LABORATORY CORRELATION OF SOIL SWELL POTENTIAL

Final Report

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TABLE OF CONTENTS

IMPLEMENTATION

Results of this study indicate poor correlations between the test data of the Third Cycle Expansion Pressure Test and that of the Potential Volume Change, Potential Vertical Rise, and Linear Expansion Tests. As a result, values of the dependent variable (E.P. test) can not be closely estimated from values of any of the independent variables (P.V.C., P.V.R., L.E. test); therefore use of these correlations is not recommended for implementation.

METRIC CONVERSION CHART

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
square yards	0.8361274	square meters
acres	0.40468	hectares
cubic yards	0.7645549	cubic meters
pounds (mass)	0.4535924	kilograms
pounds (force) per square foot	47.88026	pascals
pounds (force) per lineal foot	14.5939	newtons per meter
pounds (force) per square inch (psi)	689.4757	pascals

Conversion of degree fahrenheit to degree celsius

degree celsius (t_c) = (degree fahrenheit (t_f-32)/1.8

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Louisiana has an abundance of clay soils which, potentially, have the capacity for large volume changes, either swelling or shrinkage. In large areas of the State, the surface or near surface soils contain large quantities of montmorillonite clay mineral. There also are beds of bentonite (nearly 100% calcium montmorillonite) (1)* widespread in central and northern parts of the State. However, the problems with swelling soils in highway construction have seldom been associated with in-situ conditions. This may be due in part to the normally high natural moisture content of the soil or to a high water table, or a combination of the two. In the case of bentonite, the beds are usually less than one foot in thickness and pinch out locally. The thickest deposit known slightly exceeds ten feet, but its extent is only 4 acres.

Virtually all of the problems associated with swelling soils have occurred in construction of highway fills, the predominate materials used being soils with AASHTO groups of A-6 or A-7-6. In some sections of the State, soils with plasticity indices averaging 35 to 45, with some individual values as high as 100, are the only materials locally available.

The potential problem resulting from using this type material was not generally recognized in Louisiana until the early stages of interstate highway construction. The advent of this construction resulted in a change in the size and type of contractor's equipment, as well as techniques, used in moving and compacting the large quantities of fill material required. Prior to this most new location construction involved secondary roads, which were designed for low volume traffic, thus requiring only shallow fills for load carrying purposes.

*(1) Underlined numbers in parenthesis refer to bibliography.

It became apparent during the investigation of a 1968 construction problem (2) that continued use of soils with high plasticity indices, without regard to their potential swelling characteristic, could become very costly. In this case several bridge approach slabs had to be replaced as a result of a combination of factors, one of which was swelling soils. It was also apparent that swell potential of a material should be determined prior to placement in the fill, preferably at the source. Since most soils used are from contractor's borrow pits, it could be routinely determined along with other required soil tests for material approval prior to excavation.

During the latter part of 1972, a training course dealing with volume changes in embankments (7) was developed within the department. This course described an indirect technique, using Atterberg limits balanced with field experience, to identify and classify potential swelling soils. Use of this technique was easily implementable in that all embankment materials are subjected to mechanical and physical analyses prior to use. However, it was felt that consideration should be given to a direct technique to get more definition of soil behavior.

A review of the literature (3,4,5,6) indicates many laboratory identification and testing techniques are available to qualitatively describe the volume change behavior of soils. They can be grouped in three catagories: indirect, direct, and a combination of the two. Indirect techniques employ a measurement of a related soil property as an indication of swell potential, such as soil composition, physiochemical, physical, and index properties. Direct techniques involve measurement of one-directional swell in a loaded swell test, usually employing an odometer-type testing apparatus. This latter technique is intended to give a quantitative prediction of the magnitude of swell in any given field condition. The third, or combination technique is simply that, a combination of the first two.

The only direct technique which was available to the department testing laboratory was the single cycle expansion pressure phase of the California R-value test (8). This was the technique used to identify the swelling potential of soils in the investigation of the construction problem mentioned above. If this technique were to be implemented and used by all district laboratories, substantial purchase of R-value expansion pressure equipment would be required, since the Research Section had the only apparatus, or establishment of a correlation to another test procedure which would allow a more moderate investment for equipment. This research effort was initiated in an attempt to accomplish the latter objective.

Initially, two tests were explored for correlation to the expansion pressure (E.P.) test: the Potential Volume Change (P.V.C.) developed for the Federal Housing Administration, and the Texas Highway Department Method of Determining Potential Vertical Rise (P.V.R.). In addition, the Tentative Linear Expansion Index Test, developed by the Soils Mechanics Group of the Los Angeles Section of ASCE, was included during the course of this effort. This test is herein identified as the Linear Expansion Test.

SCOPE

The objective of the study was to determine if a correlation exists between the Potential Volume Change Test and the Potential Vertical Rise Test as compared to the Third Cycle Expansion Pressure Test. In order to accomplish this objective, samples of soils in selected areas of the State were obtained and subjected to the above tests. A direct comparison was made between the Third Cycle Expansion Pressure Test data and that of the Potential Volume Change and Potential Vertical Rise Tests. The sets of data, in each case, were regressed on linear curves. The coefficient of determination (R^2) was used to indicate the quality of "fit" achieved by the regression and was obtained by use of a computer SAS software package.

METHODOLOGY

Soils used in this research were obtained from selective areas of the State. Particular effort was made to secure samples from embankments which had distorted pavement sections due to swelling soils. Routine classification tests were performed on all soils sampled. These tests included mechanical analysis (La. DOTD-TR 407), physical analysis (La. DOTD-TR 428), moisture-density relationship determinations (La. DOTD-TR 418), and Bar Linear Shrinkage (Texas Test Method 107-E). The results of classification tests for each soil are listed in Table 1 of the appendix.

The swell test procedures used in this effort were developed by others. Brief description of each test is given below along with reference to the original development work or agency test procedure, both of which are readily available in the literature. Necessary modifications for our use of any phase of a particular test procedure is also listed where appropriate. Test results for each soil are listed in Table 2 of the appendix.

Third Cycle Expansion Pressure Test

The Third Cycle Expansion Pressure Test used in this work was developed (9) by the California DOT in 1967. It is a modification of the standard one-cycle expansion pressure test for determination of the resistance "R" value of untreated materials. Briefly, it consists of placing standard test specimens, 4.0 inches in diameter by 2.5 inches high, in the expansion pressure device (Figure 1), with a 0.33-foot cover surcharge applied. The specimen is allowed to expand overnight against a calibrated bar with water available only at the top. The following day the expansion pressure is read and released back to the starting point (zero on the dial), and the specimen allowed to expand for the second time overnight. The process is repeated by reading and releasing the pressure built during the next day and for the third and final time

By application of the soils' physical constants and other information listed above to empirically derived sets of mathematical formulae and charts, either the percent free swell or potential vertical rise (in inches) for each soil stratum can be determined.

Linear Expansion Test

This test is basically the procedure developed by the Soils Mechanics Group of the Los Angeles Section of ASCE and described in reference (11). It was designed to measure a basic index property, with no attempt made to duplicate any particular moisture or loading conditions that may occur in the field. The test procedure used was as follows:

1. Soil Preparation. Soil was oven-dried at 150° F and prepared to minus No. 4 sieve size. Water was added to the soil and the mixture slaked in plastic bags for a minimum of 16 hours. The quantity of water for each soil was equal to its respective plastic limit.

2. Compaction. The procedure was modified, as in the PVC test, to facilitate fabrication of a specimen to a given density. This allowed a given amount of soil to be compacted into a mold of known volume at 95% of its maximum dry weight density. The soils were compacted in a mold (Figure 4) consisting of three parts, a 0.5 inch top collar, 1.0 inch sample ring, and 0.5 inch bottom collar, all 4 inches in diameter. Sufficient soil was compacted to result in a specimen 2.0 inches high by 4.0 inches in diameter. The sample ring was arranged so that after compaction 0.5 inch would be trimed off top and bottom resulting in a test specimen 1.0 inch high by 4.0 inches in diameter.

3. Test Interval. The top and bottom collars were rejoined to the sample ring containing the test specimen, with a porous stone being placed on the top and bottom of the specimen. This unit was then placed in a plastic container with a weight equaling one psi surcharge on the test specimen. Water was added to completely submerge the soil for 24 hours with the inches of vertical swell read from a dial placed on the surcharge weight.

DISCUSSION OF RESULTS

In an effort to "fit" the data to a known function, each set of data was regressed on the following curves:

1. Linear curves ($y = a + bx$)
2. Exponetial curves ($y = ae^{bx}$ with $a > o$)
3. Logarithmic curves ($y = a + b \ln x$)
4. Power curves ($y = a x^{b}$ with $a > o$)

The coefficient of determination R^2 was used to indicate the quality of fit achieved by the regression, and was obtained by use of an SAS software package.

The analysis indicated that there was a relationship between the test data of the Third Cycle Expansion Test (dependent variable) and test data for each of the P.V.C., P.V.R. and Linear Expansion Tests (independent variables). In each case, the relationship was found to fit a linear curve more than any of the other three listed above. The R^2 values for the three correlations ranged between 0.1144 and 0.5056. These values and the linear curve equation are shown on Figures 5, 6 and 7, along with the plot of the respective data.

It is apparent from the figures that values of the dependent variable can not be closely estimated from the values of the independent variables. Therefore, as a result of the poor correlation and variations within each testing method, none of the three test methods should be used for routine determination of swell potential. Further, it is recommended that the Expansion Pressure Test also not be used for routine determination of swell potential. This is based on the variation of test results in this research effort and on the findings of a recent expansive soil study (13) conducted by the California Department of Transportation. The California investigation indicated that the structural section design indices (R-value expansion or cover by 3rd cycle) did not correlate with the magnitude of the observed distress. Their laboratory work indicated that some routine soil classification tests are equal to, or better than, certain cumbersome tests recommended by other researchers for identifying expansive soils.

