RELATIVE MERITS OF COTTON AND JUTE CEMENT SACKS

By Robert J. Morris

ABSTRACT

This paper contains information concerning the tests made and the apparatus used in determining the relative merits of one type of cotton osnaburg and several types of jute burlap sacks used as containers for Portland cement. A brief description is given of the physical tests made, such as breaking strength, thread count, length, width, stretch, and, of greater importance, the resistance to failure from dropping or rough handling; also of the practical tests made, such as the service test, for which the sacks were put into actual service; the hot-cement test, in which the sacks were filled with hot, freshly ground cement; the humidity test, in which samples were exposed to various atmospheric conditions; and the moisture test, during which the sacks of cement were subjected to excessively damp conditions. The results of all these tests are given in tabular and graphical form. From these data the type of sack with the most serviceability was chosen.

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I. INTRODUCTION

Much of the cement used in this country is packed, shipped, and stored in cloth containers. Whenever one of these containers is badly torn by rough handling or seriously caked by exposure to moisture, there may be a loss of both the cement and the sack.

To meet the demand of the cement industry, approximately 75,000,000 cotton osnaburg sacks are required each year, representing an annual outlay of about $13,000,000. The same number of "high-count" Dundee burlap sacks can be purchased for about $10,000,000. The problem of reducing the expense either by increasing the life of the sacks or by finding a lower-priced sack that is no less serviceable led the Portland Cement Association, in cooperation with the Bureau of Standards, to investigate the performance of containers of various types.

A committee was appointed by the Portland Cement Association to select the types of sacks to be investigated. This committee selected and sent to the Bureau of Standards five different types of sacks, namely, one cotton osnaburg, two high-count jute Dundee, and two low-count jute Dundee. The osnaburg sack is the kind now used by the cement industry, and the particular osnaburg selected for this investigation was considered to be the best of its kind available. Of the four jute sacks, the two high-count types represent the better class of jute sacks and the remaining two are of a poorer grade.

The laboratory tests described in this paper were all conducted at the Bureau of Standards by a research fellow of the Portland Cement Association.

Each of the five types investigated was given a distinguishing number, the cotton sack being designated No. 1, the two high-count jute sacks No. 2 and No. 5, and the other two jute sacks No. 3 and No. 4. In all, over 600 sacks were used in the course of the work.

Grateful acknowledgment is made to W. D. Lober, chairman of the package committee of the Portland Cement Association, and to F. R. McGowan, formerly of the Bureau of Standards, for helpful suggestions in connection with this investigation.

II. METHODS OF DETERMINING PHYSICAL PROPERTIES OF THE FABRIC

As criteria of the condition of a sack before and after exposure to any particular treatment, the following physical characteristics of the fabric were studied: Resistance to failure from dropping, breaking strength, stretch, thread count, dimensions, and oil content. Except where specifically stated otherwise, the material was always allowed to remain for at least three hours in an atmosphere of 65 per cent relative humidity at 70° F. (21° C.) before any physical tests were made. The characteristics or properties were determined in the following manner:

1. RESISTANCE TO FAILURE FROM DROPPING

The resistance to drop failure was determined by means of the apparatus shown in Figure 1. The sack was filled with 94 pounds of Portland cement and placed lengthwise along the line where the door of a closed trapdoor joined. When this trapdoor was sprung

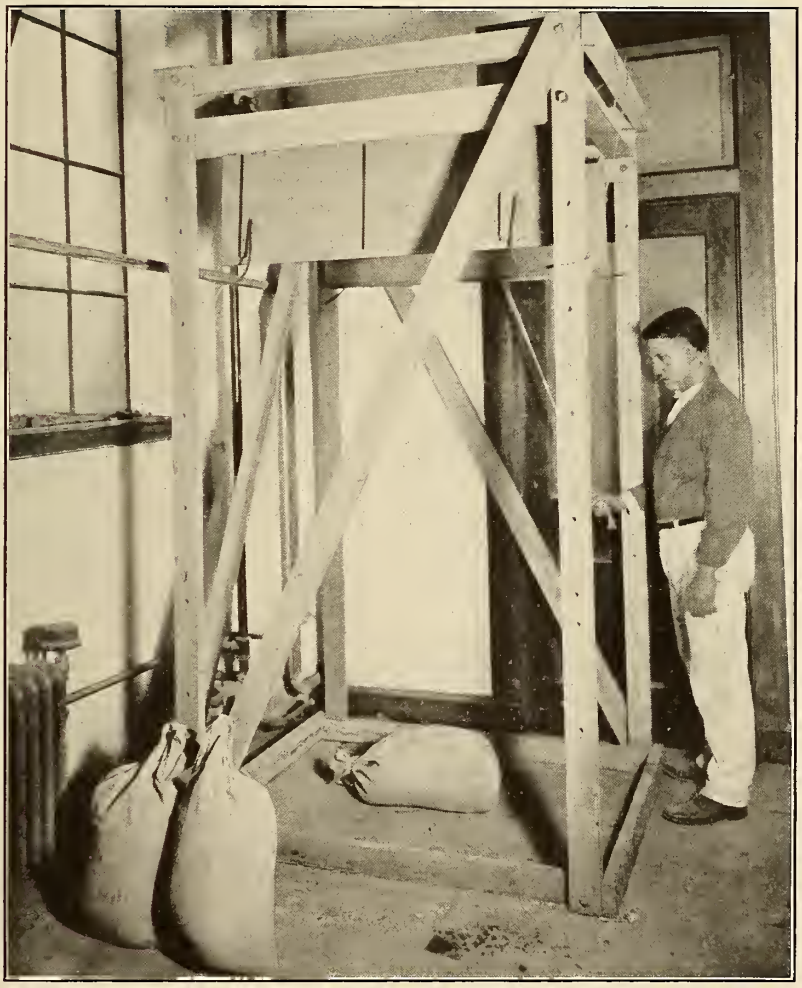

FIG. 1.—*Apparatus for determining the resistance to failure from dropping*

the sack was dropped a distance of 8 feet upon a smooth concrete floor. This arrangement prevented the sack from turning while falling, for no case was observed in which the sack fell on its side or

