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A test was developed which uses a soap solution for expanding the clay particles, then a flocculating agent (Separan NP-10) to obtain a column height in a glass graduate. The column height gives an indication of the expansive potential of the soil.

The test appears to correlate reasonably well with Test Method 354 and can classify soils into groups requiring 24 inches or less of cover and those that are more expansive and require further testing.

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HIGHWAY RESEARCH REPORT

DEVELOPMENT OF A RAPID FIELD TEST FOR EVALUATING THE EXPANSIVE POTENTI... OF C... ...JCTION

STATE OF CALIFORNIA

TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 633139

Prepared in Cooperation with the U.S. Department of Transportation, Bureau of Public Roads June, 1967

State of California
Department of Public Works
Division of Highways
Materials and Research Department

June 1967

Mr. J. C. Womack
State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is

A

REPORT

ON THE

DEVELOPMENT OF A RAPID FIELD TEST

FOR EVALUATING THE EXPANSIVE POTENTIAL

OF CLAY SOILS DURING CONSTRUCTION

ERNEST ZUBE
Principal Investigator

CLYDE GATES
MAS HATANO
Co-Investigators

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

REFERENCE: C. Gates and M. Hatano, "Development of a Rapid Field Test for Evaluating the Expansive Potential of Clay Soils During Construction," State of California, Department of Public Works, Division of Highways, Materials and Research Department. Research Report 633139-1, June 1967

ABSTRACT: The development of a short field method for detecting the troublesome clays is discussed. At the present time, California uses Test Method No. Calif. 354 entitled, "Method of Test for Evaluating the Expansive Potential of Soils Underlying Portland Cement Concrete," for evaluating clay soils used under concrete pavements. Due to the lengthy testing time required for the above test, this project was undertaken.

A test was developed which uses a soap solution for expanding the clay particles, then a flocculating agent (Separan NP-10) to obtain a column height in a glass graduate. The column height gives an indication of the expansive potential of the soil.

The test appears to correlate reasonably well with Test Method 354 and can classify soils into groups requiring 24 inches or less of cover and those that are more expansive and require further testing.

KEY WORDS: Testing, Test Methods, clays, expansive clays, expansive soils, field tests.

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INTRODUCTION:

In 1954 a portland cement concrete pavement which had been constructed only a few months began to show extreme slab curling after the first heavy rain. The structural section consisted of 8" PCC Pavement, 4" Cement Treated Base and 8" Imported Subbase over expansive clay. An investigation disclosed that the underlying cement treated base, in many cases, had cracked at the pavement joints and permitted water to pass through the permeable subbase to the expansive soil beneath in concentrated areas near the joints of the pavement. This caused the pavement to raise at the joints by as much as 3/4 of an inch and created a very rough riding pavement.

In order to prevent a recurrence of slab curling due to expansive soils, an interim design procedure was developed, based upon the expansion pressure of the underlying soils. This design generally resulted in very thick structural sections, often as much as four feet, whenever clayey soils were encountered. It soon became evident that the design was too conservative. A further study resulted in the development of Test Method No. Calif. 354, Method of Test for Evaluating the Expansive Potential of Soils Underlying Portland Cement Concrete Pavements, commonly called the "Third Cycle Expansion Pressure Test."

This test has been very useful but the procedure is lengthy and requires testing equipment found only in laboratories which perform the R-value test, Test Method No. Calif. 301. In order to reduce the number of Third Cycle Tests, there is a need for a quick simple test for identifying soils which have expansion potential.

The following report describes the attempts to develop a rapid test, by use of chemicals, for evaluating the expansive potential of clay soils.

SUMMARY AND CONCLUSIONS:

After trying numerous chemicals and techniques, a rapid test procedure was developed for evaluating the expansive potential of clay soils. The test consists of using a soap solution of expanding the clays and then a Separan NP-10 solution for flocculating the clay to obtain a column height in a glass graduate. The detailed test procedure is shown in Appendix A.

This test procedure correlates reasonably well with the Third Cycle Expansion Pressure Test, Method No. Calif. 354, for soils having low to moderate expansive potential. However, for the more expansive soils, the correlation is not good. Therefore, the test has some possibilities for classifying soils into the two groups as follows:

1. Soils requiring 24 inches or less of cover.
2. Soils needing further testing by the Third Cycle Expansion Pressure Test.

The results of this research study are not as gratifying as had been hoped. However, we feel that we have proceeded as far as we can along the method we have explored. It is, therefore, our recommendation that this research project be terminated. The information found may be of some value to future researchers who wish to study this subject perhaps from a different approach.

DISCUSSION:

The initial work on this project consisted of reviewing literature. One report on this subject which appeared applicable to our work was authored by John W. Jordan.* Initial experiments, trying to duplicate his work and correlating the results with our Third Cycle Expansion Pressure data, were not successful. However, it formed some of the basis for our subsequent work.

It was felt that a procedure patterned after the sand equivalent test and using similar pieces of equipment would be desirable. If a small soil sample could be placed in a sand equivalent tube with some chemicals and tested in a set procedure, it was hoped that a column height could be derived which could be related to the cover requirements indicated by the Third Cycle Expansion Pressure Test.

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* Organophilic Bentonite by John W. Jordan, Mellon Institute, Pittsburgh, Pennsylvania, presented at American Chemical Society, Cambridge, Massachusetts, June 1948

Our research then centered on finding suitable additives. During the developmental stage, various chemicals such as sodium, ammonium, potassium, and aluminum hydroxides, hydrochloric acid, alcohol trisodium phosphate, oxalic acid, sodium oleate, aerosol, calgon, arquad and benzene were used individually and in various combinations.

The most promising chemicals found were ethylene glycol, soap, sodium borate decahydrate, and separan NP-10 (Dow Chemical). The detailed test procedure is shown in Appendix A.

The test data from this procedure was correlated with data from the Third Cycle Expansion Pressure Test, Test Method No. Calif. 354 and is shown in Table A.

Figure 1 represents material screened to pass the No. 4 sieve. Column heights of 2.8 inches or less indicate 24 inches or less of cover while column heights greater than 2.8 inches indicate cover heights from 18 to 48 inches will be required.

Figure 2 represents material pulverized to pass the No. 50 sieve. Column heights of 3.8 inches or less indicate 24 inches or less of cover while column heights greater than 3.8 inches indicate cover heights from 18 to 48 inches will be required.

Briefly, the test procedure, attached to this report, consists of the following steps:

Solution Preparation

1. Prepare NP-10 Separan Solution by dissolving 0.3 grams of Separan NP-10 in 600 ml. of distilled water.
2. Prepare soap solution by dissolving 100 grams of Baker and Adamson Castile Soap Powder in 3400 ml. of distilled water.
3. Prepare expansion solution by dissolving 200 grams of Sodium Borate Decahydrate in 3400 ml. of Ethylene Glycol and combining it with the soap solution.