In addition to the correlation attempts discussed above, the relationship of the test data for each of the four methods of determining soil swell potential versus plasticity indices was examined. This was suggested as possible correlation (direct test versus indirect test) by some researchers in the literature cited previously. The relationships appear to be linear, but with poor correlation. An exception is for the P.V.R. method versus plasticity indices where there is very good correlation. This was expected due to the plasticity indices being one of the prime criteria used in the P.V.R. method of determining inches of rise or percent swell of a soil. The plot of the data for each case is shown in Figures 8 through 15, inclusive, of the appendix.

The cause of the apparent variability in method was not determined. It would have required a large experimental design with many repetitions for each test procedure. It has been documented (11,12) that many factors such as initial water content, initial dry density, soil structure, surcharge load, sample size and shape, stress history and testing time, influence volume change in expansive soils. To determine the degree of influence in each case was beyond the scope of this research.

SUMMARY AND CONCLUSIONS

The analysis of the test data indicated there was a linear relationship between the Third Cycle Expansion Test (dependent variable) and test data for each of the P.V.C., P.V.R. and Linear Expansion tests. The coefficient of determination (R^2) values ranged between 0.1144 and 0.5056.

There was poor correlation between the sets of test data compared, along with considerable variation of test data within individual test methods, thus values of the dependent variable can not be closely estimated from values of the independent variables.

Neither the cause of the apparent variability in test results, nor the degree of influence in each cas, was determined.

RECOMMENDATIONS

A review of the literature on swelling soils indicates much research effort has been expended toward developing identification and prediction techniques relative to the expansive characteristics of soils; the latest and most complete study is the on-going research being conducted by the U.S. Corps of Engineers (14, 15). There appears to be numerous and widely differing methods available for testing and classifying potentially expansive soils, none of which are universally accepted as a standard procedure.

Presently there appears to be neither an indirect method of identification of swelling potential that has general application nor a direct testing procedure which takes into account the in-situ conditions, expected loading, varying construction techniques, and the ambient environmental conditions which influence volume change necessary for a reliable and reproducible test.

Based on the results of this research, a review of the literature, and the state-of-the-art for laboratory and field determinations of soil swell potential, it is recommended that the present Department policy for using embankment materials with swelling potential, established and implemented during the course of this study, be continued. It appears that this procedure is the most rational and practical for application to Louisiana embankment materials and construction procedures. This procedure is listed in the appendix.

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APPENDIX

TABLE 1

RESULTS OF ROUTINE CLASSIFICATION TESTS

Laboratory Number	Soil Type	MECHANICAL ANALYSIS Coarse Sand (>.420 mm)	Fine Sand (.420 mm to .074 mm)	Silt (.074 mm to .005 mm)	Clay (<.005 mm)	Colloids (<.001 mm)	ATTERBERG LIMITS Liquid Limit	Plastic Limit	Plasticity Index	MOISTURE-DENSITY RELATIONSHIPS Max. Dry Wt. (lbs./ft.^{3})	Opt. M.C. (%)
SR-228	Silty Clay A-7-6(16)	0	2	54	44	32	43	14	29	105.1	18.2
SR-234	Silty Clay A-7-6(19)	0	0	56	44	35	56	17	39	103.6	18.6
SR-248	Medium Silty Clay A-7-6(17)	0	7	39	54	38	45	15	30	103.6	18.6
SR-249	Medium Silty Clay A-7-6(19)	0	1	39	60	44	53	18	35	96.3	23.2
SR-251	Silty Clay A-6 (12)	1	10	56	33	23	33	13	20	113.4	14.0
SR-252	Light Silty Clay A-7-6(15)	0	13	44	43	32	41	13	28	109.1	16.1
SR-253	Medium Silty Clay A-7-6(19)	0	4	38	58	44	53	17	36	94.3	24.7
SR-254	Heavy Clay A-7-6(20)	0	12	21	67	52	74	21	53	89.1	28.2
SR-268	Heavy Clay A-7-6(20)	0	1	13	86	67	84	30	54	80.5	34.9
SR-282	Light Silty Clay A-7-6(18)	0	2	49	49	37	56	18	38	97.3	22.6
SR-286	Silty Clay A-7-6(15)	1	5	55	39	28	43	18	25	97.3	22.6
SR-326	Heavy Clay A-7-6(20)	1	2	26	71	54	68	24	44	90.8	26.6
SR-330	Heavy Clay A-7-6(20)	1	2	16	81	62	74	27	47	87.4	29.6
SR-332	Heavy Clay A-7-5(20)	1	1	6	92	72	81	30	51	84.9	31.1
SR-334	Heavy Clay A-7-6(20)	1	3	25	71	54	59	23	36	91.6	26.0
SR-335	Heavy Clay A-7-5(20)	0	1	16	83	67	76	28	48	86.8	30.0
SR-337	Medium Silty Clay A-7-6(18)	1	3	42	54	41	55	19	36	99.7	21.0
SR-338	Light Silty Clay A-7-6(15)	2	4	48	46	36	42	15	27	103.6	18.6
SR-339	Medium Silty Clay A-7-6(18)	1	4	40	55	45	52	18	34	97.3	22.6
SR-340	Heavy Clay A-7-5(19)	1	3	29	67	51	57	19	38	96.3	17.8
SR-344	Silty Clay A-7-6(16)	0	6	55	39	32	43	15	28	105.1	18.2
SR-345	Medium Silty Clay A-7-6(20)	0	4	33	63	46	58	20	38	94.3	24.7
SR-347	Silty Clay A-6 (12)	0	6	63	31	24	36	15	21	109.6	16.1
SR-348	Heavy Clay A-7-5(20)	0	2	23	75	56	73	21	52	88.4	28.8
SR-349	Heavy Clay A-7-6(20)	0	1	30	69	55	73	24	49	87.4	29.6
SR-350	Heavy Clay A-7-5(20)	0	1	18	81	61	82	23	59	84.9	31.1
SR-352	Silty Clay A-6 (13)	0	6	62	32	25	36	14	22	105.9	17.9
SR-353	Heavy Clay A-7-6(20	0	2	31	67	52	65	24	41	90.8	26.6
SR-354	Heavy Clay A-7-6(20)	0	2	29	69	53	70	21	49	90.8	26.6
SR-355	Heavy Clay A-7-6(20)	0	2	29	69	53	69	22	47	89.7	27.6
SR-356	Heavy Clay A-7-6(20)	1	1	32	66	52	67	20	47	89.7	27.6
SR-357	Heavy Clay A-7-5(20)	1	1	15	83	63	83	26	57	86.2	30.4
SR-359	Medium Silty Clay A-7-6(19)	0	4	45	51	41	53	16	37	96.8	22.9
SR-360	Heavy Clay A-7-6(20)	0	2	25	73	59	75	22	53	86.8	30.0
SR-363	Silty Clay A-7-6(17)	0	5	50	45	34	43	14	29	105.1	18.2
SR-364	Heavy Clay A-7-6(20)	1	2	27	70	49	63	20	43	94.8	24.2
SR-396	Light Silty Clay A-7-6(19)	4	6	44	46	32	57	18	39	101.1	19.0
SR-397	Medium Silty Clay A-7-6(20)	1	2	43	54	41	75	21	54	95.4	23.7
SR-399	Light Silty Clay A-7-6(20)	2	2	49	47	36	64	19	45	99.7	21.0
SR-403	Medium Silty Clay A-7-6(20)	1	3	45	51	38	58	18	40	99.0	21.5
SR-405	Silty Clay A-7-6(19)	0	1	51	48	36	56	17	39	105.1	18.2
SR-408	Silty Clay A-6 (13)	1	2	59	38	29	38	16	22	106.6	17.6
SR-411	Silty Clay Loam A-6 (12)	0	13	58	29	18	32	14	18	109.1	16.1
SR-412	Heavy Clay A-7-6(20)	2	1	32	65	44	72	20	52	93.0	25.3
SR-413	Medium Silty Clay A-7-6(20)	1	2	35	62	46	70	22	48	95.4	23.7
SR-414	Medium Silty Clay A-7-6(20)	0	2	44	54	38	63	17	46	98.6	21.9
SR-415	Silty Clay A-7-5(18)	0	2	57	41	32	50	16	34	101.8	20.0
SR-418	Medium Silty Clay A-7-6(19)	1	5	44	50	38	52	15	37	101.8	20.0
SR-419	Silty Clay A-7-6(18)	1	2	50	47	37	49	16	33	102.5	19.5
SR-852	Heavy Clay A-7-6(20)	1	1	23	75	50	73	23	50	94.3	24.7
SR-853	Heavy Clay A-7-6(20)	0	1	33	66	52	60	20	40	94.3	24.7

TABLE 2

LISTING OF SWELLING SOILS DATA USED IN PROC PLOT PROCEDURE

Identification of Labeling of Input Data Used in PROC Plot Procedure

X 1 = Liquid Limit
X 2 = Plasticity Index
X 3 = PVR % Swell - Zero Surcharge
X 4 = PVR Inches of Rise - Zero Surcharge
X 5 = PVR % Swell - One PSI Surcharge
X 6 = PVR Inches of Rise - One PSI Surcharge
X 7 = Linear Expansion Test - % Swell (only 21 soils tested)
X 8 = Linear Expansion Test - Inches of Rise (only 21 soils tested)
X 9 = R-Value Expansion Pressure - % Swell (24 hours)
X10 = R-Value Expansion Pressure - PSF (24 hours)
X11 = R-Value Expansion Pressure - % Swell (72 hours)
X12 = R-Value Expansion Pressure - PSF (72 hours)
X13 = PVC - % Swell
X14 = PVC - PSF
X15 = Bar Linear Shrinkage - % Shrinkage

TABLE 2 (Continued)

