GUARD RAIL ANCHORAGE INVESTIGATION

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

James F. Bovill

1948

Guard Rail Anchorage Investigation

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

by

James F. Bovill

Candidate for the Degree of

Bachelor of Science

July 1948

THESIS

PREFACE

This investigation is a continuation of H. I. Bacon's "Experimental Investigation of Michigan State Highway Guard Rail Anchorages." Mr. Bacon established a method of experimentation and constructed the necessary equipment for such experiments. The procedure of experiments is similar to Mr. Bacon's, but attempts are made to verify certain fundamental relationships in guard rail anchorage not yet established.

GUARD RAIL ANCHORAGE INVESTIGATION

The study of guard rail anchorage is a current project in progress at the Michigan State Highway Department Research Laboratory, and this is a phase of the more general subject which will be beneficial for actual use in our present day highway construction. The idea of contributing to a project which is designed to eliminate "guess work" in engineering practice directed my selection of thesis subject to guard rail anchorage.

PURPOSE

The guard rail anchorage project is past its primary stage. Mr. Bacon has set up scale model apparatus and determined a method of experimentation. The secondary stage, which is the present phase of the project, consists of experiments with the scale model apparatus to determine certain graphical relationships existing under controlled conditions. The third and final stage will be the full scale pull outs conducted by the Michigan State Highway Department.

HISTORY

A history of guard rail anchorage experimentation can be simply described as insufficient. D. C. Hubbard, working for the A. B. Chance Co. on patented metal anchors, gives a general picture of full scale anchor pull outs. His tests were made in various soils and were accomplished by means of a pole, block and tackle, a strong spring scale and a caterpillar tractor. No control was made of variable and only depth of burial was changed. A curved line variation was stated in regard to depth and 15% variation in results was recognized due to different soil conditions.

R. T. Haggerstrom wrote in his thesis, "An Experimental Study of Special Anchors in Sand and Clay," that a 45° pull out angle and a greater depth of burial provided larger pull out forces.

"An Experimental Investigation of Michigan State Highway Guard Rail Anchorages," by H. I. Bacon is very valuable because of his methods and apparatus. He has set up a reliable method of experimentation which has been changed only slightly, and his apparatus is quite consistant as to results.

The specific purposes of this investigation are to find: the relationship between anchor area and pull out value, the relationship between anchor depth and pull out value and the relationship between soil moisture content and pull out value. These factors can be estimated from practical experience or guessed at from other works on similar problems, but the object of this study is to control the variables in such a manner that guess work can be eliminated.

APPARATUS

Figure 1 shows the scale model apparatus built by H. I. Bacon. A 3 foot by 4 foot by 28 inch box was built to the scale of 3 inches = 1 foot for the purpose of holding the sand. It has a glass observation window opposite the angle iron bracket. The bracket is arranged to accommodate the applied load through a pulley system. The vertical adjustment of the pulley makes possible the control of the pull out angle. Brackets are attached to the inside of the box to hold the arm of a portable vibrating machine.

Figure 1a. General view of apparatus showing observation window.

Figure 1b. General view of apparatus showing load-application system.

Figure 1c. General view of apparatus showing shoulder section.

Figure 1d. View of typical anchor pull out.

MATERIALS

As this is a controlled experiment, the type of anchor is constant. The anchors are made of hard wood and are all of the oval type as shown in Figure 2. The oval type anchor was used because it proved to have the greatest pull out value according to both Mr. Haggerstrom and Mr. Bacon. The hard wood was treated against moisture absorption by boiling it in linseed oil for one-half hour. The anchor specifications are as follows:

	Type	Dimensions	Area	Weight
a	oval-wood	1/2 in. x 7.8 in. x 3.9 in. dia.	24 sq. in.	1 lb.
b	" "	1/2 in. x 7.2 in. x 3.6 in. dia.	30 " "	1-1/4 in.
c	" "	1/2 in. x 6.6 in. x 3.3 in. dia.	36 " "	1-1/2 in.
d	" "	1/2 in. x 5.88 in. x 2.94 in. dia.	42 " "	1-3/4 in.