Sample Preparation and Testing

1. Weigh 20 grams of dry pulverized clay sample to be tested.
2. Place test sample in a sand equivalent tube, add water to 11.5 inch level and shake for 100 cycles.
3. Add 5 ml. of the NP-10 solution and invert 4 times.
4. Decant to 7-1/2 inches and add 5 ml. of NP-10 solution and 4 inches of expansion solution.
5. Shake for 30 cycles, let stand for 10 minutes, and read column height.

The test data from this procedure was correlated with the Third Cycle Expansion Pressure Test data (Table A). Figure 1 shows that column heights of 2.8 or less indicate 24 inches or less of cover while column heights of greater than 2.8 inches indicate cover requirements from 18 to 48 inches. These samples were tested on the material passing the No. 4 sieve.

Figure 2 shows test data on the same, as well as additional samples, screened to pass the No. 4 sieve and then pulverized with a mortar and pestle so that all the material passed the No. 50 sieve. Pulverizing the material raises the column height of the soils sensitive to the test by permitting a more rapid dispersion of the clay particles. Those materials having low column heights were not affected by pulverizing. The correlation between the 3rd cycle tests and the rapid expansion test is improved by pulverizing. Column heights of 3.8 inches or less indicate 24 inches of cover while column heights greater than 3.9 inches indicate cover requirements ranging from 18 to 48 inches. Tests on the pulverized material indicate 51% of the total samples tested required 24 inches or less of cover. Although pulverizing adds to time and difficulty in sample preparation, it appears to be desirable in order to obtain more refined test results.

Temperature also appears to have an effect on column height. The expansion solution begins to congeal at a temperature of about 55 degrees Farenheit. Table B shows tests performed on three samples at varying temperatures.

Due to effects of temperature, it is recommended that this test be performed in a laboratory with controlled temperature between 70 to 80°F.

Most samples contain varying amounts of moisture when received in the laboratory. A chart was developed to determine the wet weight of material necessary to obtain a 20 gram dry weight of material. However, tests performed with varying amounts of moisture with different materials indicated inconsistent test data. Since it was impossible to determine what materials were affected, the test procedure was written so that all samples would be dried to a constant weight at a temperature of 230°F.

Figure 3 shows typical curves of column heights versus settling time. The rate of settling varies with different materials. The test data indicated ten minutes would be sufficient settling time for our purpose.

Figure 4 shows a plot of column height versus Plasticity Index. The material used for these tests came from one source. It is interesting to note the good correlation obtained between these two tests.

Figure 5 shows a plot of column height versus Plasticity Index for materials from varied sources. The correlation is not as good as the plot shown on Figure 4 for materials from one source. It is believed that some of the inconsistencies were due to using an outdated soap solution. This work was done before studies were made of solution age.

It is rather difficult to state categorically what the test indicates. There is a general correlation with the X-ray analysis of soil samples when the basis of evaluation is the montmorillonite content. There is also a general relation between column heights and fineness as determined by hydrometer analysis (-200 and 5U grain sizes). Materials such as washed sand, Ottawa sand, and silica, all pulverized to various grades, give column heights almost identical to their own volume before pulverizing. Bentonite develops a gel that cannot be measured. Kaolinite gives a high column height though in theory it is not expansive. Illites 35 and 36 (a commercial clay from Wards Natural Science Establishment Inc.) give low and high test results, although here again, they both should have been high. Therefore it cannot be said that a fully reliable test for expansive clays developed. The question of whether the specific gravity of soils has a direct relation to column heights has been investigated sufficiently to eliminate the possibility that gravity is a significant factor. The results do not correlate directly with the "third cycle" results. It was interesting to note that with a group of about thirty different soil samples, the column heights by the test procedure agreed with an observed but not measured shrinkage when the samples were soaked in water for 48 hours and dried without disturbing to 230°F. The ability of a soil to contract cannot be accepted as the reverse of its ability to expand but it is known that a relation does exist. Since the total surface area is not measured directly by the test, there remains only the consideration of penetration of or the absorption by the individual particles and these are the major factors in the expansion of clay soils. What the agent in the expansion solution is, or what the agents are, cannot be determined with available equipment and materials. Some clays take up moisture rapidly while others more slowly. Any lumps also retard absorption. It was for this reason that it was decided to pulverize all soils to passing a 50 mesh sieve.

In the final analysis, the rapid test method for clays gives a fairly reasonable indication of the clay content of soils. Unfortunately, this is not directly related in all cases to the expansive potential of clays with respect to the portland cement concrete curl problem.

The advantage of the rapid test over other methods, for indicating the expansive potential for soils, lies in the time differential for obtaining test results. The rapid method requires about 30 minutes as compared to several days for the other tests. In addition the rapid method gives a "cut off" point where soils can be classed as requiring 24 inches or less of cover.

Time studies of expansion solutions with respect to age were conducted and the results are shown on Figure 6. The test data indicates that the solution is affected by age. The column heights vary considerably during the first three days and then appear to gradually diminish with time. The column heights appear to be affected to a greater extent for the medium and highly expansive soils. Therefore a criteria was established to provide a curing period of 5 days for the expansion solutions and a maximum use period of 15 days.

Further studies indicated the solution should be stirred vigorously and allowed to set for a minimum of 45 minutes before daily use.

The use of a soil, established as a standard, is desirable to detect any variation in test solutions.

APPENDIX A

TENTATIVE METHOD FOR THE DETERMINATION OF THE EXPANSIVE POTENTIAL OF SOIL (RAPID INDICATION OF SOIL EXPANSION)

SCOPE:

This method covers the procedure for a test to determine the expansion potential of soil. This test is intended as an aid in sample classification and is not to be used as the final authority in design and control situations.

PROCEDURE:

A. Apparatus

1. 1 - Hot plate or oven.
2. 1 - Torsion balance, 500 gm. capacity, graduated to 0.1 gm.
3. 1 - Timer alarm or stop watch.