LISTING OF SWELLING SOILS DATA USED IN PROC PLOT PROCEDURE

OBS	LAB_NO	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
1	SR228	43	29	11.2	0.34	8.0	0.18	.	.	0.86	935	1.84	462	0.20	1069	14
2	SR234	56	39	16.0	0.43	12.5	0.31	.	.	0.43	445	1.02	200	.	.	17
3	SR248	45	30	11.6	0.31	8.4	0.20	4.3	0.043	0.72	750	1.41	330	0.19	993	15
4	SR249	53	35	13.4	0.32	10.1	0.20	7.5	0.075	0.92	970	1.96	420	0.13	665	15
5	SR251	33	20	7.5	0.23	4.6	0.14	.	.	0.19	199	0.38	70	0.12	614	9
6	SR252	41	28	10.7	0.30	7.6	0.18	5.3	0.053	0.73	740	0.83	300	0.23	1212	13
7	SR253	53	36	13.7	0.32	10.4	0.20	8.2	0.081	1.61	1710	3.00	610	0.16	850	16
8	SR254	74	53	19.5	0.49	15.8	0.43	.	.	1.43	1510	3.10	710	0.21	1116	20
9	SR268	84	54	19.1	0.60	16.2	0.45	9.0	0.090	0.66	700	1.73	450	0.22	1161	22
10	SR282	56	38	14.5	0.32	11.1	0.22	6.1	0.061	0.61	645	1.55	270	0.21	1128	15
11	SR286	43	25	9.6	0.29	6.5	0.19	.	.	0.42	450	0.95	200	0.16	858	13
12	SR326	68	44	16.6	0.44	13.1	0.31	.	.	0.62	690	1.30	350	0.21	1141	21
13	SR330	74	47	17.6	0.46	14.0	0.34	4.5	0.045	0.43	480	0.95	260	0.22	1155	21
14	SR332	81	51	18.9	0.49	15.2	0.40	6.4	0.064	0.42	470	0.97	270	0.26	1366	24
15	SR334	59	36	13.7	0.33	10.4	0.20	6.9	0.069	0.54	600	1.18	240	0.20	1088	17
16	SR335	76	48	17.9	0.48	14.3	0.40	.	.	0.24	275	0.42	110	0.23	1211	24
17	SR337	55	36	13.7	0.33	10.4	0.20	.	.	0.30	320	0.93	200	0.24	1276	16
18	SR338	42	27	10.4	0.31	7.3	0.18	.	.	0.36	390	1.16	225	0.21	1130	14
19	SR339	52	34	13.0	0.32	9.7	0.20	.	.	0.66	690	1.54	340	0.19	1018	19
20	SR340	57	38	14.5	0.34	11.1	0.22	.	.	0.72	770	1.50	365	0.23	1254	19
21	SR344	43	28	10.7	0.31	7.6	0.18	.	.	0.29	300	0.73	310	0.24	1285	15
22	SR345	58	38	14.5	0.34	11.1	0.22	.	.	0.89	930	1.85	480	0.21	1105	19
23	SR347	36	21	8.1	0.23	5.1	0.15	.	.	0.04	40	0.08	30	0.12	640	11
24	SR348	73	52	19.2	0.48	15.5	0.43	.	.	1.45	1520	2.30	820	0.21	1105	21
25	SR349	73	49	18.2	0.44	14.6	0.39	.	.	0.70	770	1.65	450	0.16	867	22
26	SR350	82	59	21.3	0.52	17.5	0.44	9.4	0.093	1.18	1280	2.48	660	0.17	920	21
27	SR352	36	22	8.4	0.23	5.4	0.15	.	.	0.18	195	0.96	90	0.13	673	8
28	SR353	65	41	15.5	0.37	12.1	0.27	.	.	0.30	315	0.70	205	0.17	914	19
29	SR354	70	49	18.2	0.48	14.6	0.36	.	.	1.09	1180	2.32	610	0.25	1352	22
30	SR355	69	47	17.6	0.40	14.0	0.34	.	.	1.05	1120	2.30	420	0.20	1074	21
31	SR356	67	47	17.6	0.40	14.0	0.34	.	.	0.69	745	1.95	610	0.20	1049	20
32	SR357	83	57	20.8	0.51	17.0	0.48	.	.	0.55	590	2.15	330	0.23	1189	23
33	SR359	53	37	14.0	0.34	10.7	0.22	5.2	0.052	.	.	.	.	0.17	934	17
34	SR360	75	53	19.5	0.50	15.8	0.43	8.3	0.082	0.94	1020	2.76	610	0.23	1228	20
35	SR363	43	29	11.2	0.32	8.0	0.18	5.0	0.050	0.72	780	1.50	390	0.24	1279	15
36	SR364	63	43	[illegible]	0.38	12.7	0.31	7.6	0.075	0.84	870	1.60	370	0.20	1052	20
37	SR396	57	39	14.3	0.34	10.9	0.22	.	.	0.66	700	0.95	190	0.21	1083	19
38	SR397	75	54	19.8	0.50	16.1	0.46	.	.	0.92	1000	1.60	310	0.23	1259	23
39	SR399	64	45	16.6	0.39	13.1	0.31	5.8	0.058	0.68	735	1.13	210	0.19	1007	19
40	SR403	58	40	15.1	0.35	11.7	0.27	.	.	0.72	765	1.34	310	0.14	769	17
41	SR405	56	39	14.8	0.35	11.4	0.25	5.1	0.051	0.52	555	0.95	160	0.20	1038	18
42	SR408	38	22	8.4	[illegible]	5.4	0.15	.	.	0.07	70	0.13	30	0.11	600	13
43	SR411	32	18	[illegible]	[illegible]	4.6	0.09	.	.	0.11	115	0.23	65	0.04	250	12
44	SR412	72	52	[illegible]	[illegible]	[illegible]	0.47	9.3	0.092	[illegible]	1150	2.00	370	0.24	1301	19
45	SR413	70	48	17.9	0.47	[illegible]	0.41	.	.	0.48	510	1.02	[illegible]	0.24	1274	20
46	SR414	63	45	17.3	[illegible]	13.7	0.34	.	.	0.70	[illegible]	1.42	[illegible]	0.20	1043	19
47	SR415	50	34	[illegible]	[illegible]	9.7	0.20	3.8	0.038	0.53	575	0.59	145	0.18	839	13
48	SR418	52	37	[illegible]	[illegible]	10.7	0.22	8.1	0.081	0.80	925	1.72	410	0.22	1158	18
49	SR419	49	33	13.7	[illegible]	8.4	0.23	.	.	0.36	375	0.95	185	0.23	1200	17
50	SR852	73	50	18.5	[illegible]	14.9	0.39	7.4	0.074	0.65	710	1.20	270	0.24	1304	18
51	SR853	60	[illegible]	15.1	[illegible]	11.7	0.27	7.6	0.078	0.63	675	1.76	525	0.19	1018	18