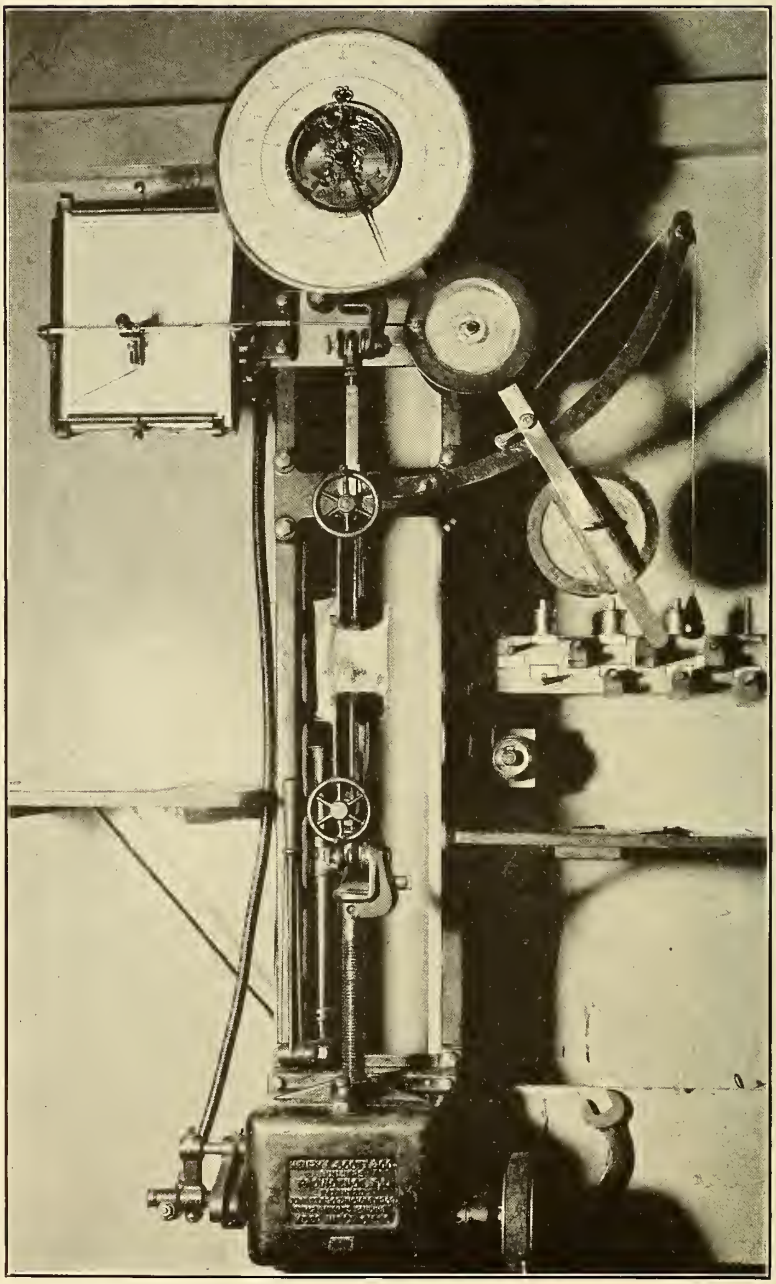

Fig. 2.—*Apparatus for determining breaking strength*

end. The test was repeated until the fabric failed, the number of drops necessary to produce failure indicating the resistance to drop failure.

The drop test is intended to simulate the severest treatment the cement sack may receive in actual service. Preliminary work was done in order to determine the most satisfactory method of tying the top of the sack. A number of sacks were filled and tied very closely in such a way as to take up all possible slack at the neck of the sack. An equal number of the same kinds of sacks were tied in the usual manner; that is, with as much space as possible between the cement and the wire used to tie the top of the sack. It was found that a fewer number of drops were required to cause failure when the sacks were tied closely, and therefore, in order to make the work progress more rapidly, the tests were made in this way. In actual service it is suggested that this information be utilized by tying the sacks near the top, so that the cement will have space in which to move when dropped or suddenly jarred.

2. BREAKING STRENGTH

The breaking strength was determined by the usual 1 by 1 by 3 inch grab method on the machine shown in Figure 2. Twenty test specimens 6 inches long by 4 inches wide were cut from each sack, 10 in the direction of the warp and 10 in the direction of the filling, care being taken that no two specimens included the same threads. No specimens for test were taken less than 8 inches from either selvage.

The machine used was of the inclination-balance type with a maximum capacity of 300 pounds. The lower or pulling jaw traveled at the uniform rate of speed of 12 inches per minute under no load. The distance between the jaws at the start of the test was 3 inches. The inside or back half of each jaw was 2 or more inches in width; the other half was 1 inch in width. The jaws used had a smooth, flat surface with the edges slightly rounded in order to prevent cutting the specimen by the jaw.

3. STRETCH

The stretch was determined by measuring the increase in the length of the specimen at the breaking point over the length of the same specimen when under a tension of 10 pounds. Dividing this increase by the original length and multiplying by 100 gives the percentage stretch. The slight tension of 10 pounds was taken as the starting point for the stretch test, because when under no tension the length of the specimen is indefinite. These measurements were taken from the autographic record obtained during the breaking strength test described above. (See fig. 3.)

4. THREAD COUNT

The actual number of threads in 1 inch of width was counted in each sack at three different places for both the warp and filling directions and the results averaged for each direction. These counts were made at least 6 inches apart, and no warp reading was taken at less than 8 inches from the selvage.

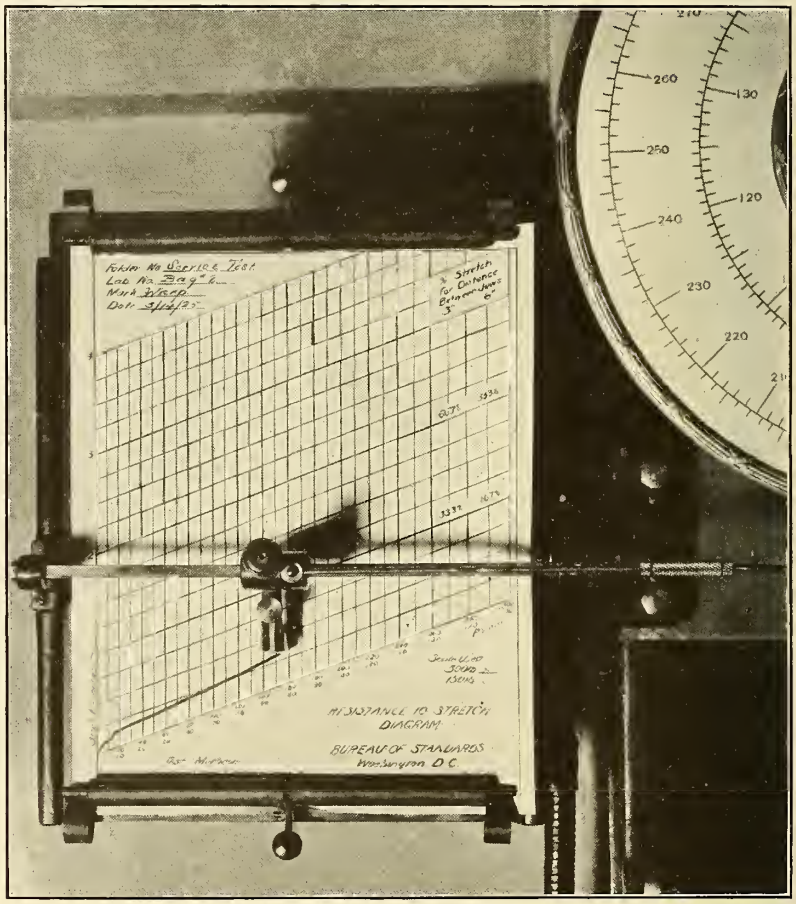

Fig. 3.—*Autographic recording device for recording stretch*

5. DIMENSIONS

The length and width of the sack were determined by laying it on a flat surface without tension and measuring with a steel tape to the nearest one-eighth of an inch. The measurements were taken for the length and width at three different places in the sample and the results averaged.