4. 1 - No. 4 sieve, No. 50 sieve, and collecting pan.
5. 3 - 2 gal. plastic "carboy" with faucet using tubing and pinch clamp.
6. 1 - 10 ml. plastic graduate, pharmaceutical.
7. 2 - Graduated plastic cylinder (used in sand equivalent test)
8. 1 - Manually operated Sand Equivalent shaker
9. 1 - Bottle, Dropping plastic.
10. 2 - Spatula 3 inches in length.
11. 3 - 100 ml. beaker.
12. 1 - Aspirator Pump or rubber bulb.
13. 1 - Sand Equivalent irrigator tube.
14. 1 - 5 ft. rubber tubing (1/4") 3/16 I.D.
15. 2 - Bottle, French square 32oz.
16. 2 - 2000 ml. Pyrex beaker
17. 1 - Mortar and Pestle
18. 1 - 1" Paint Brush or similar
19. 1 - 1000 ml. graduate
20. 2 - No. 7 Rubber Stoppers
21. 1 - Metal Stirring Rod - 14"
22. 2 - Plastic Stirring Paddle
23. 1 - Funnel - 5" at Lip - Plastic

B. Reagents and Materials

1. Separan NP-10 (.05% solution)
Dissolve .3 gm. of Separan NP-10 in 600 ml. of distilled water. Shake vigorously and let set for four hours minimum. Store in clear glass bottle. The solution is ready for use when:

a. The material is completely dissolved.
b. Upon shaking, the air bubbles hang and then rise very slowly to the top of the solution.

Note: Discard the solution 20 calendar days after mixing.

2. Expansion Solution

a. Borate Solution: Dissolve 200 grams of "Sodium Borate Decahydrate" directly in 3400 ml. of Ethylene Glycol[1]. Stir periodically until the Borate is thoroughly dissolved. Dissolving time is approximately 4 hours.

1 Reagent grade or better

b. Soap Solution: Add about 100 ml. of distilled water to 100 grams of B & A[2] Castile Soap Powder NF (Hard Soap) Code 1562. Stir until mixture becomes uniformly moist. Then add 100 ml. additional water and stir for a few minutes. Continue adding larger increments of water until a total of 3400 ml. of water is used. Dissolving time of the soap will vary from 1 to 6 hours depending on whether powder or a mixture of powder and soap chips are used.

c. The soap solution is critical to time and should be mixed with the Borax solution immediately after the soap is thoroughly dissolved.

d. The solution is ready for testing after aging for 5 days and must be discarded 15 days after preparation.

e. The solution should be vigorously agitated and allowed to stand for 45 minutes before daily use.

f. Drain the contents of the rubber drain hose before daily testing.

g. The solution prepared according to the amount of material specified should be sufficient for about 80 tests. Larger quantities in the same proportions can be made up for extensive testing.

3. Distilled Water - 5 gallons

4. Standard Testing Material

It is desirable to use a selected soil as a standard for use as a means of testing the two solutions. The soil should:

1. Give column heights of approximately 6".
2. Produce good tests without voids or separations in "floc" column.
3. Be of such uniformity that reproducibility of results is possible throughout the amount prepared. This can best be accomplished by using only that portion of a soil which passes the No. 200 sieve.
4. Standard materials whose column heights are lower may be prepared and used if desired in addition to the high standard.

2, Allied Chemical Corp. General Chemical Division - Baker and Adamson

C. Sample Preparation

1. Split or quarter a 150 grm. ± specimen from the passing No. 4 fraction of the primary sample for the expansion test.

2. If the sample is wet, carefully dry on a hot plate until the material can be graded on the No. 4 sieve.

3. Pulverize material to pass a 50 mesh sieve and weigh out a 20 gram test sample.

D. Pre-expansion Phase of Test

1. Add 4" of distilled water to a sand equivalent (SE) tube.

2. Add 20 grms. of dry pulverized material to the SE tube.

3. Fill the SE tube to the 11.5 inch mark with distilled water and stopper the cylinder. Then shake for 100 cycles on the SE shaker. Follow Test Method No. Calif. 217-D Section F Method B entitled "Manual Shaker Method".

4. Next, remove SE tube from shaker and add 5 ml. Separan NP-10 Solution. Once again stopper the cylinder and invert 4 times. Set the SE tube on a level vibrationless work table for 2 minutes. Observe and record column height.

E. Decantation Phase of Test

1. Using an aspirator pump, fitted to the SE Irrigator Tube with rubber tubing, decant and waste the solution above 7-1/2 inches, or use a rubber squeeze bulb if an aspirator pump set-up is not available.

F. Expansion Phase of Test

1. Gently add the expansion solution to the material remaining in the SE graduate. Fill to the 11.5 inch mark, directing the flow of soapy solution towards the inside wall of the cylinder to minimize disturbing the solids. Add 5 ml. of Separan NP-10 solution to the graduate and stopper.

2. Shake on the SE shaker for 30 cycles. Immediately remove the SE tube from the shaker and once again set the cylinder upright on a level vibrationless work table.

3. Let stand undisturbed for ten minutes and record the height of the flocculated solids. If splitting of "floc" occurs, stir the upper part until it sinks to lower portion but do not stir after 3 minutes.

G. Analysis of Data

The expansion potential of the soil sample, based on the soil column height, may be determined as follows:

1. Column heights less than 3.8 inches requires 24 inches of cover or less by 3rd cycle.

2. Column heights more than 3.8 inches requires 24 inches of cover or more by 3rd cycle.

TABLE A

Tabulation of Test Data Used For Development of a Rapid Field Test For Evaluating the Expansive Potential of Clay Soils

