Number 306 | October, 1925

THE EFFECT OF BEET PULP UPON PORTLAND CEMENT CONCRETE AND MORTAR

O. V. Adams
Testing Engineer

Colorado Experiment Station
Engineering Division
Fort Collins

The Colorado Agricultural College

FORT COLLINS, COLORADO

OFFICERS OF THE EXPERIMENT STATION

CHAS. A. LORY, M.S., LL.D., D.Sc.	President
C. P. GILLETTE, M.S., D.Sc.	Director
LD CRAIN, B.M.E., M.M.E.	Vice-Director
L. M. TAYLOR	Secretary
ANNA T. BAKER	Executive Clerk

STATION STAFF AGRICULTURAL DIVISION

C. P. GILLETTE, M.S., D.Sc., Director	Entomologist
WM. P. HEADDEN, A.M., Ph.D., D.Sc.	Chemist
G. H. GLOVER, M.S., D.V.M.	Veterinarian
W. G. SACKETT, Ph.D.	Bacteriologist
ALVIN KEZER, A.M.	Agronomist
GEO. E. MORTON, B.S., M.L.	Animal Husbandman
E. P. SANDSTEN, M.S., Ph.D.	Horticulturist
B. O. LONGYEAR, B.S.	Forestry Investigations
I. E. NEWSOM, B.S., D.V.S.	Veterinary Pathologist
L. W. DURRELL, Ph.D.	Botanist
RALPH L. PARSHALL, B.S.	U. S. Irrig. Eng. Irrigation Investigations
R. E. TRIMBLE, B.S.	Assist., Irrig. Investigations (Meteorology)
EARL DOUGLASS, M.S.	Associate in Chemistry
P. K. BLINN, B.S., Rocky Ford	Alfalfa Investigations
MIRIAM A. PALMER, M.A.	Delineator and Assistant in Entomology
J. W. ADAMS, B.S., Cheyenne Wells	Assistant in Agronomy, Dry Farming
*CHARLES R. JONES, B.S., M.S.	Associate in Entomology
*CHARLES I. BRAY, B.S., M.S.	Associate in Animal Investigations
E. J. MAYNARD, B.S.A., M.S.	Associate Animal Husbandman
W. L. BURNETT	Rodent Investigations
FLOYD CROSS, D.V.M.	Assistant Veterinary Pathologist
WM. H. FELDMAN, D.V.M.	Assistant Veterinary Pathologist
J. H. NEWTON, B.S.	Assistant in Entomology
CAROLINE PRESTON	Artist in Botany Section
J. L. HOERNER, B.S.	Assistant in Entomology
J. W. TOBISKA, B.S., M.A.	Assistant in Chemistry
C. E. VAIL, B.S., M.A.	Assistant in Chemistry
C. D. LEARN, B.S., M.A.	Assistant in Botany
DAVID W. ROBERTSON, B.S., M.S.	Associate in Agronomy
I. G. KINGHORN	Editor
R. A. McGINTY, B.S., A.M.	Associate in Horticulture
L. A. MOORHOUSE, B.S.A., M.S.	Rural Economics
R. T. BURDICK, B.S., M.S.	Associate in Rural Economics
CHAS. N. SHEPARDSON, B.S., M.S.	In Charge of Official Testing
J. C. WARD, B.S., Rocky Ford	Soil Chemistry
J. W. DEMING, B.S.A.	Assistant in Agronomy
H. B. PINGREY, B.S.	Assistant in Agricultural Economics
IDA WRAY FERGUSON, R.N.	Assistant in Bacteriology
ROSS C. THOMPSON, B.S., M.S.	Assistant in Horticulture
DWIGHT KOONCE, B.S.	Assistant in Agronomy

ENGINEERING DIVISION

LD CRAIN, B.M.E., M.M.E.	Mechanical Engineering
E. B. HOUSE, B.S., (E.E.) M.S.	Civil Engineering
O. V. ADAMS, B.S., M.S.E.	Associate in Civil Engineering
G. A. CUMINGS, B.S.	Assistant in Mechanical Engineering

*On leave, 1925-26.

