U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 33 WASHINGTON, D. C. JANUARY, 1921

A FEDERAL-AID ROAD SURFACED WITH BITUMINOUS CONCRETE, NEAR ALEXANDRIA, LA.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number or $1.50 per year to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY
SUBSCRIPTION PRICE, $1.50 PER YEAR

SHALL THE STATE OWN AND OPERATE ITS OWN PORTLAND CEMENT PLANT?

H. E. HILTS, Principal Assistant Engineer, Pennsylvania.

IN ANALYZING the question whether the State should own and operate its own cement plant the hypothesis should be developed upon the basis of business economics; it is unsound to attempt to analyze it from the viewpoint of political expediency.

Basic industries in this country have grown and expanded because we are a forward-looking people, as free as possible to work out our individual destinies, and subject only to such governmental balance and control as may be necessary to prevent one individual or group of individuals from interfering unduly with the rights of others. Our present industrial system has grown, developed, and prospered by individual initiative, and this individual initiative it is desirable to maintain. We must not lose sight of this broad generalization in the further discussion of the economics of our question.

There are two principal reasons, I believe, for the consideration which is being given to-day to the matter of State operation of Portland cement plants. The first of these is the difficulty which, especially during the past season, has been experienced in securing cement in sufficient amounts and with sufficient regularity for economical use by the consumer. The second is the increase in the cost to the consumer which has occurred during the past few years.

Before jumping to conclusions it would be well to analyze the developments which led up to the extraordinary market conditions of 1920. It may be that the privately owned plants have not been entirely responsible for the conditions complained of. Indeed, one of the first facts encountered in any analysis of the conditions must be that the producing capacity of the cement plants in this country is at this time, and has been for a long period of years, far in excess of the consumption. Figure 1 shows very clearly the production and consumption during many years in the past. By scanning the curve it will be seen that the cement industry has had a very rapid growth, and the price curve (fig. 2) shows that this growth has resulted in intense competition, brought about by the widespread promotion of plants in all parts of the country.

As with all quick industrial growths, the efforts of commercial promoters have resulted in the establishment of many uneconomical cement plants at inferior locations. Moreover, up to within the past 8 or 10 years the promotional work had resulted in placing many of the cement mills in the hands of men who were not trained in either accounting or business methods. Yet, in spite of these facts, a conservative estimate of the rated capacity of the cement mills of the United States, at this time, is 125,000,000 barrels annually, and this capacity has been available for the past several years.

TABLE 1.—*Annual Portland cement manufacturing capacity of the United States, by commercial districts, 1917 and 1918.*

District.	Estimated capacity (barrels).		Per cent of capacity utilized.	
	1917	1918	1917	1918
Lehigh district (eastern Pennsylvania and western New Jersey)	37,016,132	36,904.000	66.0	53.4
New York	8,552,480	8,411,400	63.3	48.7
Ohio and western Pennsylvania	9,379,040	12,983,000	78.3	49.6
Michigan and northeastern Indiana	8,672,400	7,770,000	60.7	52.9
Southern Indiana and Kentucky	4,336,200	4,550,000	58.1	35.4
Illinois and northwestern Indiana	13,859,780	14,060,000	78.8	51.0
Maryland, Virginia, and West Virginia	4,384,380	4,322,200	71.2	52.7
Tennessee, Alabama, and Georgia	4,657,400	4,500,000	78.9	66.5
Iowa, Missouri, and Minnesota	13,764,480	14,040,000	85.5	67.5
Nebraska,[1] Kansas, Oklahoma, and central Texas	12,197,570	10,579,500	63.2	50.8
Rocky Mountain States (Colorado, Utah, Montana, and western Texas)	4,336,200	4,498,000	75.2	50.9
Pacific Coast States (California, Washington, and Oregon)	15,594,260	15,783,100	47.3	35.2
	136,750,322	138,401,200	67.9	51.3

[1] Nebraska had no output in 1918.

MANUFACTURING CAPACITY AMPLE.

True, the actual production of cement has not approached the limit of capacity. In 1919 the ratio of production to manufacturing capacity was only about 54 per cent, and for the first 10 months of 1920 it was about 67 per cent. Prior to 1920 the most cement that had ever been used in this country in any one year was 94,000,000 barrels in 1916.

What were the reasons for this failure to develop the full capacity of the plants? To answer the question specifically, prior to the war the reason was lack of demand; during the war it was governmental restriction; and in the last year or two it has been demoralized transportation facilities and the inability of the plants to obtain fuel, supplies, containers, etc., regularly and in sufficient quantity to permit of economical operation. These were conditions over which the private cement plants had no control. They affected all business in much the same manner. Every State highway department, for example, has felt the lack of transportation facilities, and knows that it was due, largely, to embargoes, special service orders, strikes, and the general postwar era of extravagant inefficiency of labor.