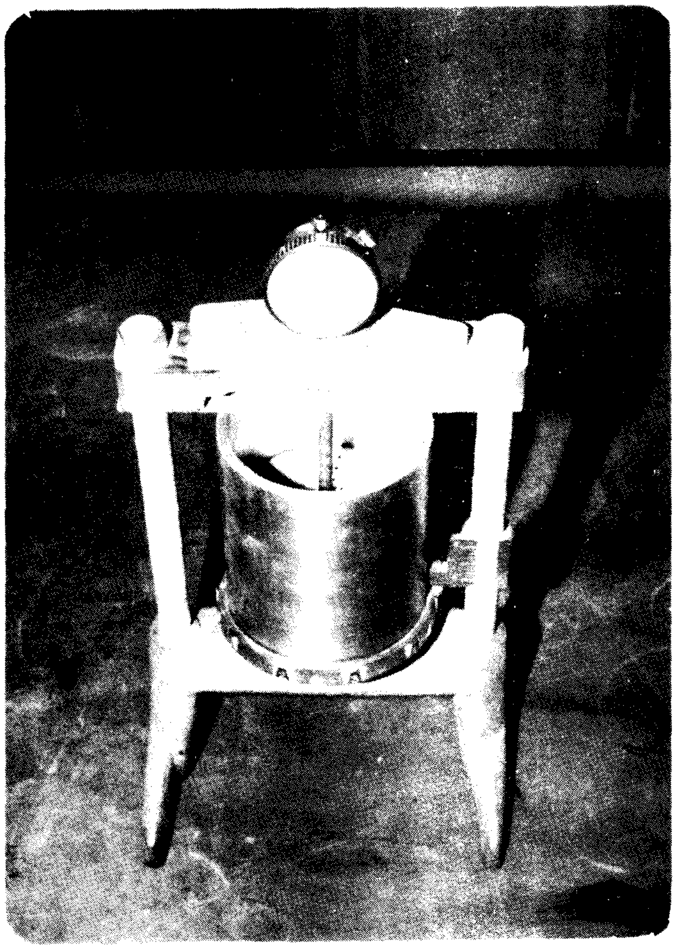

FIGURE 1

Expansion Pressure Device

FIGURE 2

Federal Housing Administration Potential Volume Change Test Apparatus

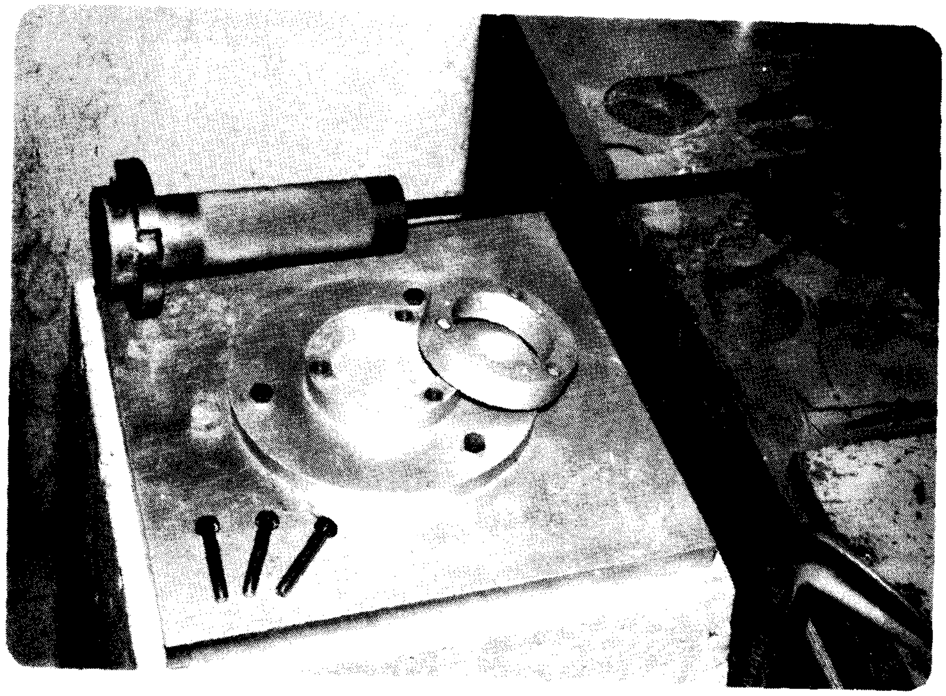

FIGURE 3

Modified Compaction Hammer and Test Mold for P.V.C. Test

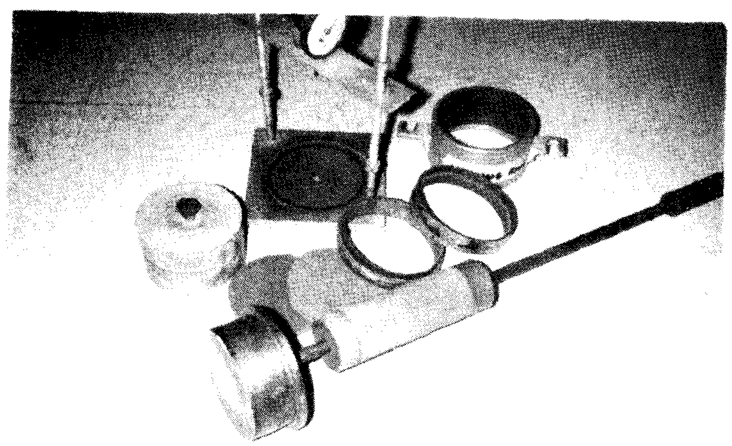

FIGURE 4

Linear Expansion Test Apparatus

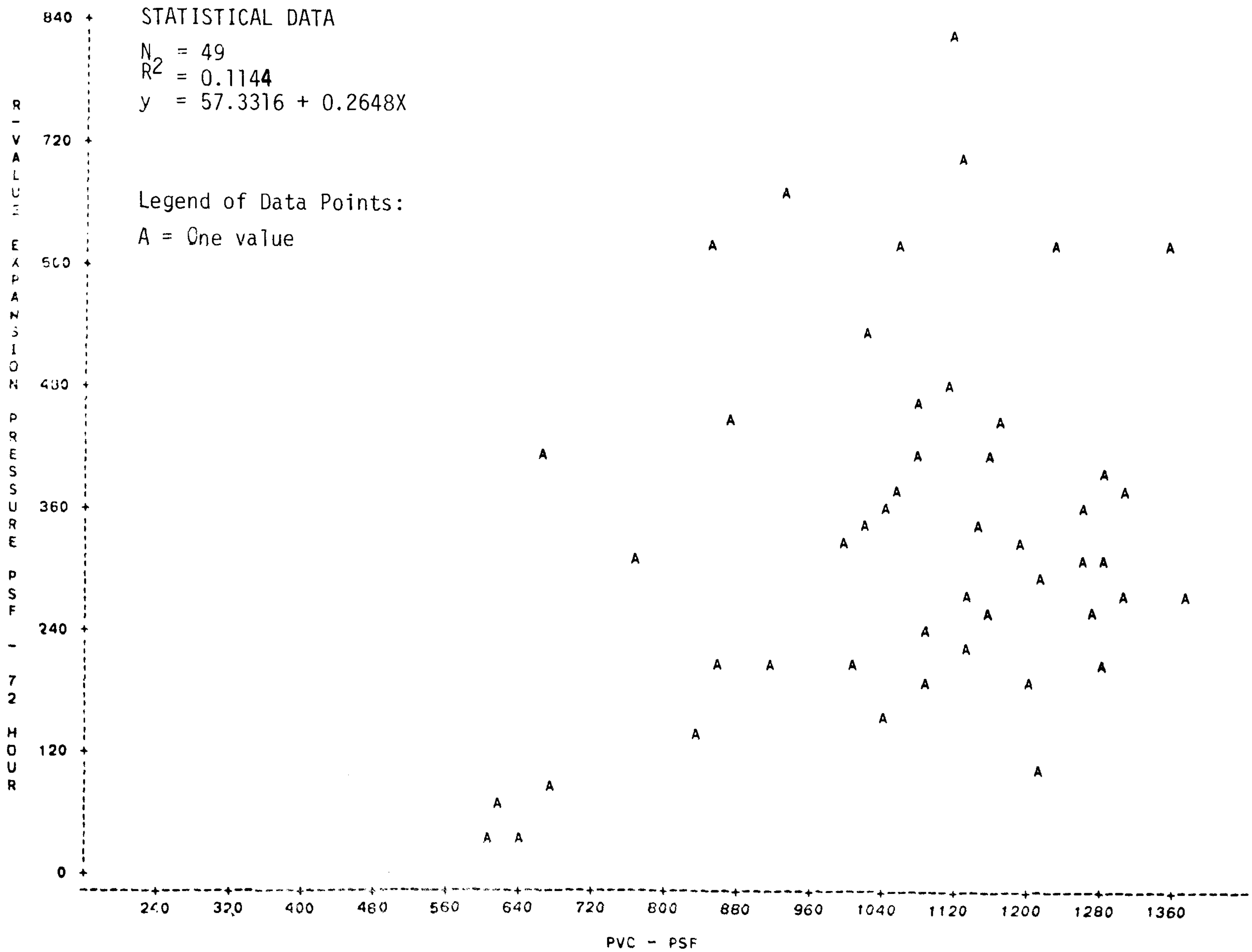

FIGURE 5

R-Value Expansion Pressure PSF - 72 Hours versus PVC - PSF

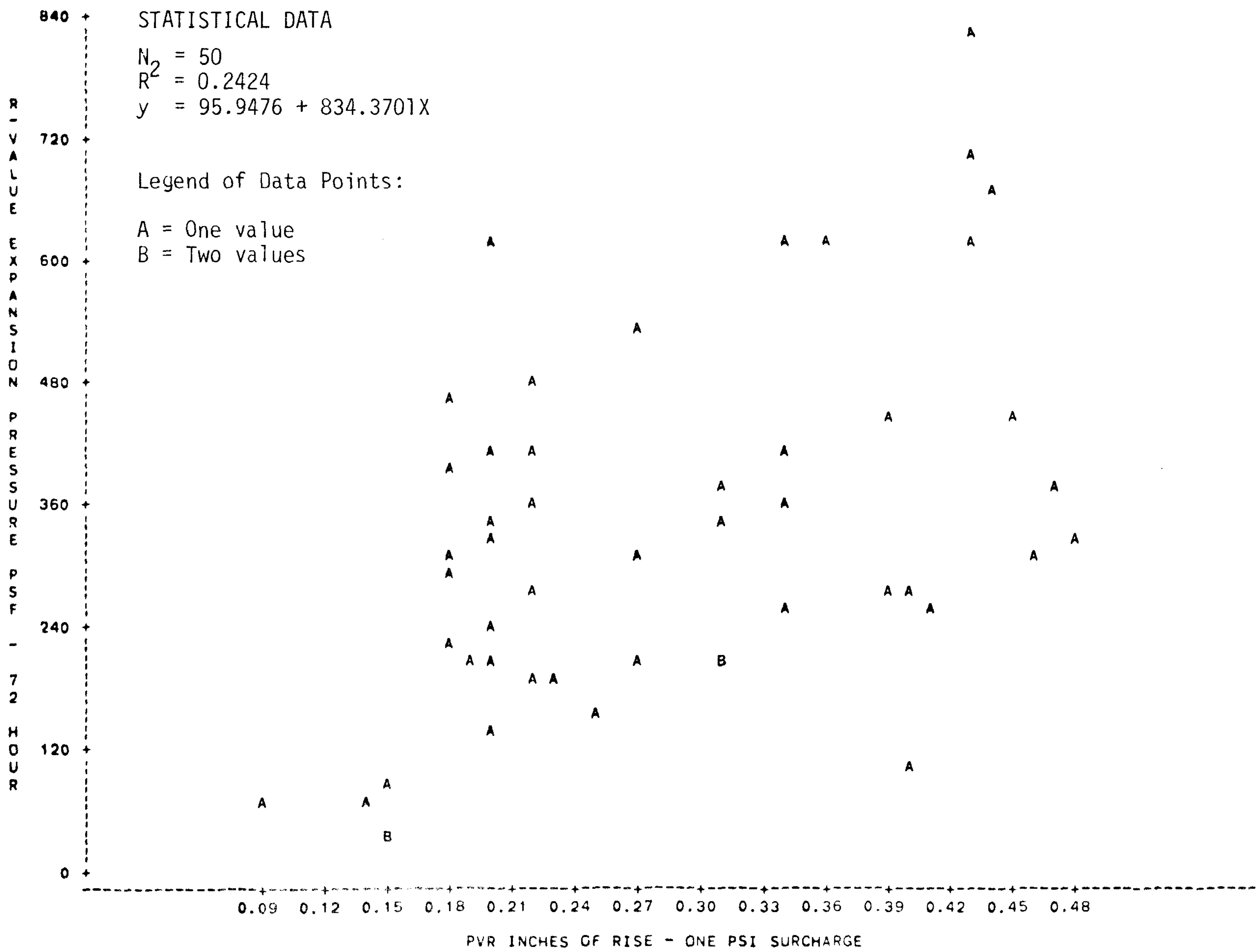

FIGURE 6

R-Value Expansion Pressure PSF - 72 Hours versus PVR Inches of Rise - One PSI Surcharge