The sand was graded sand and air dried prior to beginning the experiment.

PROCEDURE

A five-gallon can with the bottom cut out was forced down into the sand to such a depth that the center of gravity of the anchor lay at the specified depth below the sand surface. The sand contained in the can was removed and the anchor placed at a 45° angle. The sand was replaced and vibrated for 15 minutes. An initial load was always applied to take up any slack in the cable. Any disturbances in the shoulder section were repaired after each experiment. The glass observation window was not used as very little movement occurred in the sand near it. Shoulder damages and pull out cracks were similar to those found by Bacon.

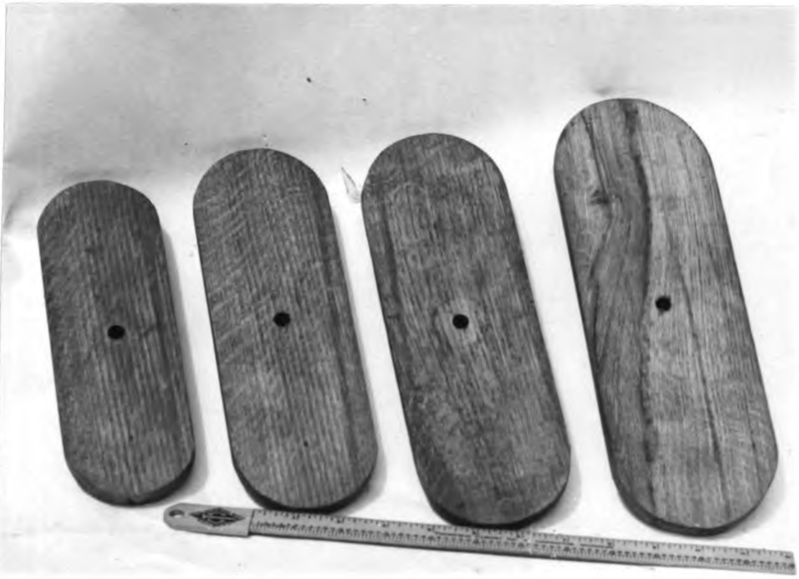


Figure 2. View showing oval type anchors.

The pull out force was the only measurement needed in this experiment and any unusual cases of pull out values or pull out actions were discarded.

DATA

Purpose

To determine the relationship between the anchor area and the pull out value.

Apparatus and Conditions

a. Oval type anchors as shown in Figure 3 with areas of 24, 30, 36 and 42 sq. in. These areas were determined by the following method:

$$K = \frac{x}{y} = 2 \;\therefore\; x = 2y$$

$$y(x) + .785(y)^2 = A$$

$$2y^2 + .785(y)^2 = A$$

$$y^2 = \frac{A}{2.785}$$

$$x = 2y$$

$$\therefore\; y_1^2 = \frac{4^2}{2.785} \qquad y_2^2 = \frac{36}{2.785}$$

$$y_1 = 3.9_1 \; x_1 = 7.8 \qquad y_2 = 7.2_1 \; x_2 = 3.6$$

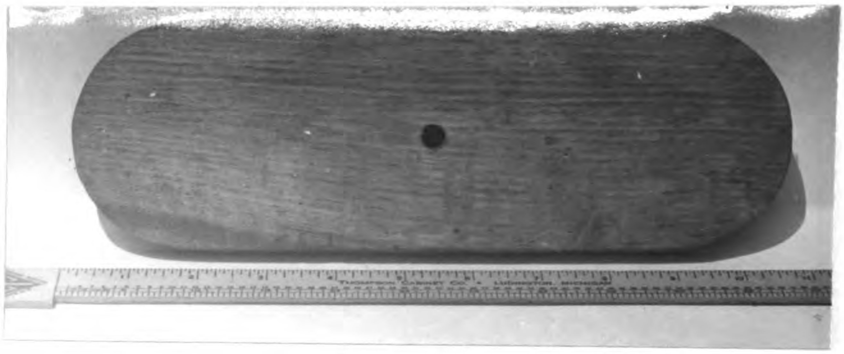
$$y_3^2 = \frac{30}{2.785} \qquad y_4^2 = \frac{24}{2.785}$$