6. OIL CONTENT

In this test specimens from the cement sacks were conditioned, weighed, and extracted for six hours in a soxhlet extractor with chloroform. The apparatus was wrapped with asbestos in order to keep the chloroform hot throughout the apparatus. In case of the sacks which had been used to hold cement, the specimen was freed from the loose cement by cleaning in a vacuum. After extraction the solution was first filtered to remove dirt and any cement that had not been removed by suction. The chloroform was then evaporated and the extract dried and weighed. This represents, of course, both the added and natural oils.

III. METHODS OF TESTING THE SACKS

1. SERVICE TEST

In the service test cement sacks were put into actual service, a certain portion being recalled at definite intervals of time and tested to determine the deterioration that had taken place. In this test 250 sacks were used, 50 of each type. They were filled with cement in the usual manner at a cement mill and shipped to a dealer in Washington, D. C. (a distance of about 200 miles), care being taken to place each test sack in the freight car at the bottom of a pile of seven. The sacks when received by the dealer were emptied and shaken for 15 minutes in a shaker customarily used for this purpose.

Five sacks of each type were kept out for this test after each trip and the remainder sent to the mill for further service. This was done until the 250 sacks had all been recalled, the last lot having thus made 10 trips.

From every lot of 25 sacks which had made a definite number of trips from the cement mill to Washington, D. C., 10 sacks (2 of each type) were tested for resistance to drop failure, 2 sacks were used for making the breaking strength determinations, and 1 of each type was saved for future use. The stretch, thread count, oil content, and dimensions were likewise determined on all of these sacks. Values for the breaking strength were determined separately for the top and bottom portions of the sacks.

2. HOT-CEMENT TEST

Two tests were made to determine how the containers were affected by being filled with hot cement. In the first of these tests 75 sacks (15 of each type) were filled at a cement mill with hot, freshly ground cement and allowed to stand for one week. The sacks were then emptied, and 3 of each type were sent to the Bureau of Standards for test. The rest were refilled in the same manner, and after being emptied 3 more of each type were sent to the bureau. This was repeated until the last 15 sacks had been filled five times.

Of the three sacks sent to the bureau after each filling one was used for the drop test, one was tested for breaking strength, and one was kept for future reference. The dimensions, thread count, and stretch were also determined. The oil content, however, was determined only for the sacks that had been filled five times.

A second test was made with more attention to temperature control. When a sack is filled with hot cement the sack may stay hot anywhere from a few hours to several days, depending upon the chance the sack has to cool. Also, the temperature of the cement at the time of filling varies considerably at different mills. It is desirable, therefore, to have information on the effect of a series of temperatures maintained for extended periods of time; and a second series of tests was accordingly made consisting of holding samples cut from sacks of each type at a constant temperature in an electric oven for various periods of time. The temperatures selected ranged from 200 to 305° F., and the time intervals during which the specimens were maintained at these temperatures ranged from 1 to 48 hours. The effect of the treatment on the sacks was measured by the change produced in the breaking strength of the fabric.

3. MOISTURE TEST

This test is not so much a test of the deterioration of the sack as of the protection it furnished to the cement contained. It was intended to determine the effect of excessive moisture on the so-called "caking" of the cement to the sack. A long wooden frame was built in a basement room equipped with atomizers for maintaining a dense fog of moisture. A waterproof covering (such as is often used on a construction job) of rubberized cotton duck completely covered the frame. (See fig. 4.) The cement sacks under test were placed in the frame beneath the waterproof covering. The purpose of the covering was to prevent water from dripping down on the sacks from the ceiling. It did not, of course, prevent the heavy fog from filling the inside of the frame. This covering thus afforded somewhat the same protection as is given to the sacks in rainy weather by the covering used by contractors.

Thirty sacks (six of each type) were weighed, then filled with fresh cement and weighed again. They were then placed under the canvas covering. The exposure continued for 18 days, 1 sack of each type being removed every third day, so that the first set of sacks was exposed 3 days, while the last set was exposed the full 18 days.

The sacks removed were first weighed to determine the moisture absorbed by the cement. They were then emptied of all the cement except the "cake," which had adhered to the sack and then weighed again.

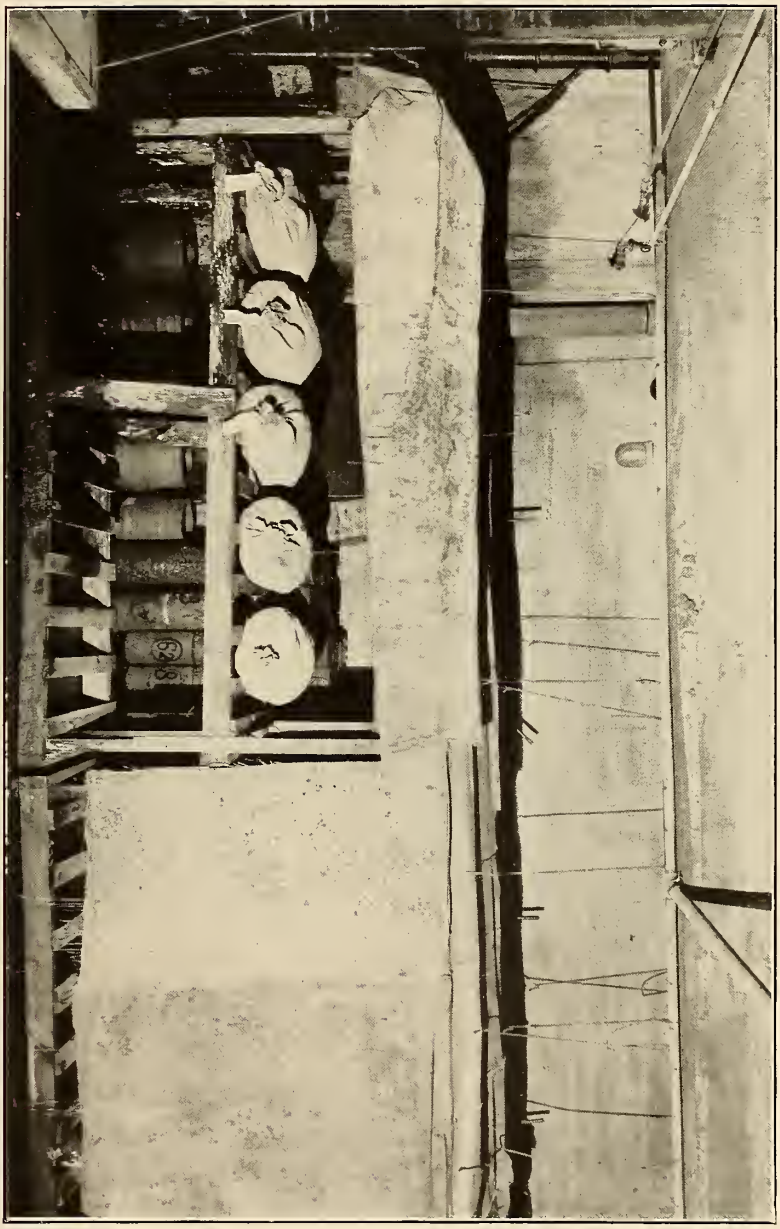

FIG. 4.—*Rack for determining the effect of excessive moisture*

4. HUMIDITY TEST

In order to find the effect of humidity on the sacks themselves, samples of each type were placed in air-tight compartments. Calcium chloride was used in one of these to maintain a low humidity; in another troughs of water were used to maintain a high humidity, while a medium humidity was maintained in the third by placing the container in a conditioning room. The three conditions maintained in this way were, respectively, 30, 90, and 65 per cent relative humidity at a temperature of approximately 70° F.