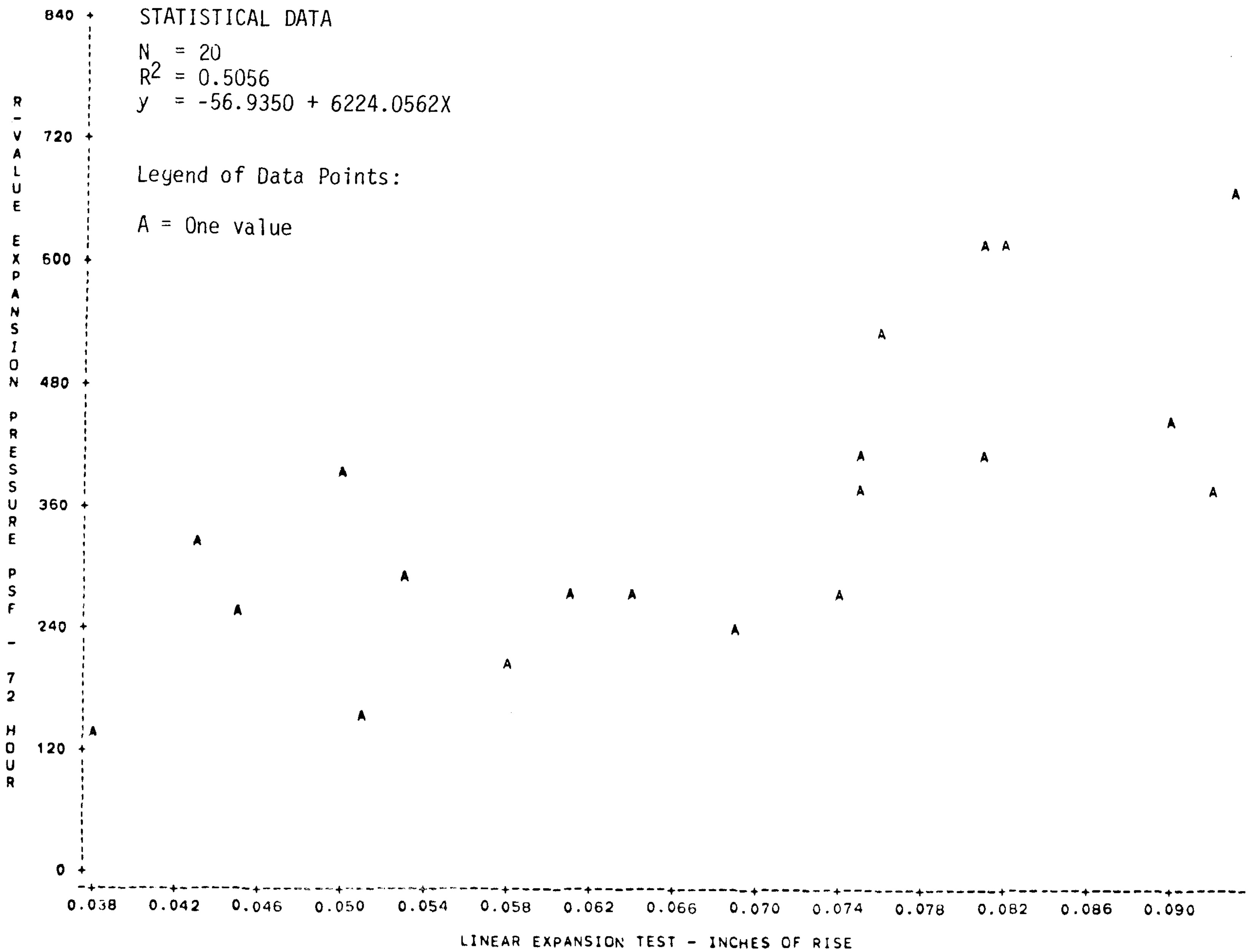

FIGURE 7

R-Value Expansion Pressure PSF - 72 Hours versus Linear Expansion Test - Inches of Rise