$$y_3 = 6.6_1 \; x_3 = 3.3 \qquad y_4 = 5.83 \; x_4 = 2.94$$

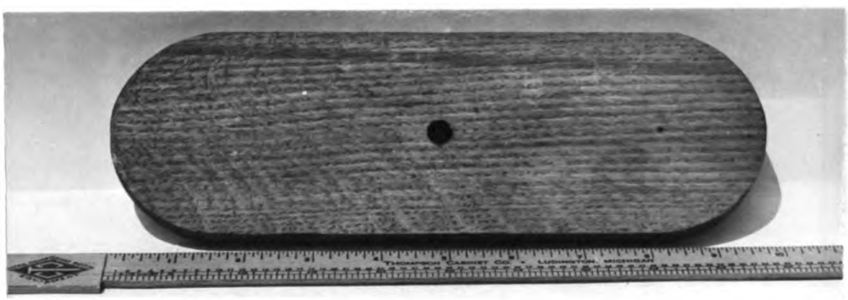
b. Air dried sand.

c. Twelve-inch burial depth.

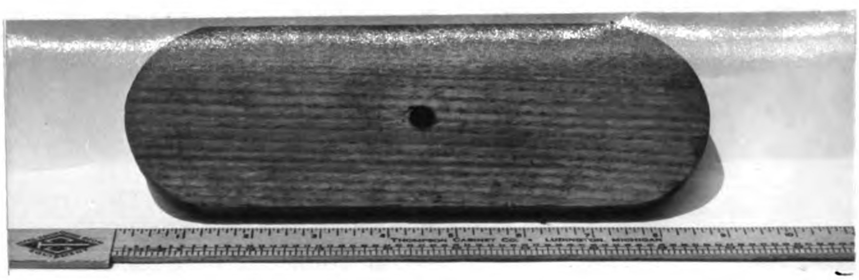
42 sq. in. area



36 sq. in. area



30 sq. in. area



24 sq. in. area

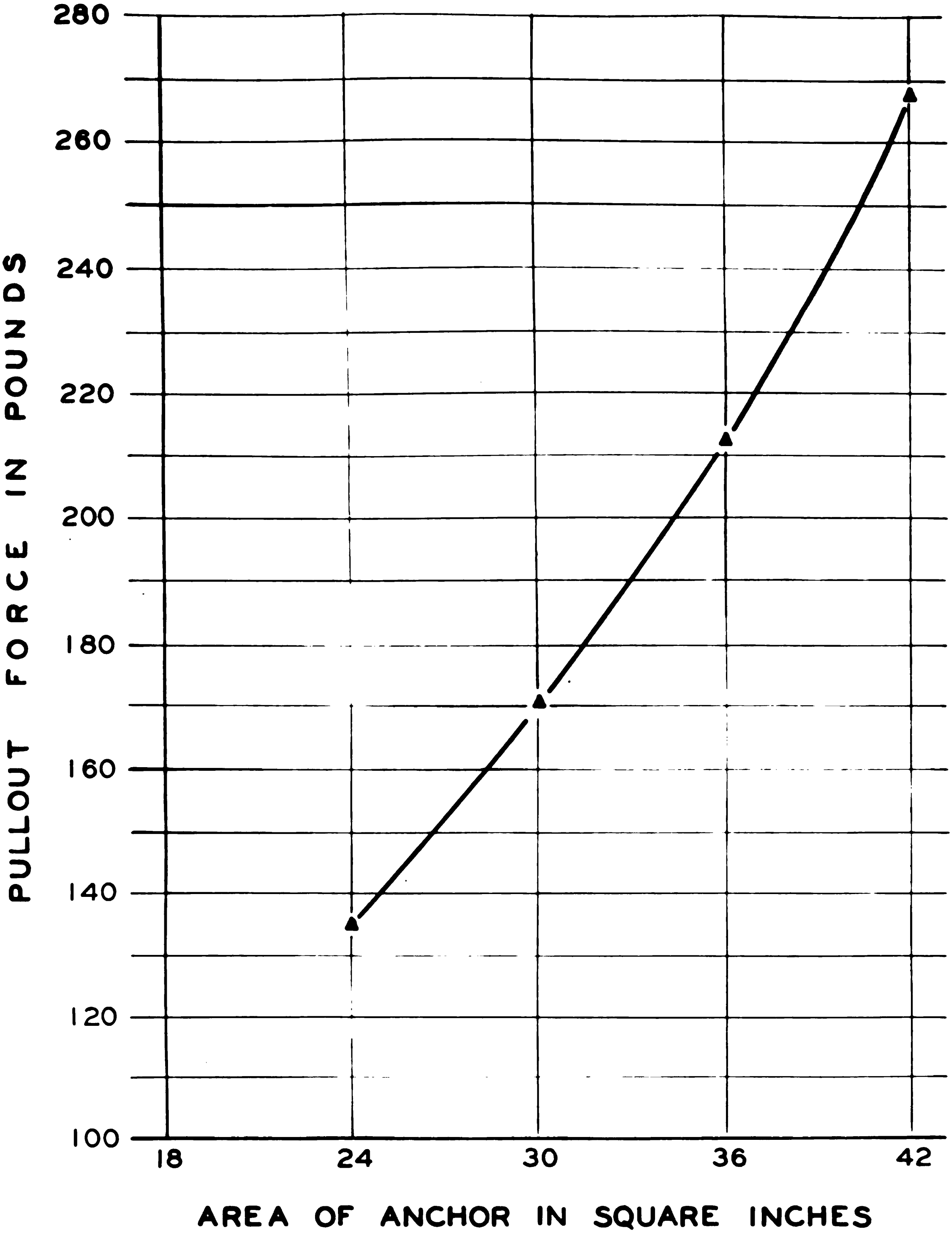
Figure 3. View of four anchors used in Area vs. Pull Out test.

Results

No.	Area	Moisture Content	Burial Depth		Dead Weight Pull Out Force
1	24 sq. in.	Air Dried	12 in.		141 lb.
2	" " "	" "	" "		130 "
3					135 "
				mean	135.5 lb.
1	30 sq. in.	Air Dried	12 in.		167 lb.
2	" " "	" "	" "		171 "
3	" " "	" "	" "		172 "
				mean	170 lb.
1	36 sq. in.	Air Dried	12 in.		209 lb.
2	" " "	" "	" "		191 "
3	" " "	" "	" "		236 "
				mean	212 lb.
1	42 sq. in.	Air Dried	12 in.		284 lb.
2	" " "	" "	" "		263 "
3	" " "	" "	" "		254 "
				mean	267 lb.

Remarks

Figure 4 shows the results of this test graphically. The slight upward trend seems to indicate a greater pull out value per square inch of surface area with a larger area as this is nearly a straight line graph, the tendency would be to interpret it as such, and to account for any curvilinear variations by such reasons as: variation in soil compaction, frictional resistance of the sand, slight differences in the rate of dead load application and the slight difference in the weights of the anchors.



EFFECT *of* ANCHOR AREA *on* PULLOUT VALUE

Figure 4

DATA (continued)

Purpose

To determine the relationship between the depth of burial of the anchor and the pull out value.

Apparatus and Conditions

a. Thirty-six sq. in. oval type anchor.

b. Air dried sand.