The changes in the breaking strength, stretch, thread count, and dimensions were used as criteria of the effect on the material.

Fig. 5.—*Typical result obtained of failure caused by dropping*

IV. RESULTS OF SACK TESTS

The results obtained from the measurements made on cement sacks that had been used for the actual transportation of Portland cement will be found in Table 2, and are plotted in Figure 6. The results obtained on the hot cement, moisture, and humidity tests are given in Tables 3, 4, and 5, as well as being shown graphically in Figures 7, 8, and 9. The loss in oil content will be found in Table 6. The results on the original sacks are shown in Table 1.

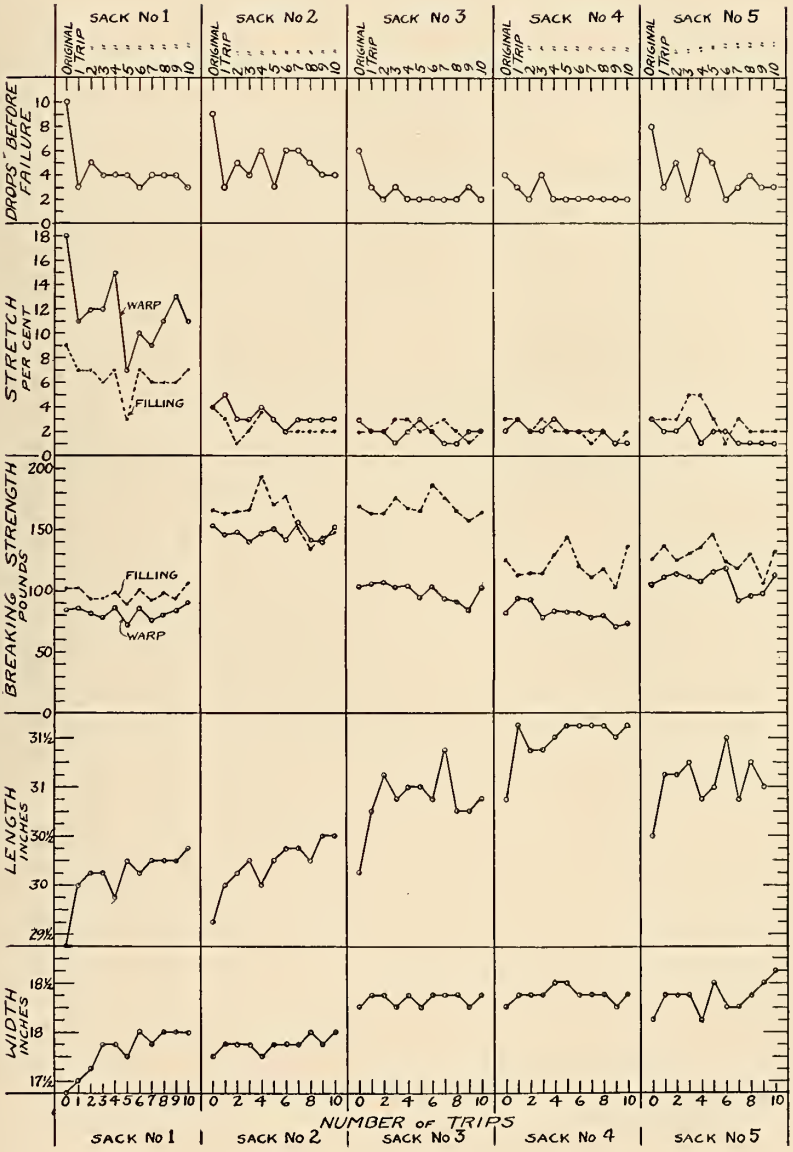

FIG. 6.—*Effect of service (shipping a distance of about 200 miles) on the physical properties of the cement sacks*

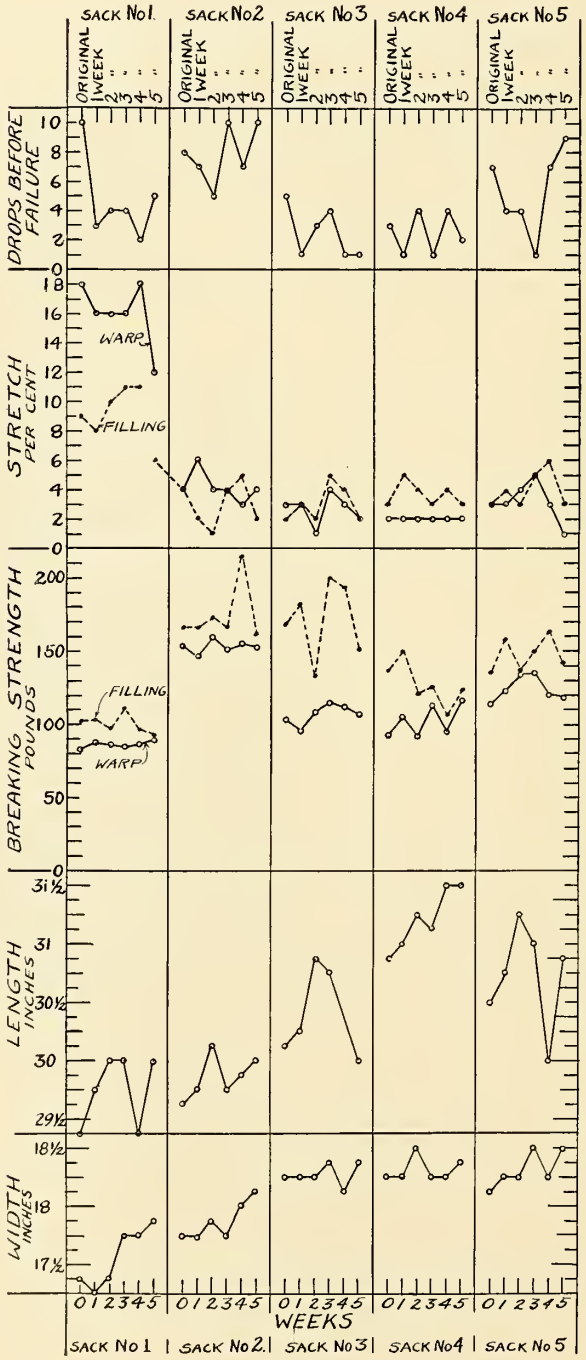

FIG. 7.—*Effect of filling the sacks with hot cement on the physical properties of the sacks*