THE EFFECT OF BEET PULP UPON PORTLAND CEMENT CONCRETE AND MORTAR

By O. V. Adams

The importance of the beet-sugar industry in the United States is shown by the following facts for the years 1921-1922:

(1) Sugar beets were grown in 18 states.

(2) The total acreage was 814,988, from which 7,782,000 tons of beets, valued at $49,154,000, were produced.

Honorable James Wilson, when secretary of agriculture, said "We are therefore justified in saying that the total area having soil and climatic conditions adapted to the production of satisfactory sugar beets is at least 274,000,000 acres."

The manufacture of beet sugar is seen to be a large industry, which has possibilities of growing to many times its present size.

In the beet-sugar manufacturing process, a substance known as pulp remains after the sugar has been extracted from the beets. Approximately one ton of pulp is produced for each four tons of beets treated. The pulp is stored in silos and later used for stock feeding.

For hauling pulp to the feeding pens, wagons equipped with ordinary boxes were formerly used. Since portland cement concrete has come into widespread use as a paving material, regulations have been adopted by some city and county governments requiring the use of water-tight wagons which must be inspected and approved before being used. They must not be loaded so that any pulp will run over the sides. Other regulations prohibit the use of the pavements by vehicles hauling pulp. Fort Collins and Larimer County, Colorado, have the former regulations, while Longmont, Colorado, has the latter.

These regulations have been passed on account of the prevailing belief that beet pulp has a detrimental effect on portland cement concrete. The behavior of concrete floors in pulp silos at some beet-sugar factories and the condition of a concrete pavement near Loveland, Colorado, which is used by beet-pulp traffic, have contributed to this belief.

Following are the facts concerning two of these instances which were obtained from officials of the Great Western Sugar Company:

WINDSOR PULP-SILO FLOOR

This floor was 6 in. thick when constructed in 1920. A 1:6 mix of portland cement and pit-run gravel was used. At the present time (July, 1924) the mortar on the surface has been eaten away leaving the coarse aggregate exposed. Figure 1, page 3 shows this condition. The concrete, to a depth of from 0.50 to 1 in., according to the estimates by officials at the Windsor plant, has either been entirely destroyed or its strength so badly impaired that it may be cut easily with a pocket knife. Protective coatings of creosote and hot asphalt or asphaltic paint have been used but have not been uniformly satisfactory, due to the difficulty of securing a bond between the coating and the concrete. Where a bond was secured, they have greatly reduced the action of the pulp. These coatings, however, must be renewed each year. The Great Western Sugar Company is now using lumber for pulp-silo floors.

CONCRETE SURFACE ON HIGHWAY NEAR SUGAR FACTORY AT LOVELAND, COLORADO

This road surface was constructed in 1915 for The Great Western Sugar Company. The specifications, under which the work was done, were furnished by the Portland Cement Association. The materials used were all tested and the aggregates were the best that could be obtained locally. The mix used was one part of portland cement to two parts of sand which passed a 0.25-in. screen to three parts gravel which passed a 1½ in. screen. The concrete surface is 18 ft. wide and was originally 8¼ in. thick at the center and 6 in. thick at the sides. The workmanship was satisfactory and the officials of the sugar company state that the pavement, when completed, appeared to be first class in every particular.

The Loveland factory has sliced from 215,000 to 240,000 tons of beets per annum during the life of the concrete pavement. Between 50,000 and 60,000 tons of beet pulp have been hauled from the factory each year. During the years immediately following the construction of the pavement, the beet pulp was hauled entirely in steel-tired vehicles. During the past few years the amount hauled in trucks equipped with rubber tires has been increasing. As the large part of the pulp hauling is done in the winter, horses must be sharp shod.

The average weight of a two-horse team and empty wagon is approximately two and one-fourth tons. When loaded, the average weight is approximately six and one-fourth tons. Therefore, about eight and one-half tons of traffic are produced for each four tons of beet pulp hauled in wagons.