Table 2.—*Estimated surplus or deficiency in local supply of Portland cement in cement-producing States, 1917–18, in barrels.*

State or division.	1917			1918		
	Shipments from mills.	Estimated consumption.	Surplus or deficiency.	Shipments from mills.	Estimated consumption.	Surplus or deficiency.
California	5,659,547	4,608,011	+ 1,051,53	4,238,424	3,606,286	+ 632,138
Illinois	4,378,233	7,189,662	− 2,811,42	3,703,471	4,925,736	−1,222,265
Indiana	8,148,678	3,425,053	+ 4,723,62	6,205,326	2,406,617	+3,798,709
Kansas	3,772,884	1,977,798	+ 1,795,08	2,586,834	1,422,877	+1,163,957
Michigan	4,313,771	4,425,533	− 111,762	3,618,088	3,266,393	+ 351,695
Missouri	5,800,988	2,548,152	+ 3,252,836	4,515,695	1,652,454	+2,863,241
New Jersey	2,397,069	3,120,589	− 723,520	(1)	(1)	(1)
New York	5,408,726	8,920,808	− 3,512,082	4,074,159	6,319,045	−2,244,886
Ohio	1,565,394	6,950,672	− 5,385,278	1,289,887	5,010,482	−3,720,595
Oklahoma	1,736,761	1,443,928	+ 292,833	1,218,841	1,118,595	+ 100,246
Pennsylvania	27,709,442	7,787,055	+19,922,387	22,238,689	6,611,108	+15,627,581
Texas	2,358,944	2,034,548	+ 324,396	1,918,919	1,509,318	+ 409,601
Utah	899,599	526,086	+ 373,513	549,593	350,603	+ 198,990
Washington	1,403,191	1,189,880	+ 213,311	1,116,754	1,044,898	+ 71,856
Maryland, Virginia, and West Virginia	3,109,098	4,087,586	− 978,488	[2] 4,362,442	[2] 7,650,679	−[2]3,288,237
Tennessee and Kentucky	2,628,388	1,852,770	+ 775,618	2,254,277	1,576,991	+ 677,286
Alabama and Georgia	1,672,173	1,267,030	+ 405,143	1,349,174	1,557,691	− 208,517
Iowa, Minnesota, and Nebraska [3]	5,731,652	7,764,443	− 2,032,791	4,196,902	5,564,697	−1,367,795
Colorado, Montana, and Oregon	2,008,930	1,978,624	+ 30,312	1,478,033	1,278,730	+ 199,303
	90,703,474	73,098,228	+17,605,246	70,915,508	56,873,200	+14,042,368

[1] Included with Maryland, Virginia, and West Virginia.
[2] Includes also New Jersey in 1918.
[3] Nebraska had no output in 1918.

A short practical discussion of these conditions as viewed by a large cement corporation is given in the testimony of B. F. Affleck, president of the Universal Portland Cement Co., with mills at Pittsburgh, Chicago, and Duluth, before the Calder committee on "Reconstruction and Production." Mr. Affleck said:

"Our difficulties dated back to August 1, 1919, since which time strikes have interfered seriously with our mill operations. As a result, some jobs for which we could have supplied cement and which might have been completed last fall carried over into this year. The year opened with an extraordinarily heavy demand so that by February 1, 1920, our mills were about 2,300 cars behind on shipments, and about March 1 this figure had grown to 3,600 cars. The peak came in the first week in May, when we were about 6,100 cars behind, the oldest order dating from January.

"The direct cause of these delays was the acute car shortage which was continuous over the first half of the year. There were times early in the year when our cement bins were taxed to capacity, making it necessary to adopt unusual means of delivery to make room for continuous operation of our mills. One of these means was the use of restricted railroad cars, privately owned cars furnished by customers and by ourselves, stock cars, open-top cars which involved the use of tarpaulins to protect the contents, and bad-order box cars. Cement, of course, under ideal conditions is shipped in box cars in good order, but this year we have had to take what we could get regardless of expense and inconvenience. Use of restricted and privately owned cars, for instance, to some extent took the distribution of our product out of our own hands. We were offered at our Buffington, Ind., plant, one day by a certain railroad a number of cars restricted to movement to Minneapolis and St. Paul. Aside from the fact that freight rates to the Twin Cities are much higher from our Buffington mill than from our Duluth mill, we did not want, at the time these cars were offered us, to move so much cement at one time into the Twin Cities, prefering rather to distribute it among a number of customers elsewhere whose needs were most urgent. Many times through the season we have received bunches of these restricted cars and have used them only because we did not have enough unrestricted cars to distribute our product equitably and to keep our loading and packing forces occupied and our mills going.