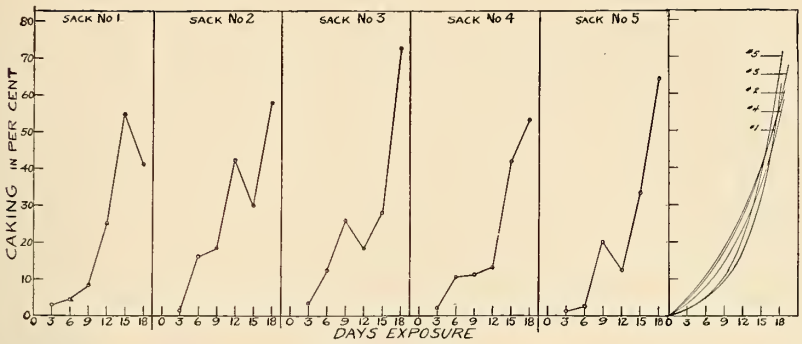

FIG. 8.—*Effect of exposing sacks filled with cement to a moisture atmosphere*

The percentage of "caking" or adhering to the sack is shown in its relation to the number of days exposure

TABLE 1.—*Physical properties of original bags*

Type of sack	Sack No.	Length	Width	Threads per inch		Breaking strength (1 by 1 by 3 inch grab)		Weight per square yard	Stretch		Drop test	
				Warp	Filling	Warp	Filling		Warp	Filling	Number of drops required for failure	Threads broken
		Ins.	*Ins.*			*Lbs.*	*Lbs.*	*Ozs.*	*P. ct.*	*P. ct.*		
Osnaburg	1	29 3/8	17 3/8	39	30	83	102	8.9	18	9	10	Warp.
High-count jute	2	30 3/4	17 3/4	18	18 1/2	153	167	11.8	4	4	8	Do.
Low-count jute	3	30 1/16	18 3/16	12 1/2	13 1/2	103	169	12.9	3	2	5	Do.
Low-count jute	4	30 7/8	18 3/16	13	13 1/2	92	136	11.7	2	3	3	Do.
High-count jute	5	30 7/16	18 1/8	17 1/2	20	114	137	11.0	3	3	7	Do.

FIG. 9.—*Effect of exposure to various humidities on the physical properties of the sacks*

The high, average, and low humidities represent (approximately) 90, 65, and 30 per cent relative humidities, respectively

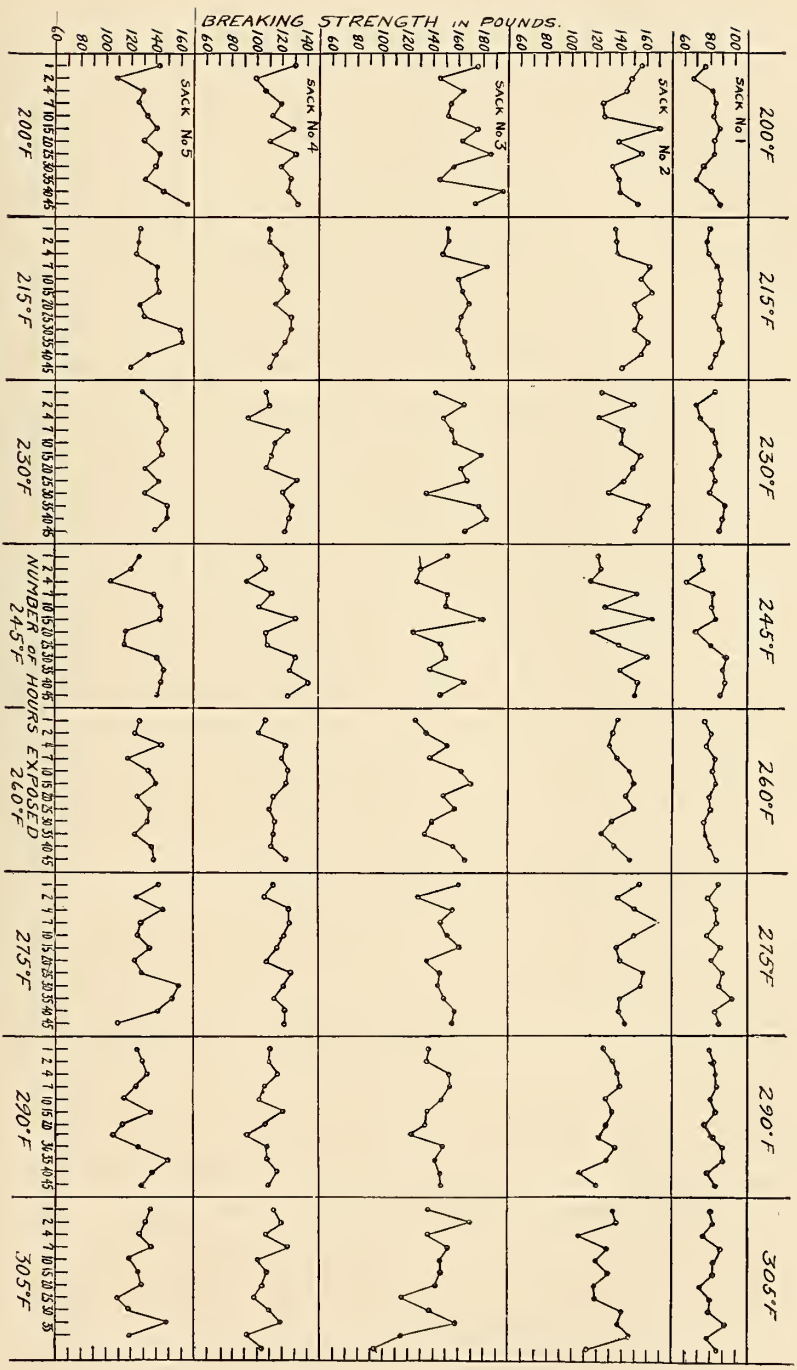

FIG. 10.—*Effect of time and temperature on the strength of the sack material.*

TABLE 2.—*Effect of service (shipping a distance of about 200 miles) on the physical properties of the cement sacks*