By actual count on three days in December, 1924, 65 percent of the total tonnage consisted of steel-tired vehicles. It seems, therefore, safe to say, that during the life of the pavement, 82½ percent of the pulp has been hauled in steel-tired, horse-drawn vehicles. For a mean annual pulp tonnage of 55,000, 45,000 tons have therefore been hauled in steel-tired, horse-drawn vehicles. This has produced 117,000 tons of traffic per annum, 96,000 tons of which was steel-tired, horse-drawn.

(Fig. 1) Beet-pulp-silo floor, Windsor factory of the Great Western Sugar Company

The pulp silo is located about one-third of a mile from the north end of the pavement. The three-day traffic count in December, 1924, showed that 38 percent of the pulp traffic went over the north end of the pavement and 62 percent over the south end. This amounts to 44,500 tons and 72,500 tons over the north and south ends respectively.

The traffic due to beet hauling is approximately 45,000 tons per annum. By using the same distribution percentages as for beet pulp, 14,000 tons and 23,000 tons of steel-tired, horse-drawn traffic passed over the north and south ends of the pavement respectively, and 8,000 tons were hauled in rubber-tired vehicles.

A three-day traffic count was made in August, 1924. The average daily traffic as shown by the August and December counts was 250 vehicles per day, exclusive of beet and beet-pulp traffic. Twelve and one-half percent of this was horse-drawn traffic. If the average weight is taken as one and one-half tons per vehicle, the total traffic per annum is found to have been 137,000 tons, 17,000 tons of which was horse-drawn.

In the following table the traffic over the pavement is summarized:

Item	Traffic, North End Steel Tired	Rubber Tired	Total	Traffic, South End Steel Tired	Rubber Tired	Total
Beet Pulp	37,000	8,000	45,000	60,000	12,000	72,000
Beets	14,000	3,000	17,000	23,000	5,000	28,000
Miscellaneous	17,000	120,000	137,000	17,000	120,000	137,000
Total	68,000	131,000	199,000	100,000	137,000	237,000
Tons per ft. of width per annum	3,780	7,270	11,050	5,550	7,610	13,160

The beet-pulp traffic occurs from about October 1 of each year until May 1 of the following year. During the greater part of this period freezing temperatures may be expected at night and thawing during the day. During the period of maximum hauling the pavement is wet nearly all the time, due to precipitation and drippings from pulp wagons, which are not required to be water tight.

The width of the pavement causes horse-drawn traffic to follow nearly the same path, thus concentrating the wear on a narrow strip.

History of Service Rendered by Pavement.—In 1916 the pavement was so badly rutted as to need repair. A covering of Tarvia A and Tarvia B was applied. This did not prove satisfactory as it soon rutted to the original pavement. Nothing more was done until 1920 when the ruts were filled with gravel and hot asphalt applied by the penetration method. This treatment proved fairly satisfactory. The ruts were filled somewhat more than level full, which encouraged the traffic on the concrete outside of the old ruts. New ruts were soon formed in the concrete.

At the present time (1924) the south three-fourths of the pavement is badly rutted. This is well shown in Fig 2, page 7.

According to statements by both the Board of County Commissioners of Larimer County, Colorado, and officials of the Great Western Sugar Company, no maintenance work has ever been done on the expansion-contraction joints. These are 30 ft. apart and were constructed of "Carey Elastite." The present condition of these joints is shown in Fig. 3, page 9. At the present time, after nine years' use, there are very few pits due to crushed or loosened aggregate, showing that surface abrasion, rather than crushing of particles, has been the cause of the present condition of the pavement.

LABORATORY TESTS

In order to obtain additional information on the effect of beet pulp on portland cement mortar and concrete, laboratory tests covering a period of nearly three years were performed. Three series of specimens, which have been designated "A," "B" and "C" were prepared. In each series, tension and abrasion tests were made on cement mortar and compression tests on cement concrete. The mortar used in all tension and abrasion specimens contained, by weight, one part cement to two parts fine aggregate, with sufficient water to produce a mortar of standard consistency.