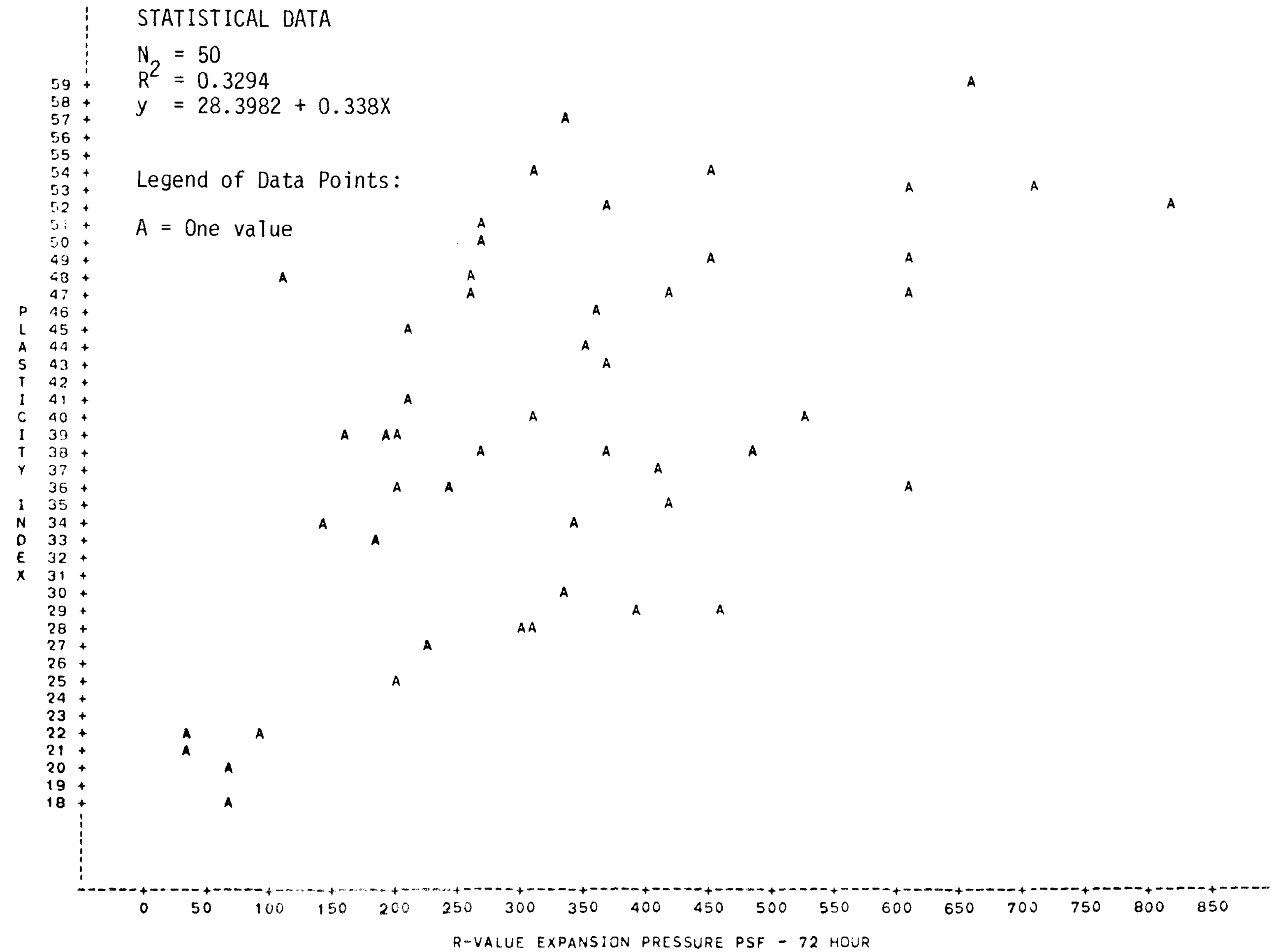

FIGURE 8

Plasticity Index versus R-Value Expansion Pressure PSF - 72 Hours

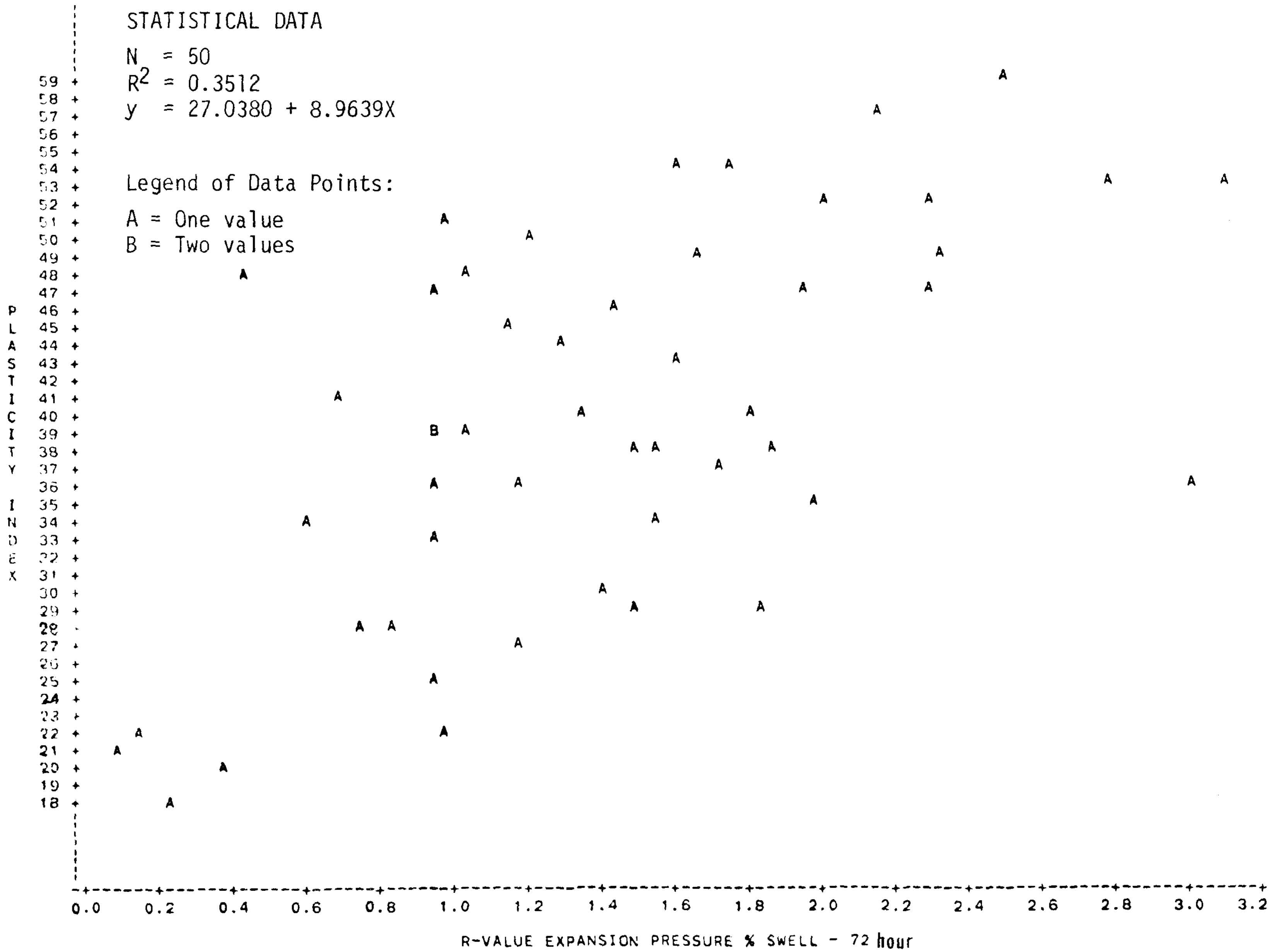

FIGURE 9

Plasticity Index versus R-Value Expansion Pressure % Swell - 72 Hours

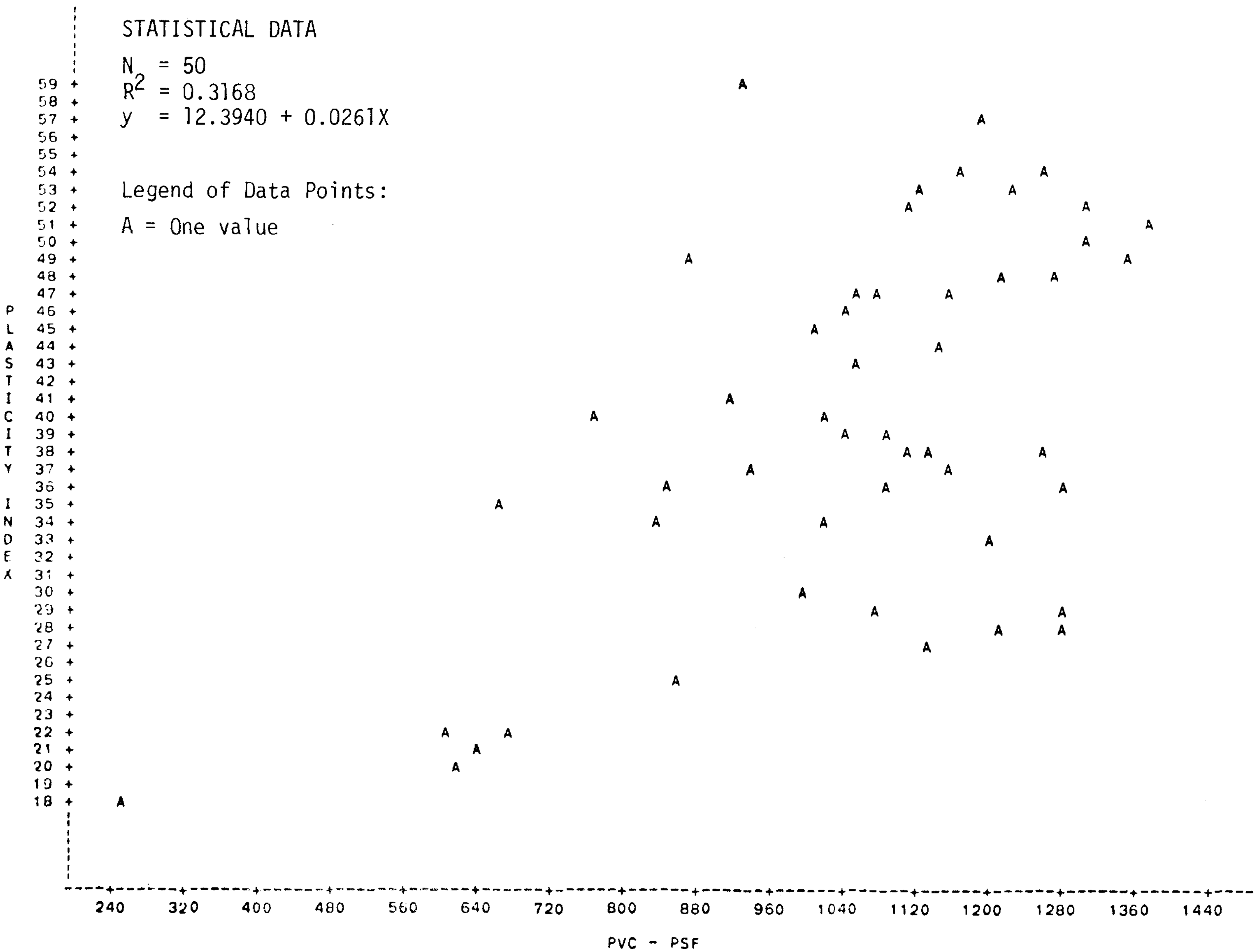

FIGURE 10

Plasticity Index versus PVC - PSF

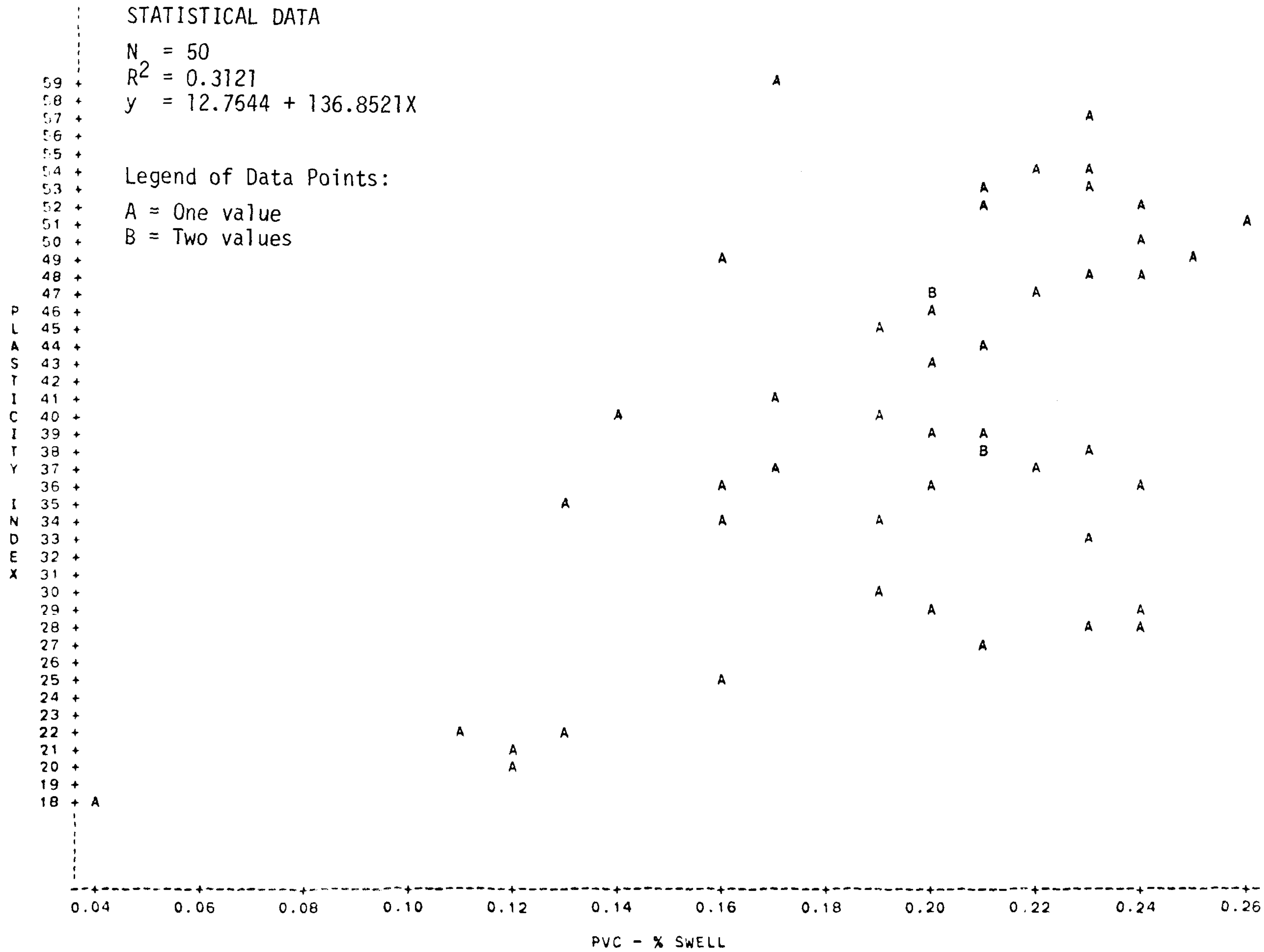

FIGURE 11

Plasticity Index versus PVC - % Swell

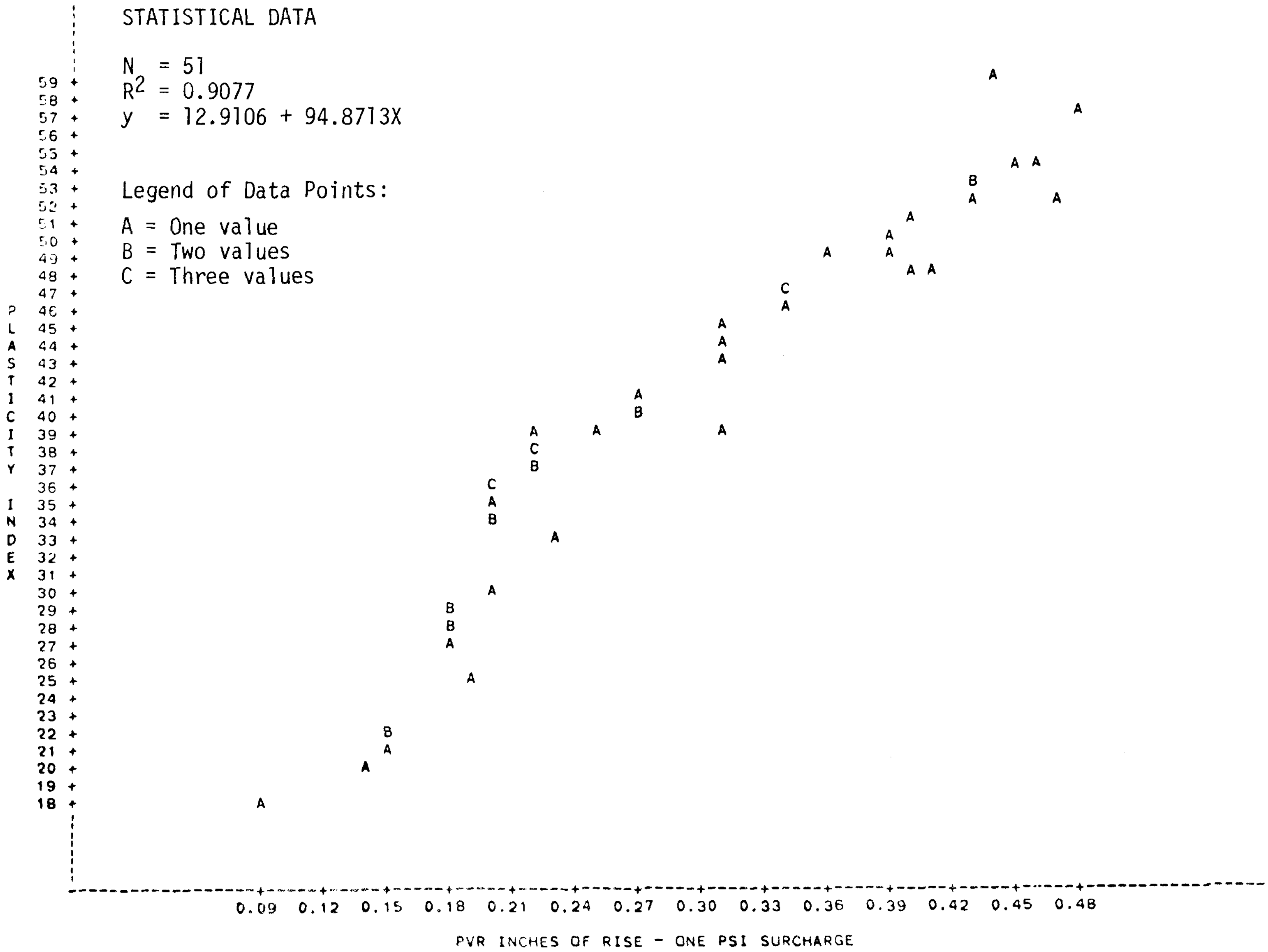

FIGURE 12
Plasticity Index versus PVR Inches of Rise - one P.S.I. Surcharge

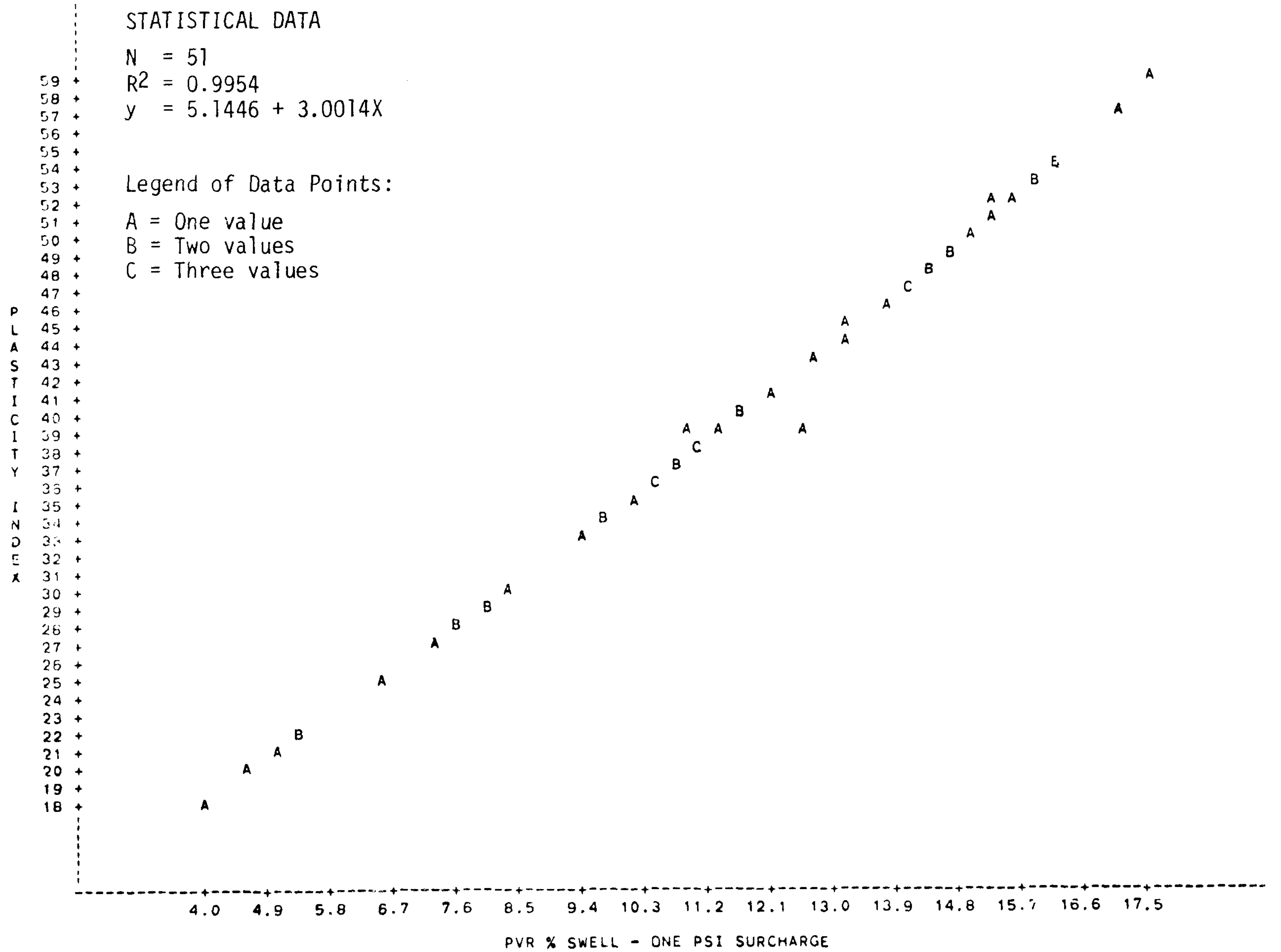

FIGURE 13
Plasticity Index versus PVR % Swell - one P.S.I. Surcharge

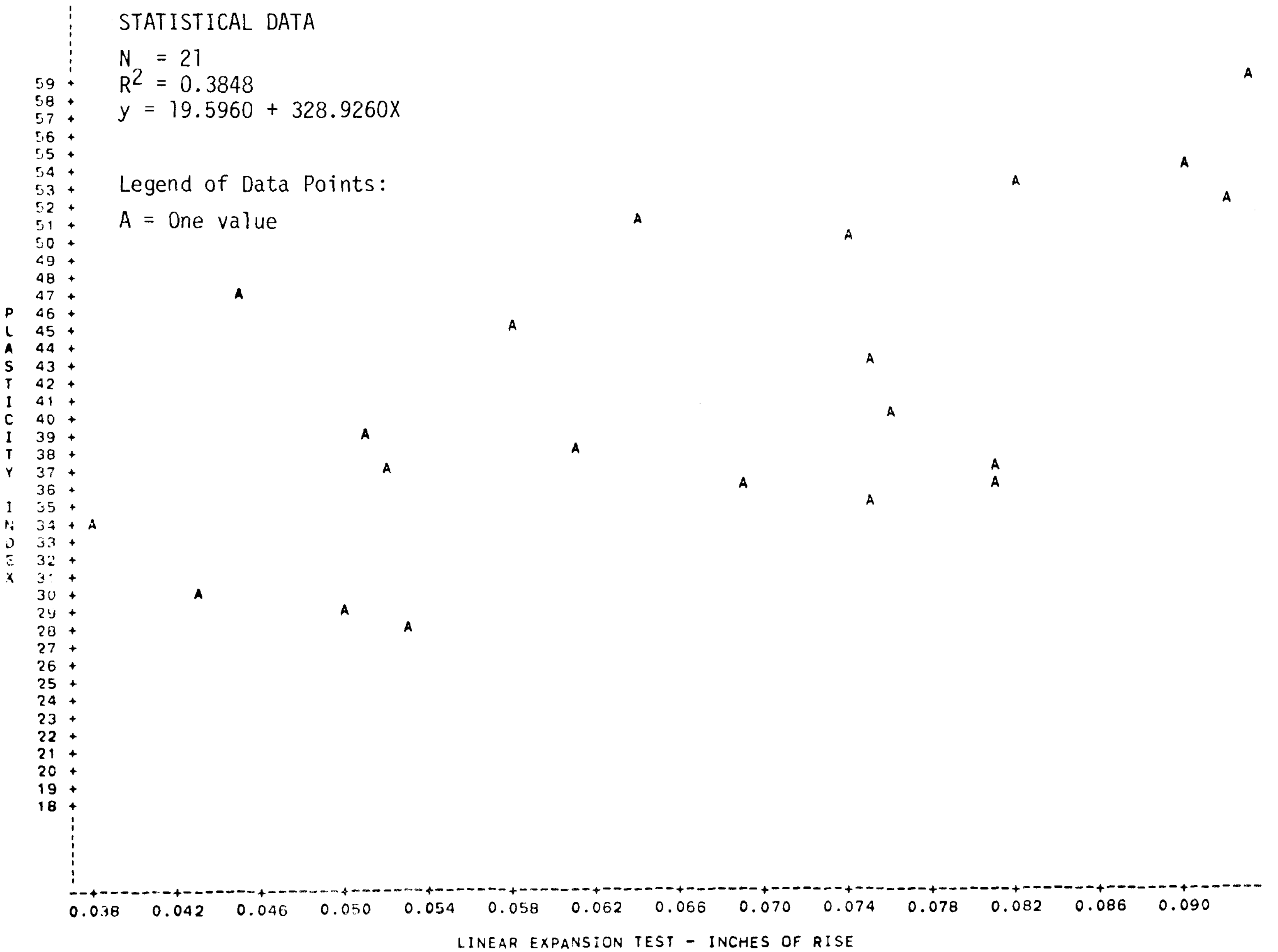

FIGURE 14

Plasticity Index versus Linear Expansion Test - Inches of Rise

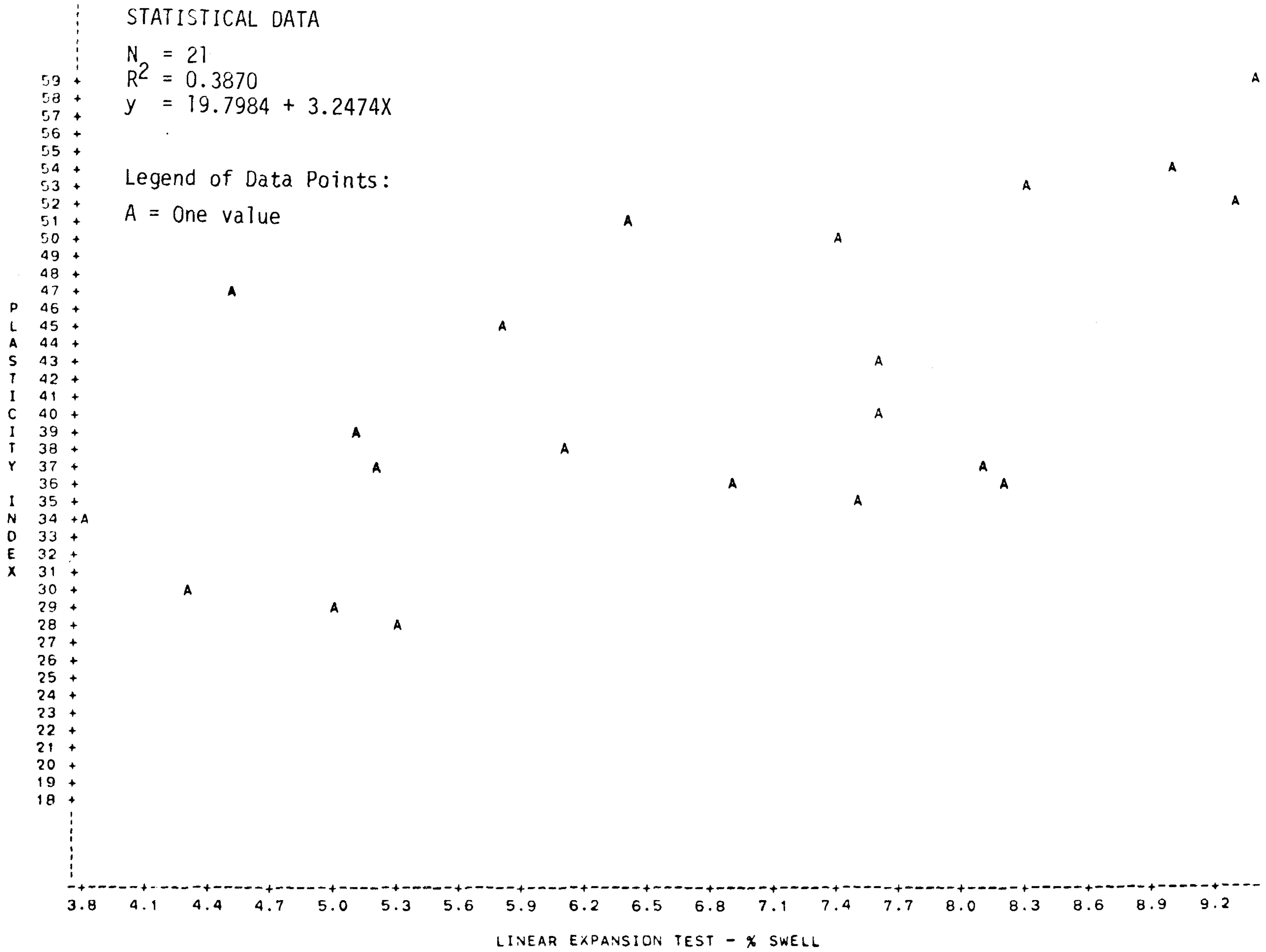

FIGURE 15

Plasticity Index versus Linear Expansion Test - % Swell

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT OFFICE OF HIGHWAYS	EDSM NO. V.1.1.1

ENGINEERING DIRECTIVES AND STANDARDS MANUAL

VOLUME V **CHAPTER** 1 **SECTION** 1 **DIRECTIVE** 1	**DATE** January 23, 1978 **SUBJECT** Policy for Using Embankment Materials With Swell Potential

1. PURPOSE: The purpose of this directive is to establish a procedure to make soils having swell potential usable in highway embankments.

2. SCOPE: This directive shall apply to all construction projects where soils having swell potential are encountered and restricted use of the soils is required. Soils having swell potential may be utilized as part of the load bearing embankment when Method A or Method B treatment is provided as described below. Soils having swell potential may be utilized without treatment only when they are not placed as part of the load bearing embankment. The load bearing embankment shall constitute crown width extended on a 1:1 slope for the height of the embankment.

3. PROCEDURE: The many varying traffic and roadway characteristics dictate a consideration of several ways to approach the problem of swelling or potentially swelling soils in embankments. Recognizing these variations, two basic methods of handling potentially swelling soils are described below.