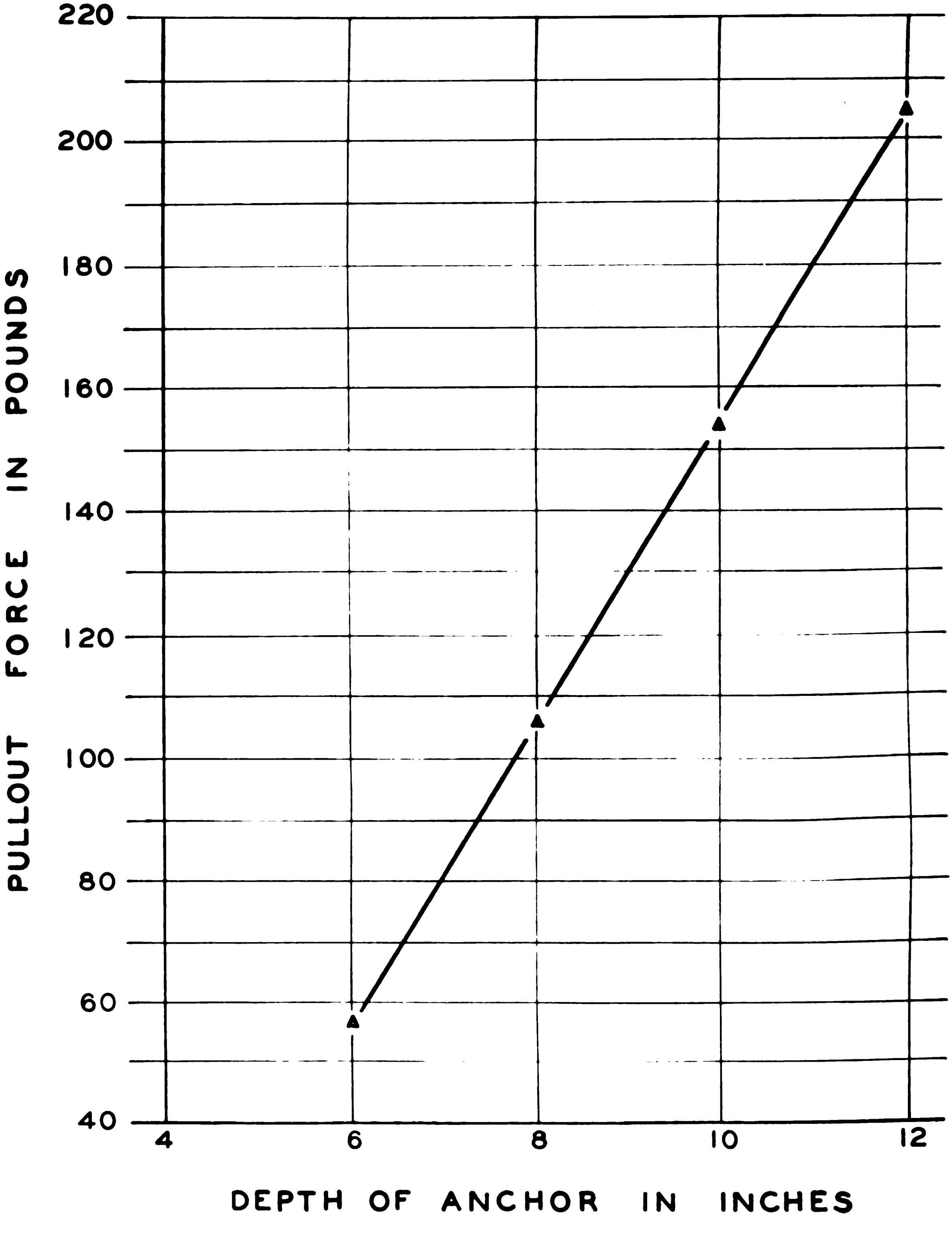
c. Six in., 8 in., 10 in. and 12 in. burial depths.