(Fig. 2) Concrete pavement south of the Loveland factory of The Great Western Sugar Co.

In series "A," the aggregate was sand and gravel of granitic origin obtained from stock piles of The Lock Joint Pipe Company, which was at that time making concrete pipe for the Fort Collins storm sewer. The gravel was screened and recombined in accordance with the gradings shown in Table 1. A 1:2:3 mix by weight was used in the compression specimens.

In series "B," the sand and gravel came from the same source as Series "A." However, the sand was washed and the grading of the gravel was changed to that shown in Table 5. The mix used in compression specimens was 1:1.46:3.54 by weight.

In Series "C," crushed red sandstone was used as coarse aggregate and "crusher fines" as fine aggregate. These were obtained from the quarry at Lyons, Colorado, owned by Mr. J. C. Brodie. The gradings used are shown in Table 1. The mix used was 1:1.46:3.21 by weight. The mix in both series "B" and "C" was designed so as to obtain as dense concrete as possible. Physical tests of the sandstone gave the following results:

Specific Gravity	2.46
Absorption	1.6 Percent
Percent of wear	3.57
Hardness coefficient	17.2
Toughness coefficient	8.0

Each series consisted of 84 tension, 288 abrasion and 36 compression specimens. The tensile specimens were briquettes of the standard form. One-and-seven-sixteenth-inch cubes were used for abrasion tests, and 4-by-8-inch cylinders, for compression tests.

Storage of Specimens.—All specimens for tension and abrasion tests were stored in the forms in a moist closet for 24 hours and then placed in moist sand until 28 days old. All compression specimens were removed from the forms after 24 hours and stored in moist sand. At the age of 28 days, one-half of all specimens were placed in beet pulp and the other half kept in moist sand. When six months old all specimens were removed from pulp or sand storage, and one-third of those in each series were tested. The remaining two-thirds were stored in air in the laboratory until October 1, 1921. At this time, all specimens originally stored in pulp were again placed in pulp and all others in moist sand. This storage period lasted until May 19, 1922, when one-half of the remaining specimens were tested and the other half stored in air in the laboratory until October 14, 1922. The third period of storage was similar to the second and lasted until September 5, 1923, when all remaining specimens were tested.

During the second period of storage, the pulp was changed on December 23, 1921, and during the third period on April 2, 1923, when the original pulp had decomposed until its acidity had become not over one-tenth of one percent.

The results of chemical analysis to determine the acidity of the pulp during two storage periods are given in Table 1. These indicate a gradual reduction in acidity as the length of time of storage is increased.

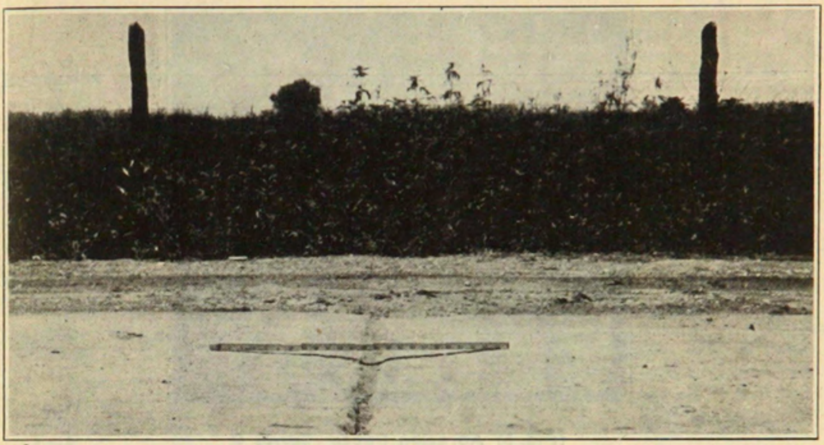
TABLE ONE

Date	Storage Period	Percent Acidity
October 14, 1921	Second	0.214
November 26, 1921	Second	0.150
December 12, 1921	Second	0.100
April 28, 1923	Third	0.918
May 12, 1923	Third	0.808
June 2, 1923	Third	0.656
July 14, 1923	Third	0.490
September 6, 1923	Third	0.367