    Method A is directed towards those projects which have a low tolerance for soil swell, such as high traffic volume, high speed, numerous or close-spaced bridges and embankments more than several feet in height. In Method A, preventative treatment is applied to the embankment soil to minimize soil swell.

    Method B is directed toward those projects which have a higher tolerance for soil swell, such as low traffic volume, low embankment heights, and infrequent bridges.

    Design treatments for soils with swell potential are identified by categories of plasticity indices as shown below. Unless indicated on the plans or in the project specifications, Method B shall be used. In the event Method A is not indicated on the project specifications and it is determined that Method A or additional lime is required on all or a portion of the project, then a supplemental agreement will be made to reimburse the contractor for the invoice cost of the additional lime required. No payment will be made for additional processing.

SOIL TREATMENT

Soil Plasticity Index Range	Method A	Method B
Less than 20	Acceptable as is	Acceptable as is
20 thru 35	5% hydrated lime by volume	Acceptable as is
36 thru 45	8% hydrated lime by volume	4% hydrated lime by volume (Note 1)
46 thru 60	11% hydrated lime	6% hydrated lime by volume (Note 2)
Above 60	Not Acceptable	Not Acceptable

Note 1: The material can be approved without lime treatment with the stipulation that the moisture content at the time of compaction will equal or exceed 2% above the optimum moisture content as determined by DOTD Designation TR 415.

This material may be used in the lower portion of embankments provided it does not constitute more than 20% of the embankment height.

In the event various ranges of PI are found in the same excavation area, and it is felt that proper excavation and mixing procedures would result in a uniform material, then the average plasticity index shall be determined representing this material.

Note 2: The material can be approved without lime treatment for use in the lower portion of embankments provided it does not constitute more than 20% of the embankment height.

