.5	88.5
	Avg.	12.5	5.1	4.8	2.114	2.395	11.7	88.3
Angelina	1.7 A	15.1	4.2		2.130	2.284	7.4	92.6
	1.7 B	15.1	4.2		2.126	2.318	7.6	92.4
	1.7 C	15.1	4.2		2.119		7.9	92.1
	Avg.	15.1	4.2	3.6	2.125	2.301	7.6	92.4
Trinity	1.1 A	7.5	3.0		2.127	2.443	12.4	87.6
	1.1 B	7.5	3.0		2.132	2.423	12.2	87.8
	1.1 C	7.5	3.0		2.171	2.417	10.3	89.7
	Avg.	7.5	3.0	5.8	2.143	2.428	11.6	88.4
Trinity	1.4 A	9.5	2.3		2.196	2.404	8.5	91.5
	1.4 B	9.5	2.3		2.188	2.397	8.9	91.1
	1.4 C	9.5	2.3		2.210		8.0	92.0
	Avg.	9.5	2.3	3.8	2.198	2.401	8.5	91.5
Trinity	1.7 A	11.6	1.7		2.189	2.431	9.9	90.1
	1.7 B	11.6	1.7		2.203	2.407	9.0	91.0
	1.7 C	11.6	1.7		2.185		9.7	90.3
	Avg.	11.6	1.7	5.3	2.192	2.419	9.5	90.5

*Not molded due to lack of material

Table A-23. Laboratory Data. Sequence IV

Aggregate Source	Sample Designation	Percent Emulsion	Percent Mixing Water	Moisture Pick Up After Vacuum Saturation, %	Bulk Specific Gravity	Rice Specific Gravity	Percent Air Voids	Percent Relative Density
Lufkin	1.1 A	7.2	4.0		1.793	2.429	27.1	72.9
	1.1 B	7.2	4.0		1.792	2.489	27.1	72.9
	1.1 C	7.2	4.0		1.797		27.0	73.0
	Avg.	7.2	4.0	15.0	1.794	2.459	27.1	72.9
Lufkin	1.4 A	9.2	3.3		1.776	2.414	26.3	73.7
	1.4 B	9.2	3.3		1.819	2.406	24.5	75.5
	1.4 C	9.2	3.3		1.816		24.6	75.4
	Avg.	9.2	3.3	14.3	1.804	2.410	25.1	74.9
Lufkin	1.7 A	11.2	2.7		1.831	2.396	22.9	77.1
	1.7 B	11.2	2.7		1.788	2.353	25.1	74.9
	1.7 C	11.2	2.7		1.831		22.9	77.1
	Avg.	11.2	2.7	14.1	1.817	2.375	23.6	76.4
Lamb	1.1 A	6.5	4.0		1.820	2.398	24.5	75.5
	1.1 B	6.5	4.0		1.819	2.423	24.6	75.4
	1.1 C	6.5	4.0		1.783		26.0	74.0
	Avg.	6.5	4.0	15.2	1.807	2.411	25.0	75.0
Lamb	1.4 A	8.2	3.5		1.829	2.417	24.2	75.8
	1.4 B	8.2	3.5		1.835	2.407	24.0	76.0
	1.4 C	8.2	3.5		1.833		24.0	76.0
	Avg.	8.2	3.5	13.7	1.832	2.412	24.1	75.9
Lamb	1.7 A	10.0	2.9					
	1.7 B	10.0	2.9					
	1.7 C	10.0	2.9					
	Avg.	10.0	2.9					