The acidity of the pulp at the time it was changed, or when the specimens were removed from the pulp storage, is shown by the following:

Date	Storage Period	Percent Acidity
June 5, 1921	First	0.06
December 12, 1921	Second	0.10
June 23, 1923	Second	Alkaline
March 28, 1923	Third	0.088
September 6, 1923	Third	0.367

Figures 4, 5 and 6 show mortar cubes which have been subjected to abrasion in the Duval Abrasion machine. (Duration of test 10,000 revolutions.)

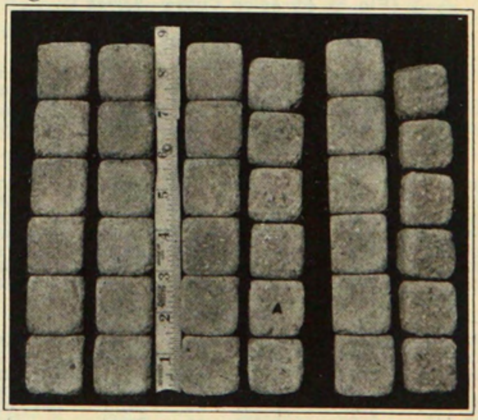


(Fig. 3) Expansion-contraction joint in concrete pavement at Loveland factory of The Great Western Sugar Company

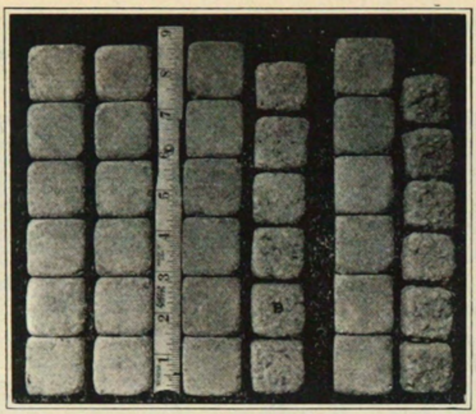
In each figure, the cubes in columns 1, 3 and 5 from left to right in figure were stored in sand and those in columns 2, 4 and 6 were stored in beet pulp.

Cubes in columns 1 and 2, 3 and 4, and 5 and 6 were tested at the end of the first, second and third periods of storage respectively.

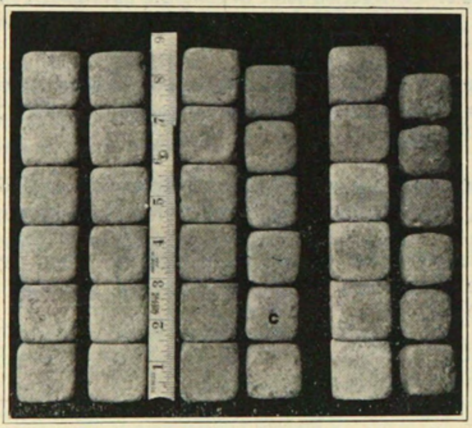
The increased wear of the pulp-stored cubes over those stored in sand and also as the length of time of storage is increased, is readily noted.



(Fig. 4) Abrasion Cubes—Series A



(Fig. 5) Abrasion Cubes—Series B



(Fig. 6) Abrasion Cubes—Series C

TABLE II—Tension Tests 1:2 Mortar

No. of Briquettes	Storage Period in Days: Moist Sand	Beet Pulp	Dry Air	Kind of Storage	Average Strength in Pounds Per Sq. In.	Ratio
			Series A			
14	28	0	0	Sand	574	
11	181	0	0	Sand	559	
12	28	153	0	Pulp	601	1.075
12	411	0	137	Sand	806	
12	28	383	137	Pulp	733	0.909
11	737	0	285	Sand	630	
12	28	709	285	Pulp	432	0.686
			Series B			
11	28	0	0	Sand	586	
12	181	0	0	Sand	584	
12	28	153	0	Pulp	617	1.055
12	411	0	131	Sand	798	
12	28	383	131	Pulp	674	0.844
12	737	0	279	Sand	660	
10	28	709	279	Pulp	397	0.600