Test No.	Dist.	Co.	Grading Sieve 200 %	Grading Size 5U %	SE	LL	PL	PI	3rd Cycle Rec. Cover (Ft.)	3rd Cycle Rec. Moist %	Column Height P#4 Matl.	R Value	Column Ht P#4 Matl. Pulverize to P #50
61-5106	10	Ala	89	64	3	70	26	44	2.5	24.8	5.5	10	6.6
61-5214	03	But	90	25	5	46	32	14	1.5	25.7	2.7	21	4.4
61-5219	03	But	76	27	5	45	31	14	1.5	24.3	2.8	14	3.2
61-5223	03	But	68	29	12	43	33	10	1.5	25.7	2.1	24	2.3
62-1030	03	Yol	69	30	6	36	17	19	1.5	*	1.7	7	2.0
62-1031	03	Yol	81	41	4	39	18	21	1.5	20.3	2.2	4	2.5
62-2370	10	Mer	95	Floc	1	55	25	30	2.5	18.2	4.1	10	5.6
62-2623	10	Mer	89	48	4	55	28	27	4.0	18.0	4.0	8	4.8
62-4136	05	Mon	44	21	11	28	16	12	1.5	10.0	1.7	15	1.9
62-4756	10	Mer	93	37	2	60	25	35	1.5	23.0	4.6	8	6.1
62-4760	10	Mer	94	67	0	61	24	37	1.5	22.2	5.4	8	6.0
62-5030	05	SB	89	66	8	83	64	19	1.5	56.0	3.7	5	5.2
62-5031	05	SB	86	55	8	72	34	38	1.5	35.0	2.7	11	3.1
62-5035	05	SB	56	28	9	73	27	46	1.5	27.5	4.6	23	6.0
62-5565	10	SJ	36	22	13	28	15	13	1.5	9.6	2.0	10	2.2
62-5566	10	Mer	75	40	5	47	26	21	1.5	18.5	2.5	7	2.8
62-5897	10	Mer	32	17	13	32	17	15	1.5	7.0	2.0	10	2.1
62-5900	10	Mer	79	51	4	46	21	25	1.5	18.0	3.0	6	4.2
62-5902	10	Mer	86	22	3	35	26	9	1.5	17.0	3.4	18	4.4
62-5905	10	Mer	50	25	9	33	17	16	1.5	10.0	1.8	11	2.0
62-5906	10	Mer	72	35	6	31	27	4	1.5	12.4	2.5	6	2.8
62-5907	10	Mer	37	25	9	44	20	24	1.5	14.0	2.5	11	2.9
62-5908	10	Mer	90	Floc	1	46	24	22	4.0	20.0	4.3	7	5.5
62-5909	10	Mer	90	50	1	51	22	29	1.5	20.0	4.1	3	5.4
62-5910	10	Mer	88	39	1	53	32	21	3.0	21.5	3.8	13	4.9
62-5911	10	Mer	37	25	9	27	21	6	1.5	12.0	1.9	12	2.2
62-5913	10	Mer	91	65	2	43	21	22	1.5	18.0	3.2	9	4.0
63-1032	10	SJ	75	37	3	38	19	19	3.0	12.5	2.9	4	4.3
63-1199	06	Ker	85	34	4	38	24	14	2.0	22.0	2.2	16	3.4
63-1201	06	Ker	78	30	2	27	16	11	1.5	13.0	2.1	10	2.4
63-1202	06	Ker	81	36	2	39	22	17	1.5	18.0	2.9	5	3.6
63-1203	06	Ker	90	51	3	53	29	24	2.0	23.0	2.9	13	4.1
63-1204	06	Ker	92	42	4	52	34	18	1.5	26.4	2.6	14	3.4
63-1205	06	Kin	71	38	1	35	16	19	1.5	16.0	2.4	6	2.4
63-1206	06	Kin	71	18	7	22	18	4	1.5	11.0	1.5	16	1.5

* No moisture control necessary

TABLE A (continued)

Test No.	Dist.	Co.	Grading Sieve Size 200 %	Grading Sieve Size 5U %	SE	LL	PL	PI	3rd Cycle Rec. Cover (Ft.)	3rd Cycle Rec. Moist %	Column Height P#4 Matl.	R Value	Column Ht. P#4 Matl. Pulverized to P #50
63-1554	10	Mer	71	35	6	39	19	20	1.5	12.0	2.4	11	2.7
63-1555	10	SJ	75	35	4	37	19	18	1.5	16.0	2.8	8	2.9
63-1207	10	SJ	68	49	3	50	35	15	2.5	19.6	4.7	10	5.9
63-2153	03	Yol	63	31	6	32	15	17	1.5	12.5	2.4	3	2.6
63-2154	03	Yol	79	37	3	36	17	19	1.5	15.2	2.8	3	3.4
63-2270	06	Ker	90	30	3	35	23	12	1.5	17.0	2.1	8	2.8
63-2271	06	Ker	89	39	3	30	17	13	1.5	14.0	4.2	7	4.3
63-2272	06	Ker	89	39	3	30	17	13	2.0	19.6	3.7	7	3.7
63-2273	06	Ker	77	34	6	32	17	15	1.5	13.0	2.2	5	2.3
63-2274	06	Ker	92	52	2	51	23	28	2.5	21.2	4.3	6	4.3
63-2275	06	Ker	98	40	2	42	23	19	2.0	20.4	3.1	10	3.1
63-2276	06	Ker	97	42	2	44	23	21	1.5	20.0	3.1	8	3.6
63-2277	06	Ker	68	33	3	31	14	17	1.5	14.0	2.2	15	2.4
63-2279	06	Ker	69	24	8	25	17	8	1.5	*	1.9	17	1.9
63-2311	03	Yol	23	15	18	36	14	22	1.5	*	1.8	13	1.8
63-2313	03	Yol	63	32	6	36	16	20	1.5	*	3.1	3	4.1
63-2314	03	Yol	25	18	18	34	14	20	1.5	*	1.8	5	1.8
63-2373	03	Yol	20	11	22	27	15	12	1.5	*	1.4	23	1.4
63-2379	03	Col	46	22	3	41	16	25	3.0	14.5	4.9	12	4.9
63-2382	03	Col	50	27	9	31	15	16	1.5	12.0	2.2	9	2.2
63-2383	03	Yol	45	20	3	36	21	15	1.5	14.2	2.9	9	3.2
63-2693	06	Fre	61	21	7	23	21	2	1.5	14.0	4.5	7	4.5
63-2697	06	Fre	71	44	2	40	23	17	3.5	15.6	4.0	7	4.0
63-2991	10	SJ	79	45	3	66	29	37	3.0	25.0	7.3	8	6.5
63-2992	10	SJ	35	18	12			NP	1.5	12.0	2.1	13	2.1
63-2994	10	SJ	30	13	15	32	24	8	1.5	*	1.8	15	1.8
63-2995	10	SJ	59	31	3	50	36	14	1.5	22.0	5.9	10	5.9
63-2997	10	SJ	84	40	3	61	29	32	1.5	26.0	5.9	7	5.9
63-3190	05	SB	95	60	3	70	26	44	3.0	21.0	4.4	6	5.1
63-3191	05	SB	81	45	16	55	33	22	1.5	22.0	1.9	13	1.9
63-4227	06	Ker	94	55	4	64	43	21	2.5	35.0	3.2	17	3.9
63-4228	06	Ker	95	62	5	67	38	29	3.5	31.0	3.6	26	4.2
63-4229	06	Ker	86	44	4	42	24	18	1.5	21.5	2.6	16	2.6
63-4230	06	Ker	97	56	7	57	34	23	3.5	26.0	2.9	22	4.1
63-4231	06	Ker	77	Floc	3	37	30	7	1.5	19.0	6.0	14	4.3
63-4232	06	Ker	96	58	5	62	33	29	2.0	30.0	3.4	16	3.4

* No moisture control necessary

TABLE A (continued)