In the event various ranges of PI are found in the same area, and it is felt that proper excavation and mixing procedures would result in a uniform material, then the average plasticity index shall be determined representing this material.

The average PI value will be determined by the Laboratory as follows:

1) Unclassified Excavation: The average PI value for each general roadway area of soils requiring lime treatment will be determined from the subgrade soil survey data, and the lime content corresponding to this PI value in the foregoing table shall be used.

2) Borrow Excavation: The average PI value will be determined for each borrow source requiring lime treatment, and the lime content corresponding to this PI value in the foregoing table shall be used. The following procedure will be used to determine the average PI value for a borrow source.

   a) Borings: A minimum of one boring per acre will be taken to the depth of the proposed excavation. (Additional borings may be taken as determined by the Laboratory Engineer or his designated representative.)

   b) PI Contribution: The PI value for each sample from each boring will be multiplied by the soil volumes.

   c) Average PI for the borrow source will be calculated as follows:

$$\text{Average PI} = \frac{\text{Total PI Contribution*}}{\text{Total Soil Volume**}}$$

   *Sum of PI Contribution of all samples
   **Sum of Soil Volumes represented by all samples

   If the materials from more than one borrow source are placed concurrently in the same embankment area, the required lime content for that embankment area will be the highest lime content determined for the borrow sources involved.

The furnishing and placing of hydrated lime for embankments will be considered as incidental to the embankment work and will not be measured for separate payment. Mixing shall be accomplished with ordinary embankment construction methods and equipment.

4. OTHER ISSUANCES AFFECTED: All directives, memoranda or instructions issued heretofore shall remain in effect for projects currently under contract.

5. EFFECTIVE DATE: This directive will apply to all projects on which bids are received beginning in March, 1978.

Dempsey D. White
DEMPSEY D. WHITE
CHIEF ENGINEER