No. of Briquettes	Storage Period in Days: Moist Sand	Beet Pulp	Dry Air	Kind of Storage	Average Strength in Pounds Per Sq. In.	Ratio
Series C						
6	28	0	0	Sand	729	
12	181	0	0	Sand	805	
12	28	153	0	Pulp	792	0.982
11	411	0	69	Sand	1029	
10	28	383	69	Pulp	799	0.776
9	737	0	217	Sand	850	
11	28	709	217	Pulp	568	0.668

TABLE III—Compression Tests on 1:2 Mortar

Kind of Storage	Storage Period in days: Moist Sand	Beet Pulp	Dry Air	Number of Cylinders	Average Strength in Pounds Per Sq. In.	Strength Ratio
Series A						
Sand	28	0	0	6	2420	
Sand	181	0	0	6	3410	
Pulp	28	153	0	6	3300	0.968
Sand	411	0	120	5	4610	
Pulp	28	383	120	6	4230	0.918
Sand	737	0	268	4	4840	
Pulp	28	709	268	7	3600	0.744
Series B						
Sand	28	0	0	7	2260	
Sand	181	0	0	6	3470	
Pulp	28	153	0	6	3155	0.909
Sand	411	0	104	6	4000	
Pulp	28	383	104	5	4040	1.010
Sand	737	0	152	8	3830	
Pulp	28	709	152	7	2610	0.682
Series C						
Sand	28	0	0	6	2930	
Sand	181	0	0	6	4390	
Pulp	28	153	0	6	4260	0.970
Sand	411	0	79	6	4720	
Pulp	28	383	79	5	4710	0.998
Sand	737	0	227	8	4950	
Pulp	28	709	227	5	3955	0.800

TABLE IV—Abrasion Tests on 1:2 Mortar

Kind of Storage	Storage Period in Days: Moist Sand	Beet Pulp	Dry Air	No. of Cubes	Weight in Grams: Initial	Final	Loss Grams	Loss Ratio	Average Weight Cubes
Series A									
Sand	181	0	0	44	5064	4920	144		115.1
Pulp	28	153	0	45	5078	4874	204	1.417	112.8
Sand	411	0	126	43	5024	4838	186		116.8
Pulp	28	383	126	46	4999	4215	784	4.215	108.7
Sand	737	0	274	43	4989	4852	137		116.0
Pulp	28	709	274	49	5044	3501	1543	11.263	102.9
Series B									
Sand	181	0	0	43	5087	4905	182		118.3
Pulp	28	153	0	43	5030	4798	232	1.275	117.0
Sand	411	0	101	43	5096	4934	162		118.5
Pulp	28	383	101	47	5086	4030	1056	6.518	108.2
Sand	737	0	249	43	5084	4955	129		118.2
Pulp	28	709	249	49	5037	3194	1843	14.287	102.8
Series C									
Sand	181	0	0	44	5004	4856	148		113.7
Pulp	28	153	0	44	5009	4795	214	1.446	113.8
Sand	411	0	76	44	4996	4843	156		113.5
Pulp	28	383	76	48	4985	3977	1008	6.462	103.9
Sand	737	0	224	44	4987	4850	137		113.3
Pulp	28	709	224	51	4947	3376	1571	11.467	97.0

TABLE V—Gradings used in Cylinders

Coarse Aggregate

Series	Percentage by Weight A	B	C
Retained on 1.25-in. screen	0.0	0.0	0.0
Passing 1.25-in. retained 1-in	16.2	25.0	25.0
" 1-in. " 0.75-in.	19.5	25.0	25.0
" 0.75-in. " 0.50-in.	23.3	25.0	25.0
" 0.50-in. " 0.25-in.	41.0	25.0	25.0
	100.0	100.0	100.0