Results

No.	Area	Moisture Content	Burial Depth	Dead Weight Pull Out Force
1	36 sq. in.	Air Dried	6 in.	56.75 lb.
2	" " "	" "	" "	54.00 lb.
3	" " "	" "	" "	59.00 lb.
				mean 56.50 lb.
1	36 sq. in.	Air Dried	8 in.	106.25 lb.
2	" " "	" "	" "	104.25 lb.
3	" " "	" "	" "	102.25 lb.
				mean 104.25 lb.
1	36 sq. in.	Air Dried	10 in.	158.00 lb.
2	" " "	" "	" "	153.00 lb.
3	" " "	" "	" "	151.75 lb.
				mean 154.25 lb.
1	36 sq. in.	Air Dried	12 in.	206.00 lb.
2	" " "	" "	" "	201.00 lb.
3	" " "	" "	" "	211.00 lb.
				mean 206.00 lb.

Remarks

Figure 5 shows the graphical results of this test. It is a straight line variation which would be expected. This is also an indication that the Area vs. Pull Out graph (Figure 4) is fundamentally a straight line.



EFFECT *of* DEPTH *of* ANCHOR *on* PULLOUT VALUE

Figure 5

DATA (continued)

Purpose

To determine the relationship between the moisture content of the sand and the pull out value.

Apparatus and Conditions

a. Thirty-six sq. in. oval type anchor.

b. Moisture content of sand varied between 0 and 20 per cent.

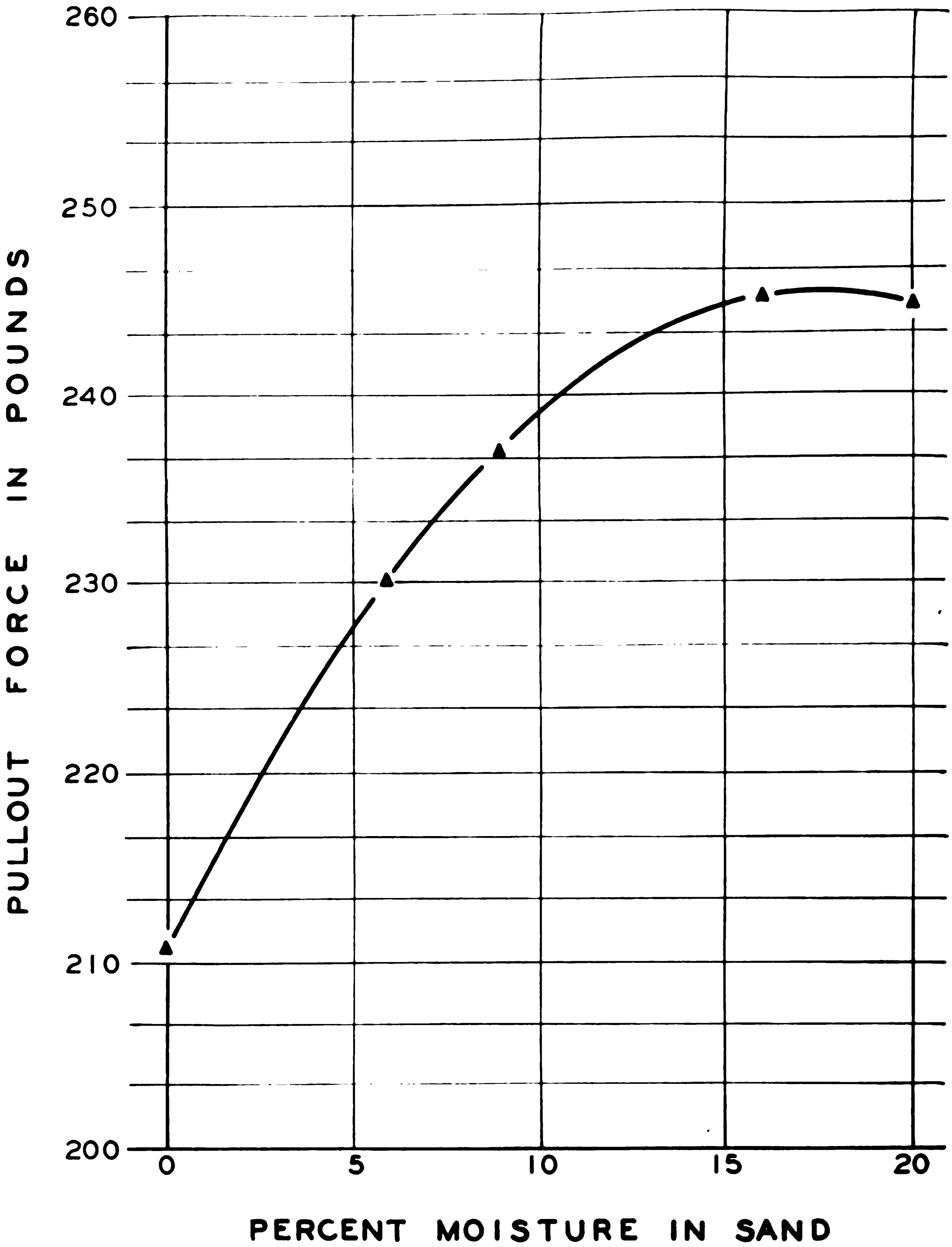
c. Twelve inch depth of burial.