Trip No.	Sack No.	Length	Width	Threads per inch		Breaking strength (1 by 1 by 3 inch grab)				Stretch		Drop test	
				Warp	Filling	Top		Bottom		Warp	Filling	Number of drops required for failure	Threads broken
						Warp	Filling	Warp	Filling				
		Ins.	*Ins.*			*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P.ct.*	*P.ct.*		
1	1	30	17½	38½	30½	83	100	85	105	11	7	3	Warp.
	2	30	17¾	18½	18½	145	157	146	171	5	3	3	Do.
	3	30¾	18¼	12	13	107	161	104	167	2	2	2	Do.
	4	31 9/16	18⅜	13	13	103	133	102	110	3	3	2	Do.
	5	31⅛	18⅜	17½	20	111	149	130	144	2	3	2	Do.
2	1	30 1/16	17 9/16	39	31	80	95	81	93	12	7	5	Do.
	2	30⅛	17⅞	18½	18½	146	166	148	163	3	1	5	Do.
	3	31⅛	18 5/16	12	13	105	165	110	163	2	2	1	Do.
	4	31⅜	18 5/16	13	13½	102	126	101	126	2	2	1	Do.
	5	31⅛	18 5/16	17	20½	128	127	121	143	2	3	4	Do.
3	1	30⅛	17⅞	39	30½	79	95	77	93	12	6	4	Do.
	2	30¼	17⅞	18	18½	137	155	143	157	3	2	4	Do.
	3	30⅞	18¼	12	13½	103	177	103	175	1	3	2	Do.
	4	31⅜	18⅜	13	12½	83	116	93	131	2	3	3	Do.
	5	31 3/16	18⅜	17	19½	122	139	120	142	3	5	1	Do.
4	1	29⅞	17⅞	38	29	82	99	89	99	15	7	4	Do.
	2	30	17¾	18	18	148	190	102	195	4	4	6	Do.
	3	31	18⅜	12½	12½	105	165	143	169	2	3	1	Do.
	4	31½	18½	13	13	93	138	95	143	3	2	1	Do.
	5	30⅞	18⅛	17½	20	117	149	116	140	1	5	5	Do.
5	1	30¼	17¾	39	29½	73	90	70	87	7	3	4	Do.
	2	30¼	17⅞	18	18½	148	168	162	171	3	3	3	Sewing.
	3	31	18¼	12	13	95	156	92	172	3	2	1	Warp.
	4	31⅝	18½	12½	13½	97	156	89	154	2	2	1	Do.
	5	31	18½	17	19	117	153	126	159	2	3	4	Do.
6	1	30⅛	18	39	30	87	96	85	103	10	7	3	Do.
	2	30⅜	17⅞	18	18½	140	180	141	174	2	2	6	Do.
	3	30⅞	18⅜	12	13	104	188	104	185	2	2	1	Do.
	4	31⅝	18⅜	12½	13	91	126	95	135	2	2	1	Do.
	5	31½	18¼	17	19½	138	128	118	143	2	1	1	Do.
7	1	30¼	17⅞	38	30	76	99	75	85	9	6	4	Do.
	2	30⅜	17⅞	18	18	159	144	150	148	3	2	6	Do.
	3	31⅜	18⅜	12	13	93	168	93	183	2	3	1	Do.
	4	31⅝	18⅜	12½	13½	95	120	82	122	2	1	1	Do.
	5	30⅞	18¼	17	20½	102	129	100	127	1	3	2	Do.
8	1	30¼	18	39	29½	80	99	------	------	11	6	4	Do.
	2	30¼	17⅞	18	18	141	133	------	------	3	2	5	Sewing.
	3	30¾	18⅜	12	13	91	165	------	------	2	2	1	Warp.
	4	31⅝	18⅜	12½	13½	89	127	------	------	2	2	1	Do.
	5	31¼	18⅜	17	18½	104	140	------	------	1	2	3	Do.
9	1	30⅛	18	39	29½	85	94	------	------	13	6	4	
	2	30½	17⅞	18	18	140	143	------	------	3	2	4	
	3	30¾	18¼	12	13½	84	157	------	------	2	1	2	
	4	31½	18¼	12½	13½	80	113	------	------	1	1	1	
	5	31	18½	17½	20	106	116	------	------	1	2	2	
10	1	30⅜	18	39	29	90	107	------	------	11	7	3	
	2	30½	18	18½	18½	152	149	------	------	3	2	4	
	3	30⅞	18⅜	12½	13	102	163	------	------	2	2	1	
	4	31⅝	18⅜	12½	13½	83	147	------	------	1	2	1	
	5	31⅛	18½	17½	20½	120	153	------	------	1	2	2	

TABLE 3.—*Effect of filling with hot cement on the physical properties of the sacks*

Period of time in weeks	Sack No.	Length	Width	Threads per inch		Breaking strength (1 by 1 by 3 inch grab)		Weight per square yard	Stretch		Drop test	
				Warp	Filling	Warp	Filling		Warp	Filling	Number of drops required for failure	Threads broken
		Inches	*Inches*			*Pounds*	*Pounds*	*Ounces*	*Per cent*	*Per cent*		
1	1	29¾	17¼	39	30	87	103	8.8	16	8	3	Warp.
	2	29¾	17¾	18	18	146	166	13.9	6	2	7	Do.
	3	30¼	18¼	12	12½	96	185	13.6	3	3	1	Do.
	4	31	18¼	13	14	105	161	12.3	2	5	1	Do.
	5	30¾	18¼	17	20	123	159	11.2	3	4	4	Do.
2	1	30	17⅜	38	29	86	97	8.9	16	10	4	Do.
	2	30⅛	17⅞	18	17½	159	174	12.1	4	1	5	Sewing.
	3	30⅞	18¼	12	12½	108	133	12.3	1	2	5	Warp.
	4	31¼	18½	12½	14	92	122	12.0	2	4	4	Do.
	5	31¼	18¼	17	19	134	137	11.3	4	3	4	Do.
3	1	30	17¾	39	31½	85	111	9.7	16	11	4	Do.
	2	29¾	17¾	18	17½	151	167	12.4	4	4	10	Sewing.
	3	30¾	18⅜	12	13½	115	200	12.6	4	5	4	Warp.
	4	31⅛	18¼	12½	13	113	126	12.8	2	3	1	Do.
	5	31	18½	17	19	135	150	11.6	5	5	1	Do.
4	1	29⅜	17¾	39	29½	86	96	8.9	18	11	2	Do.
	2	29⅞	18	18	17½	156	214	13.1	3	5	7	Do.
	3	30⅜	18⅛	12	13½	112	194	13.1	3	4	1	Do.
	4	31½	18¼	12½	13	95	106	12.4	2	4	4	Do.
	5	30	18¼	17	19½	120	164	11.3	3	6	7	Do.
5	1	30	17⅞	39	29½	89	92	8.6	12	6	5	Do.
	2	30	18⅛	18	18½	152	162	11.4	4	2	10	Do.
	3	30¾	18⅜	12	13	107	151	12.7	2	2	1	Do.
	4	31½	18⅜	13	13	117	125	12.3	2	3	2	Do.
	5	30⅞	18 7/16	17½	19½	118	142	11.5	1	3	9	Do.

TABLE 4.—*Effect of exposing sacks filled with cement to a moist atmosphere*

Sack No.	Days' exposure	Original weight of sack	Original weight of sack and cement	Weight of sack and cement after exposure	Weight of sack and "cake" after exposure	Increase in weight of sack and cement	Weight of "cake"	Percentage of cement "caked"
		Pound	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Per cent*
1	3	0.45	92.4	93.3	3.1	0.9	2.65	2.9
2	3	.64	93.1	94.1	1.7	1.0	1.06	1.1
3	3	.78	92.4	93.2	3.8	.8	3.02	3.3
4	3	.71	92.4	93.2	2.6	.8	1.89	2.1
5	3	.60	92.4	93.0	2.0	.6	1.40	1.5
1	6	.44	94.9	96.1	4.8	1.2	4.36	4.6
2	6	.66	93.8	96.8	15.4	3.0	14.74	15.8
3	6	.74	93.4	95.6	12.1	2.2	11.36	12.3
4	6	.69	93.1	94.3	10.1	1.2	9.41	10.2
5	6	.62	92.4	93.4	3.3	1.0	2.68	2.9
1	9	.46	92.4	93.7	7.5	1.3	7.04	7.7
2	9	.67	93.0	94.4	17.4	1.4	16.73	18.1
3	9	.72	92.6	95.6	24.4	3.0	23.68	25.8
4	9	.72	93.4	95.2	10.8	1.8	10.08	10.9
5	9	.63	93.4	95.7	19.6	2.3	18.97	20.4
1	12	.44	94.0	95.5	23.7	1.5	23.26	24.9
2	12	.63	92.4	97.5	39.6	5.1	38.97	42.5
3	12	.74	93.1	96.2	17.6	3.1	16.86	18.3
4	12	.71	93.7	96.1	13.2	2.4	12.49	13.4
5	12	.59	93.6	96.1	11.7	2.5	11.11	11.9
1	15	.47	93.6	96.1	51.1	2.5	50.63	54.4
2	15	.65	93.1	95.8	28.0	2.7	27.35	29.6
3	15	.76	93.1	94.9	26.6	1.8	25.84	28.0
4	15	.71	93.6	96.0	39.6	2.4	38.89	41.9
5	15	.66	93.1	95.5	31.4	2.4	30.74	33.3
1	18	.45	94.6	96.8	29.6	2.2	29.15	31.0
2	18	.66	92.9	95.3	53.7	2.4	53.04	57.5
3	18	.77	92.9	95.3	67.7	2.4	66.93	72.6
4	18	.71	92.4	96.8	49.5	4.4	48.79	53.2
5	18	.67	94.0	98.3	63.1	4.3	62.43	66.9