Test No.	Dist.	Co.	Grading Sieve 200 %	Grading Size 5U %	SE	LL	PL	PI	3rd Cycle Rec. Cover (Ft.)	3rd Cycle Rec. Moist %	Column Height P#4 Matl.	R Value	Column Ht. P#4 Matl. Pulverized to P #50
63-4233	06	Ker	86	58	4	67	38	29	2.5	30.5	3.5	16	4.1
63-4234	06	Ker	93	55	8	56	28	28	3.0	25.0	6.0	6	5.8
63-4694	05	Mon	83	37	2	37	14	23	1.5	*	2.4	6	2.4
63-5019	10	SJ	84	41	3	42	27	15	1.5	*	2.8	20	2.8
63-5022	10	SJ	86	43	14	48	32	16	1.5	31.0	2.5	31	2.5
63-2025	10	SJ	93	49	6	58	37	21	1.5	29.0	3.1	26	3.1
64-1016	03	Sac	70	36	6	38	23	15	1.5	21.0	2.6	19	2.6
64-1018	03	Sac	72	31	11	48	23	25	2.0	24.0	2.7	18	2.7
64-1020	03	Sac	80	45	5	47	17	30	2.0	19.0	3.6	6	3.6
64-1021	03	Sac	71	33	14	38	16	22	1.5	14.5	2.6	5	2.9
64-1022	03	Sac	89	45	3	44	19	25	2.5	18.0	3.8	6	4.5
64-1036	03	Sac	65	18	8	40	19	21	2.0	21.5	2.5	15	2.5
64-1045	03	Sac	86	42	3	43	17	26	1.5	19.0	4.3	13	4.3
64-1048	03	Sac	93	57	Floc	51	18	33	2.0	20.0	5.1	10	5.1
64-1050	03	Yol	99	75	Floc	70	29	41	3.0	24.0	5.5	5	5.5
64-1053	03	Yol	97	53	Floc	52	31	21	1.5	27.0	2.9	16	2.9
64-1056	03	Yol	97	83	Floc	64	22	42	2.0	23.0	5.5	7	5.5
64-1058	03	Yol	97	83	Floc	65	23	42	4.0	22.5	5.1	12	6.4
64-2378	03	Sac	95	39	1	39	26	13	1.5	17.5	2.8	10	2.8
64-2379	03	Sac	96	67	7	71	37	34	4.0	31.5	3.5	12	4.6
64-2383	03	Sac	87	50	5	52	23	29	1.5	20.5	4.3	7	5.0
64-4106	03	Yol	80	46	2	47	22	25	3.0	18.5	**	8	5.2
64-4105	03	Yol	69	31	4	44	20	24	1.5	14.0	**	6	3.4
64-4068	10	SJ	90	40	3	49	21	28	1.5	18.1	**	7	6.2
64-4066	10	SJ	89	41	1	49	21	28	1.5	18.0	**	8	5.1
64-4063	10	SJ	71	38	3	58	28	30	1.5	25.0	**	10	5.1
64-4065	10	SJ	82	53	3	52	20	32	1.5	18.0	**	7	6.1
64-4064	10	SJ	82	36	4	49	24	25	1.5	19.4	**	10	4.7
64-4062	10	SJ	88	44	2	53	34	19	2.0	19.4	**	9	5.9
64-4067	10	SJ	78	34	4	46	22	24	1.5	18.0	**	6	4.0

* No moisture control necessary

** No test performed

TABLE B

	Sample A		Sample B		Sample C	
Temperature ^{o}F	66	106	64	106	65	102
Column Height	5.7	5.0	4.5	3.9	3.2	2.6