Results

No.	Area	Moisture Content	Burial Depth		Dead Weight Pull Out Force
1	36 sq. in.	0%	12 in.		209.00 lb.
2	" " "	"	" "		191.00 lb.
3	" " "	"	" "		236.00 lb.
				mean	212.00 lb.
1	36 sq. in.	6%	12 in.		221.00 lb.
2	" " "	"	" "		234.00 lb.
3	" " "	"	" "		235.75 lb.
				mean	230.25 lb.
1	36 sq. in.	9%	12 in.		240.00 lb.
2	" " "	"	" "		241.00 lb.
3	" " "	"	" "		230.00 lb.
				mean	237.00 lb.
1	36 sq. in	16%	12 in.		255.00 lb.
2	" " "	"	" "		250.00 lb.
3	" " "	"	" "		235.00 lb.
				mean	245.00 lb.
1	36 sq. in.	20%	12 in.		242.00 lb.
2	" " "	"	" "		248.00 lb.
3	" " "	"	" "		236.00 lb.
				mean	242.00 lb.

Remarks

Figure 6 shows the results of this experiment graphically. The apparent rise and decline of the pull out value at increasing moisture



EFFECT *of* MOISTURE CONTENT *on* PULLOUT VALUE

Figure 6

contents can be explained this way: The optimum moisture content of this sand is 18.6%, and by checking the graphical results one can see that the maximum pull out force came at about the optimum moisture content. It seems reasonable that at the point of maximum density, the greatest pull out value would be obtained. A rough check of saturated sand was made and the pull out force was found to be considerably less than at 0% moisture.

SUMMARY

Three tests were run: Anchor Area vs. Pull Out, Anchor Depth vs. Pull Out and Moisture Content vs. Pull Out.

Anchor Area vs. Pull Out is a curvilinear variation almost approximating straight line variation. For all practical purposes it can be interpreted as a linear graph. Thus, the crossectional area of the anchor is directly proportional to the force required to cause failure of the soil to hold the anchor.

Anchor Depth vs. Pull Out is a linear variation making the depth of burial directly proportional to the force required to cause failure of the soil to hold the anchor.

Moisture Content vs. Pull Out is a curvilinear graph showing that at the optimum moisture content of the soil, the greatest pull out force can be expected.

Further investigation on full scale models can be governed by these results. As these results are based on a small scale, accurate predictions are not warranted but general trends and estimates of values may be made successfully from any of the information submitted.