Fine Aggregate

Passing thru sieve	Retained on sieve	Percentage by Weight A	B	C
Series				
	0.25-in.	0.0	0.0	0.0
0.25-in.	10-mesh	26.2	43.3	29.3
10-mesh	20-mesh	30.2	38.5	38.8
20- "	30- "	17.8	11.3	15.6
30- "	40- "	7.8	3.0	6.7
40- "	50- "	4.4	1.4	0.7
50- "	80- "	5.8	1.1	2.6
80- "	100- "	1.0	0.2	0.9
100- "	200- "	2.5	0.3	3.4
200 "		0.7	0.6	2.0
Silt		3.6	0.3	0.0
Total		100.0	100.0	100.0

DISCUSSION

Discussion of Laboratory Tests

Study of the data given in Tables I and V, supplemented by Fig. 4 to 6 inclusive, brings out the following points:

1. The pulp-storage tension specimens showed no appreciable reduction in strength after having been stored in pulp 153 days, but did show a marked reduction for 383 and 709 days storage.

2. The average strength of tensile specimens for 709 days pulp storage was only 65 percent of that of specimens stored in moist sand.

3. There was a slight reduction in compressive strength of pulp-storage as compared with sand-storage cylinders for 153 days storage.

4. For 383 days pulp storage there was an increase in compressive strength over that for 153 days pulp storage for all three series.

5. Only in series A was there a marked reduction in compressive-strength ratio for 383 days storage, as compared with 153 days storage.

6. There was a marked reduction in both the actual compressive strength and the compressive-strength ratio of all series for 709 days as compared with 383 days pulp storage.

7. There was an increase in compressive strength up to 709 days moist-sand storage for Series "A" and "C" and up to 383 days moist-sand storage for Series "B."

8. The strengths of cylinders stored in moist sand for 709 days for Series "A," "B" and "C" were 200, 169 and 169 percent, respectively, of the 28-day strength.

9. The abrasion-loss ratio was always greater than one and increased progressively as the pulp-storage time was increased.

10. The pulp-storage cubes were lighter at the end of all three storage periods than the sand-storage specimens.

11. The loss in weight of pulp-storage cubes amounted to 11.3, 13.1 and 14.7 percent for Series "A," "B" and "C," respectively for 709 days storage.

The Concrete Highway at the Sugar Factory at Loveland, Colorado

In this discussion the following points should be emphasized:

1. The fact that apparently a first-class concrete pavement was constructed by the contractor.

2. Results of tests by the U. S. Bureau of Public Roads show that steel-tired traffic is destructive to concrete pavements. This road has carried approximately 100,000 tons of steel-tired traffic per annum.

3. That, especially during the winter months, the natural precipitation and drippings from pulp wagons were alternately frozen and thawed on the surface of the pavement, which increased the surface wear.

4. That when ruts had started to form, the precipitation and pulp juices were held in these depressions, thereby producing a more favorable condition for action by the pulp acids.

5. That the disintegrating action of frost and pulp juices was increased by the abrasive action of the steel-tired traffic which soon removed the weakened surface film and exposed a fresh layer.

6. That the tracking of horse-drawn traffic serves to concentrate the destructive agencies just mentioned.

7. That lack of maintenance of expansion-contraction joints permitted excessive wear at these joints and contributed to the generally unsatisfactory condition of the surface of the pavement.

CONCLUSION

1. Beet pulp has a destructive effect upon both the mortar and concrete specimens used in laboratory tests.

2. This destructive action is not great up to 150 days of pulp storage but increases progressively for longer periods.

3. Results of tests and field observations show that while there is no doubt that concrete and mortar are affected by beet pulp, it cannot be said that the rutting and wear on the concrete pavement at Loveland, Colorado, has been due to beet-pulp action alone.

BIBLIOGRAPHY

F. H. JACKSON and C. A. HOGENTOGLER

Accelerated Wear Tests by the Bureau of Public Roads, Public Roads, June, 1921.

F. H. JACKSON, and J. F. PAULA

Wear of Concrete Pavements Tested, Public Roads, May, 1924.