Figure 1

RAPID METHOD FOR DETERMINING EXPANSIVE
POTENTIAL OF CLAY SOILS

PASSING #4 MATERIAL USED
91 SAMPLES

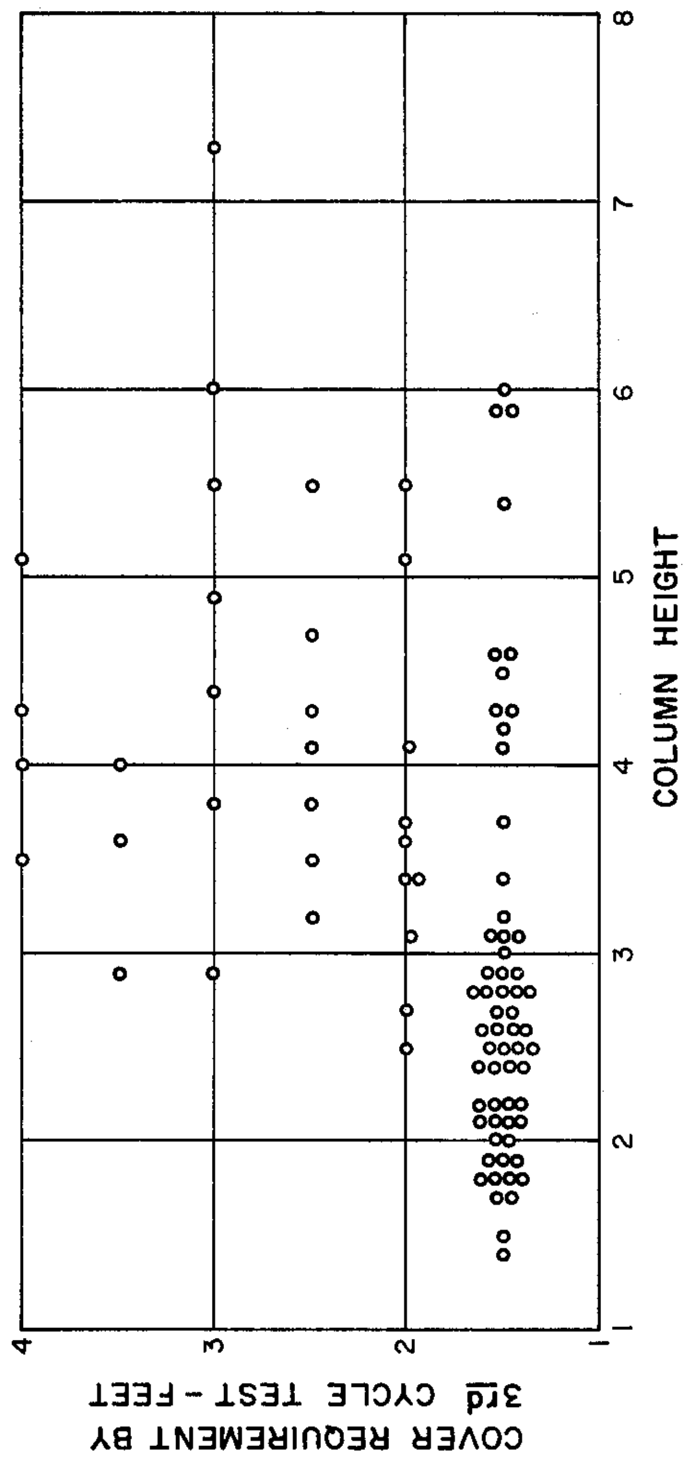


Figure 2

RAPID METHOD FOR DETERMINING EXPANSIVE POTENTIAL OF CLAY SOILS