TABLE 5.—*Effect of exposure to various humidities on the physical properties of the sacks*

Relative humidity and time	Sack No.	Length	Width	Threads per inch		Breaking strength (1 by 1 by 3 inch grab)		Stretch	
				Warp	Filling	Warp	Filling	Warp	Filling
		Inches	*Inches*			*Pounds*	*Pounds*	*Per cent*	*Per cent*
High relative humidity, 1 month	1	29½	17¼	39	30½	90	104	--------	--------
	2	29¾	17⅝	18½	18½	158	176	--------	--------
	3	30	18⅛	12	12½	114	210	--------	--------
	4	30¾	18 1/16	13	13	105	142	--------	--------
	5	30¾	18 3/16	17½	18	142	146	--------	--------
Low relative humidity, 1 month	1	29¼	17 1/16	39	29½	78	89	--------	--------
	2	29¾	17¾	18	18	149	159	--------	--------
	3	30⅛	18 3/16	12½	13	110	167	--------	--------
	4	30⅞	18⅛	13	13	109	120	--------	--------
	5	30⅝	18 1/16	17½	19½	127	131	--------	--------
Average relative humidity, 1 month	1	29 9/16	17¼	39	30	78	87	--------	--------
	2	29¾	17⅝	18½	18	137	147	--------	--------
	3	30⅜	18 5/16	12	13½	103	171	--------	--------
	4	30⅝	18	13	13	110	111	--------	--------
	5	30¾	18 3/16	17	18	141	133	--------	--------
High relative humidity, 2 months	1	29⅛	17⅛	39	30½	91	104	16	8
	2	29⅝	17½	18½	18½	165	188	5	4
	3	30⅛	18⅛	12½	13	117	209	3	2
	4	30¾	18	12½	14	125	126	2	4
	5	30½	18	17½	19	125	141	4	3
Low relative humidity, 2 months	1	29½	17⅜	39	30	75	86	15	10
	2	30⅛	17¾	18	18	136	145	5	4
	3	30½	18¼	12½	13	93	146	4	5
	4	30¾	18¼	13	13	92	115	3	4
	5	30¾	18⅛	17	18	121	106	4	3
Average relative humidity, 2 months	1	29½	17⅜	39	30½	81	94	19	10
	2	29¾	17⅝	18½	18	135	144	5	4
	3	30⅝	18⅛	12	13	102	146	3	4
	4	31⅛	18⅜	12½	13	96	116	3	4
	5	30¾	18⅛	17½	17½	132	122	3	5
High relative humidity, 4 months	1	29¼	17⅛	39	30½	88	108	17	11
	2	29⅝	17½	18½	19	156	175	5	3
	3	30⅜	18⅛	12	13	124	210	2	4
	4	30⅝	18⅛	12½	13	101	142	3	3
	5	30½	18	17½	18	134	152	2	5
Low relative humidity, 4 months	1	29¾	17½	39	30	80	100	13	9
	2	29⅝	17¾	18	18	134	164	3	3
	3	30½	18⅛	12½	13	108	172	2	3
	4	30¾	18¼	13	13½	90	119	2	3
	5	30¾	18¼	17	20½	120	142	2	2
Average relative humidity, 4 months	1	29⅝	17½	39	30½	86	95	20	9
	2	30⅛	17¾	18	18	154	167	6	4
	3	30¼	18¼	12	13	114	192	2	4
	4	31⅛	18⅜	12½	13½	94	138	3	3
	5	30⅞	18⅛	17½	20½	137	122	2	4
High relative humidity, 6 months	1	29⅜	17	40	30½	85	102	17	12
	2	29¾	17⅝	18	18½	143	182	5	3
	3	30	18⅛	12	13	106	218	2	2
	4	30⅞	18	13	13	95	119	2	3
	5	30⅜	18⅛	17½	20	128	147	1	4
Low relative humidity, 6 months	1	29½	17⅜	40	29½	80	89	12	9
	2	29¾	17¾	18½	19	139	162	5	4
	3	30⅜	18¼	12	13	107	191	3	4
	4	31⅛	18⅛	13	13	107	118	3	4
	5	30⅝	18⅛	17½	18½	134	118	2	4
Average relative humidity, 6 months	1	29⅝	17⅜	39	30	82	92	14	7
	2	29¾	17¾	18½	18	149	158	2	2
	3	30⅜	18¼	12½	12½	112	177	2	2
	4	31¼	18¼	12½	13	102	120	2	3
	5	30⅝	18⅛	17	20½	123	144	3	3

TABLE 6.—*Per cent loss of natural oil in the service test*

Sack No.	Original	Service (fifth trip)	Hot cement (fifth filling)
	Per cent	*Per cent*	*Per cent*
1	1.65	1.55	1.45
2	3.29	.73	.84
3	3.58	1.21	.99
4	3.23	1.09	1.00
5	4.99	1.87	2.64