"Another means adopted to keep our product moving was the use of motor trucks, involving, of course, additional expense to ourselves and our customers. From all our plants about two and a quarter million barrels of cement were moved by truck for the nine months ending September 30. The movement from our Chicago plant at Buffington, Ind., was just under 2,000,000 barrels, of which about a quarter of a million barrels moved to team tracks of trunk lines that do not enter our mills, and more than a quarter of a million barrels to a dock where the cement was loaded onto boats for transportation to lake ports. The extreme to which our Chicago plant went in truck deliveries is shown by the fact that as many as 613 trucks were loaded in a single day, the equivalent of about 120 cars. This was at the rate of more than a truck per minute. The cement requirements of Chicago for this year have been more satisfactorily supplied than perhaps any other city in the country by the use of trucks, and at a saving of about 7,500 railroad cars in a time of acute car shortage.

"The crying need in the construction industry is production in its broadest sense, not only of building materials, but of everything necessary to keep industry going—transportation, labor, fuel, credits, confidence, and the last perhaps is greatest of all, since the others will follow it. Confidence and production are needed, and lack of them simply adds in a greater or less degree to the high cost of living, and forms a part of the "vicious circle" that has been with us through these war and postwar times."

NOT FAIR TO JUDGE INDUSTRY BY RECENT PAST.

Taking these conditions by and large, it would seem that the extraordinary obstacles encountered during the past six years militate against considering these years as fair criteria in passing judgment on the ability of the industry to produce and deliver in sufficient quantities to meet the demands of 1921 and succeeding years. A State-owned plant would probably have fared no better during these strenuous times, and, very likely, would have suffered in the same ratio as the private industry.

It now seems that our economic processes are in course of orderly adjustment, and that the conditions which have hampered us in the past are slowly but surely being righted. It is fair to assume, therefore, that as conditions improve the production of cement will more nearly approach the potential producing capacity of the existing plants; and certainly there is little to be gained by building new plants, whether privately owned or State operated, until the conditions permit the full operation of existing plants. Having in mind the pronounced activity of the manufacturers in their efforts to augment production and distribution on economical lines, and considering, also, that our transportation facilities will gradually right themselves under private operation, it is likely that more desirable conditions will soon materialize. At any rate, it is improbable that the States will again experience the abnormal conditions which held during the summer of 1920, providing the State officials will acquaint the producers with their estimated requirements.

Taking these features into consideration, it would seem that the necessity for a State-owned plant, as far as demand is concerned, might be analyzed on the bases:

1. That the construction of a new State plant is not justified in a State where the rated production capacity was greater than the demand during 1920.
2. Where the total demand in the State was less than, say, 400,000 barrels in 1920.
3. Where it can not be conservatively estimated that the demand for State business, year in and year out, will be practically steady.