PASSING #4 MATERIAL PULVERIZED TO PASS #50 SIEVE
100 SAMPLES

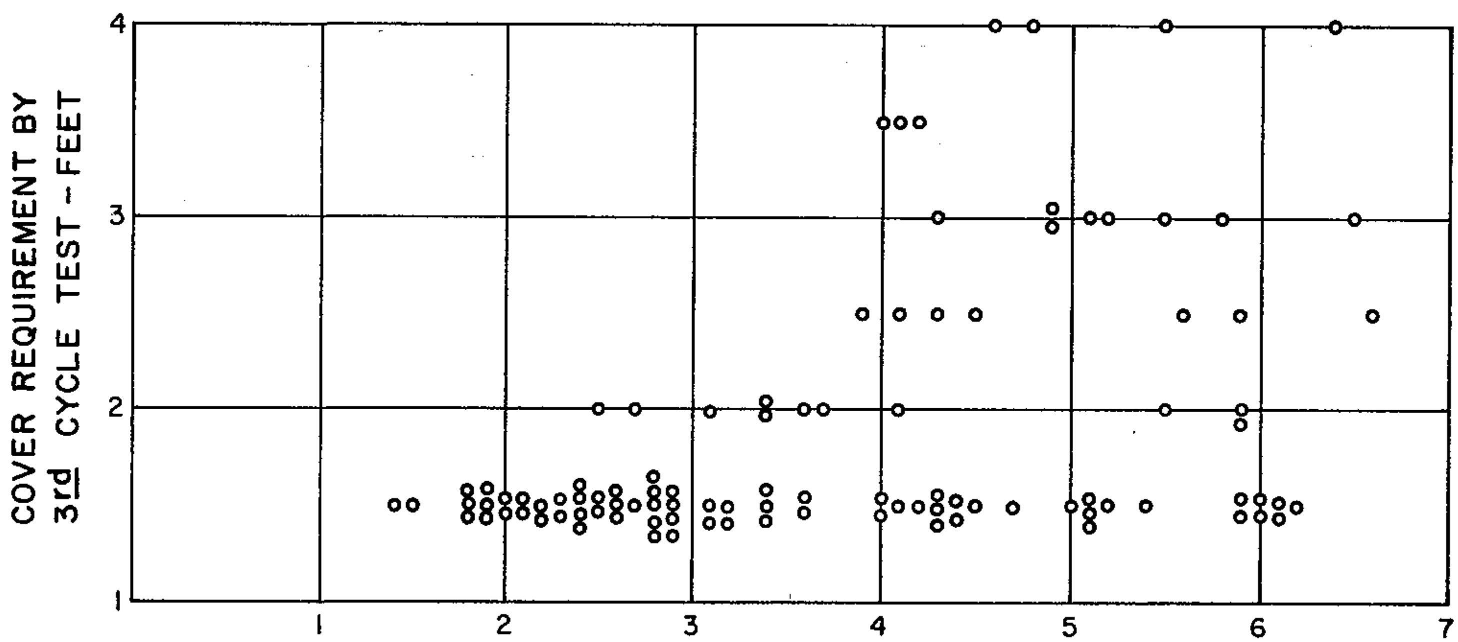


Figure 3

COLUMN HEIGHT VERSUS SETTLING

TIME FOR VARIOUS CLAY MATERIALS

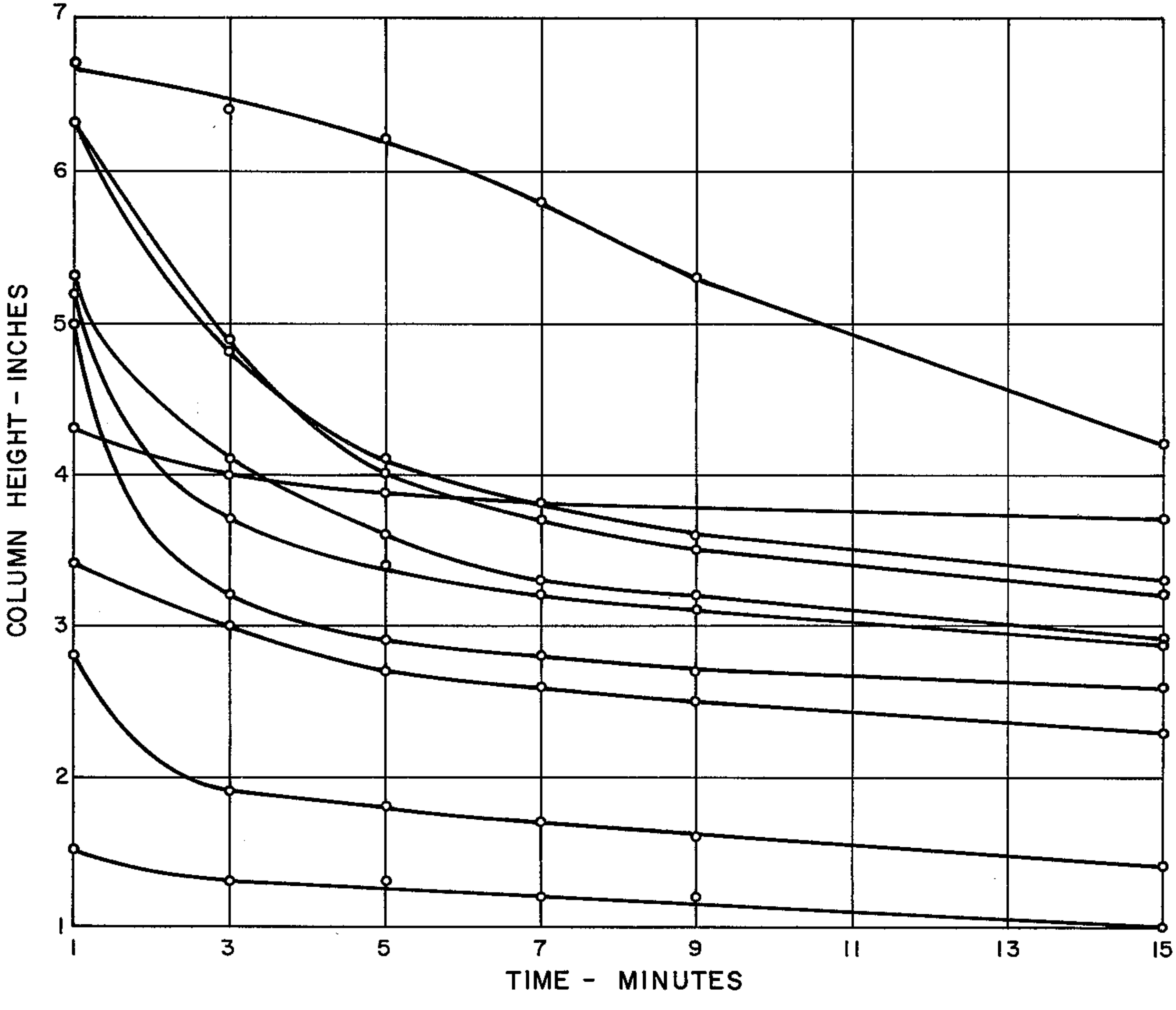
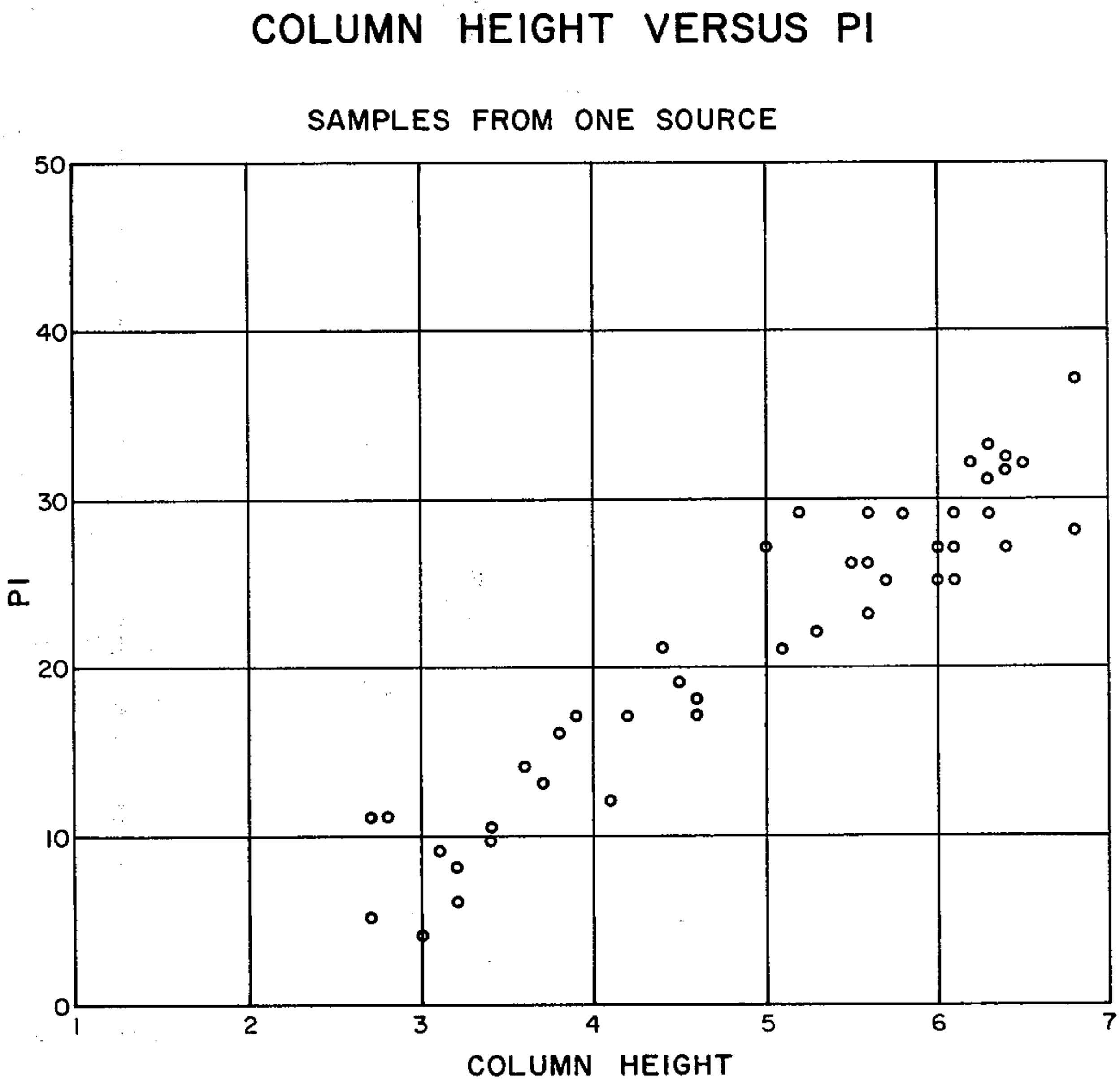