TABLE 7.—*Effect of time and temperature on sack material*

Sock No.	Number of hours	Average breaking strength at—							
		200° F.	215° F.	230° F.	245° F.	260° F.	275° F.	290° F.	305° F.
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	1	76	82	84	72	78	85	80	79
	2	67	78	70	74	82	79	82	80
	4	81	78	72	63	79	86	83	72
	7	84	84	82	84	83	86	85	87
	10	81	89	84	83	81	77	80	80
	15	87	88	86	86	87	89	83	80
	20	82	88	81	69	80	81	76	69
	25	82	84	84	80	79	90	81	79
	30	76	88	80	93	74	88	89	76
	35	72	89	92	88	76	99	89	90
	40	80	84	92	91	80	85	76	77
	45	88	80	88	88	85	87	81	82
2	1	158	134	125	121	139	155	124	143
	2	149	137	150	123	133	138	132	145
	4	147	138	122	117	130	151	136	117
	7	124	162	142	152	137	171	139	139
	10	129	156	139	127	147	150	129	123
	15	170	164	156	166	150	137	134	130
	20	136	149	149	119	144	138	129	118
	25	158	154	141	138	150	157	123	118
	30	133	150	135	161	132	155	144	140
	35	138	161	166	137	126	138	134	136
	40	139	154	154	153	132	137	166	145
	45	153	140	153	151	149	143	130	109
3	1	177	152	142	152	137	171	148	144
	2	147	152	167	130	147	139	146	180
	4	164	149	148	126	164	166	163	144
	7	156	193	156	152	148	157	164	163
	10	152	160	157	151	172	162	157	157
	15	176	163	180	187	180	173	147	157
	20	163	169	162	134	157	145	143	142
	25	187	164	168	158	168	156	134	126
	30	157	160	135	161	149	154	157	138
	35	145	165	178	148	144	159	151	158
	40	196	168	184	176	167	168	156	112
	45	174	173	165	155	176	166	155	93
4	1	120	111	109	103	108	116	113	113
	2	99	110	110	108	103	107	111	120
	4	107	120	94	92	125	126	118	106
	7	120	124	124	113	121	127	108	124
	10	112	120	116	103	127	122	103	100
	15	129	125	112	132	126	118	121	108
	20	109	117	109	107	115	108	109	104
	25	132	129	133	108	110	128	90	97
	30	120	129	121	131	117	121	109	111
	35	127	124	129	127	115	114	109	121
	40	126	115	127	143	114	122	117	90
	45	135	110	124	125	124	122	108	102
5	1	143	128	129	127	128	141	125	136
	2	109	126	140	121	126	125	130	132
	4	130	125	142	105	146	146	136	127
	7	125	141	149	139	119	129	125	137
	10	133	141	141	144	135	126	115	120
	15	141	142	145	143	140	136	138	126
	20	130	128	132	116	126	124	114	128
	25	143	129	143	115	134	128	105	109
	30	140	159	131	140	133	159	127	119
	35	130	161	150	147	122	155	149	148
	40	146	134	150	143	136	141	137	119
	45	164	120	140	141	139	111	127	89

V. DISCUSSION OF RESULTS

The ability to withstand rough handling, as shown in this paper, by the test for the resistance to failure from dropping is undoubtedly one of the most important characteristics of a cement container. Besides having a high resistance to drop failure initially, a sack must retain this property throughout a considerable period, and therefore it should be affected as little as possible by service conditions, such as filling with hot cement, handling, transportation in freight cars, or exposures to various humidities. During this investigation sacks were put in service which duplicated the above features and measurements made of the resistance to drop failure at intervals during this service.

Throughout any set of service conditions a sack should be able to afford adequate protection to its contents during damp or rainy weather. A study of this property was made on new sacks only because it was not thought necessary to determine how this resistance to moisture was affected by actual service. This is largely a question of closeness of the weave and absorption qualities of the material.

With these ideas in mind as a basis for selecting the best of the five types tested, there is but little doubt that sack No. 2 should give the longest and most satisfactory service. This sack, as can be seen from Figure 6, has an initial resistance to drop failure greater than any other sack except the osnaburg, and after being in actual service shows the highest resistance of any. Bags Nos. 3 and 4, it will be noted, had very little resistance to drop failure, for after making but two trips these sacks nearly always ruptured on the first drop. These two sacks, therefore, need not be considered further.

The breaking strength and stretch characteristics furnish information which indicates how a sack with high resistance to drop can be constructed, and thus indirectly shows the quality of the sack.

The charts on the results of breaking strength (fig. 6) show that sack No. 2 has a balanced strength condition; that is, the warp and filling strengths are very nearly equal. The results are the highest of all sacks, for although some of the strengths of the filling of sack No. 3 are higher the warp strength is considerably under. It is noted that the per cent stretch of both warp and filling is about equal for sack No. 2. Inasmuch as the filling threads in a sack extend through the length of the sack, they are longer than the warp threads and the actual stretch is greater. Considerable advantage may result by increasing the ability of the warp threads to stretch. This may be accomplished by increasing the crimp of the warp threads by decreasing the warp tension in the loom. In service the load is distributed more equally and causes the warp threads to break less easily. Another improvement is suggested—that a better grade of sewing

thread be used. Several breaks occurred in the sewing thread during the tests for resistance to drop on sack No. 2.

Figure 5 shows a typical failure during the drop test. The warp threads in the sacks here shown run around the shorter dimension of the sack. The warp threads broke in every case except those cases where the failure was in the sewing thread and not in the fabric.

The results of the effect of hot cement charted in Figure 7 show that the superiority of sack No. 2 over the osnaburg is even greater in this test than in the service test. Its breaking strength and its resistance to drop failure are not at all affected by this treatment, while the qualities of sack No. 1 depreciate markedly. Sack No. 5 deteriorates rapidly at first, but later shows an improvement. This behavior is peculiar, and this anomalous behavior possibly indicates a lack of uniformity in the quality of the sacks themselves rather than an increase in resistance caused by this treatment. Even so, sack No. 5 does not at any time have as great a resistance to drop as sack No. 2, and this fact, together with its lack of uniformity, makes it inferior. Sack No. 1 likewise is definitely inferior in performance to sack No. 2.

The moisture test, results of which are shown graphically in Figure 8, indicates that the amount of "cake" increases with the length of exposure to dampness. It also shows that all five of the sacks afford equal protection to the cement contained.

VI. SUMMARY

Five types of cement sacks—a cotton osnaburg and four jute burlap types—were studied to determine their relative merits in regard to their suitability as cement containers.

Various conditions of service were simulated as follows: (*a*) Repeated shipping between two points about 200 miles apart; (*b*) filling with hot, freshly ground cement; (*c*) exposure to various atmospheric conditions; and (*d*) exposure to excessively damp conditions.

Tests were made of the physical properties in order to determine the effect of these conditions and exposures. These tests included determinations of dimensions, thread count, weight, breaking strength, and resistance to drop. Standard methods of test were followed for all of these except drop, for which no method had been formulated.

A drop test was formulated, as follows: Apparatus [1] was built which would permit the sack to be dropped from a trap door through a distance of 8 feet to a smooth cement floor. The trapdoor consisted of a double door, upon which the sack was placed lengthwise

[1] Blue prints may be secured from the Bureau of Standards, Washington, D. C., upon request.

along the line where the doors joined. This arrangement prevented the sack from turning while falling. The test was repeated until the fabric failed, the number of drops necessary to produce failure indicating the resistance to drop.

The tests made in this investigation have clearly demonstrated that a cement sack can be made of jute burlap and be not only as good but considerably superior to the more expensive cotton osnaburg tested. It should be borne in mind that only one type of osnaburg sack was used in these tests. Undoubtedly other types may now or eventually be placed on the market, which may be better than the type used. Of course, jute sacks of poorer quality may prove unsatisfactory, but if the jute sack selected is similar to sack No. 2 in this investigation better service, together with considerable saving, price conditions remaining the same, will result. The tests of this sack made on the original material showed the following characteristics: Thread count, warp 18, filling 18½; breaking strength (1 by 1 by 3 inch grab method), warp 153 pounds, filling 167 pounds; weight, 11.8 ounces per square yard; stretch, warp 4 per cent, filling 4 per cent; number of drops necessary before failure, 8.

WASHINGTON, June 26, 1925.