Figure 4



COLUMN HEIGHT VERSUS PI
SAMPLES FROM ONE SOURCE
PI
COLUMN HEIGHT
0
10
20
30
40
50
1
2
3
4
5
6
7

Figure 5

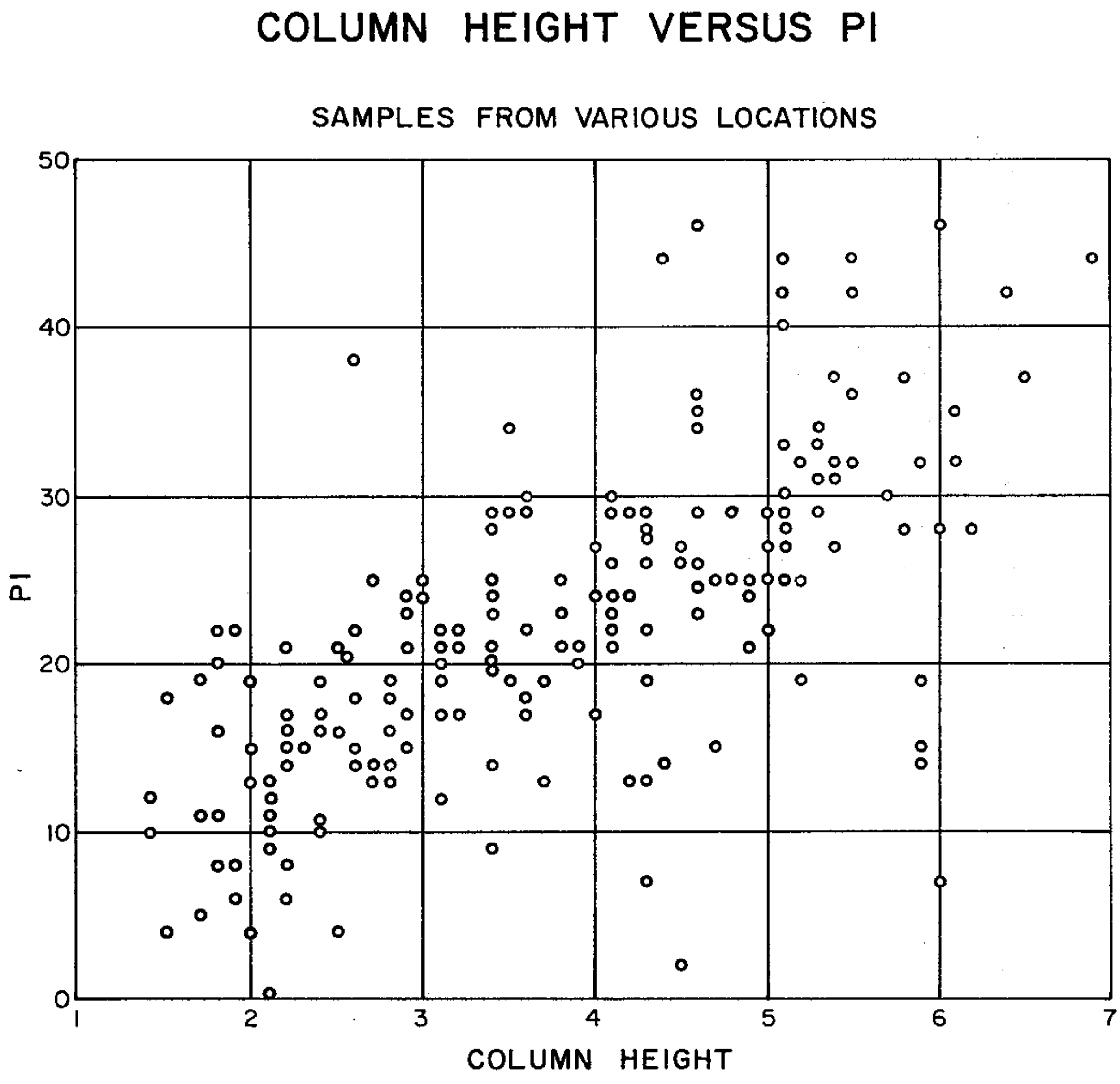
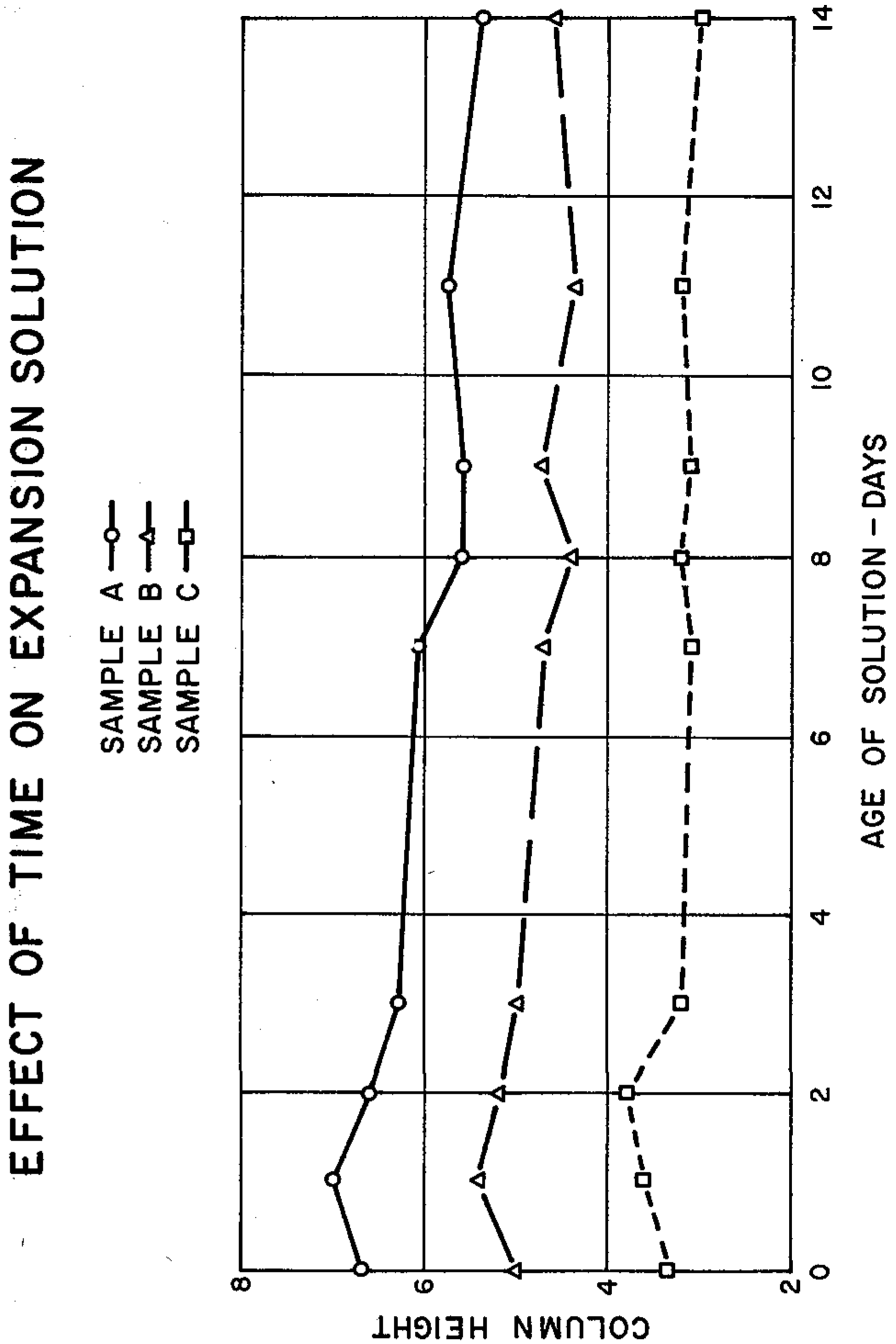

COLUMN HEIGHT VERSUS PI
SAMPLES FROM VARIOUS LOCATIONS
PI
COLUMN HEIGHT
0
10
20
30
40
50
1
2
3
4
5
6
7

Figure 6


EFFECT OF TIME ON EXPANSION SOLUTION
SAMPLE A
SAMPLE B
SAMPLE C
COLUMN HEIGHT
8
6
4
2
AGE OF SOLUTION - DAYS
0
2
4
6
8
10
12
14