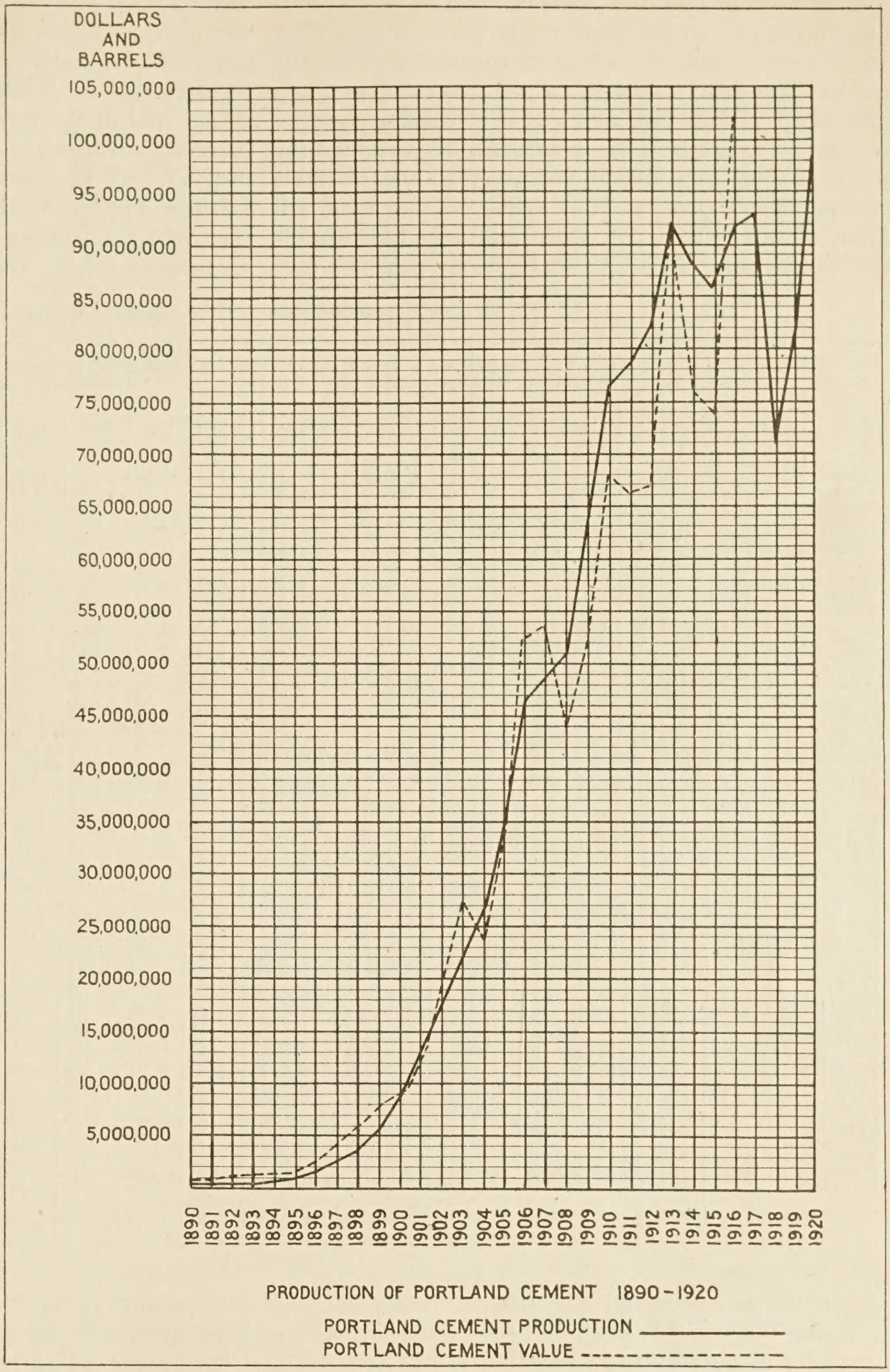


FIG. 1.—PRODUCTION OF PORTLAND CEMENT.

ENFORCING OPTIONS STABILIZES BUSINESS.

To obtain better service from the private cement plants it is most important that the States cooperate with the manufacturers to that extent. It is obvious that to operate any manufacturing plant intelligently and economically there must be at all times in the mind of the operator a reasonably clear idea of its obligations. Theoretically, whenever a company makes a sale it sets aside a certain quantity of its product to discharge the obligation under that sale. If a manufacturer should give an option on 100,000 barrels of cement to 100 customers he would be obliged to supply 10,000,000 barrels if every customer should enforce his option. The manufacturer, therefore, must keep himself in a position to supply that quantity of cement at the contract unit price. Conversely, if some or all of the holders of options should take less than the full quantity covered by their options, the manufacturer would have on hand a quantity of unsold cement which he, perhaps, could have disposed of elsewhere to advantage if he had known his outstanding options would not be enforced. This point is a most important one, involving, as it does, the manufacturer's relations with a large consumer such as a State highway department.

It is possible that even with the utmost of cooperation on the part of the State the problem of obtaining an adequate supply of cement at reasonable price will not be capable of solution without resorting to State ownership. But before we go to that extreme it would be well to exhaust all other means. To acquaint the producers, at least approximately, with the probable amount of our cement requirements, so that they will know what we will expect of them at least four months before they must begin delivering material, is one very important way in which we can aid in the solution of our own problems by utilizing the existing private agencies. In many States the present yearly cement requirements for State highway work are from 15 to 20 per cent of the total available production, and this percentage is required during the six months of heaviest demand. It is essential, therefore, that the manufacturer schedule his output so that the other customers shall receive as large a proportion of their requirements as possible during the months of minimum demand.

Table 3.—*Consumption of Portland cement by States.*

	Consumption (barrels, even thousands).					Consumption per capita (barrels).					Consumption (per cent).				
	1915	1916	1917	1918	1919	1915	1916	1917	1918	1919	1915	1916	1917	1918	1919
Alabama	385,000	458,000	468,000	840,000	577,000	0.17	0.20	0.20	0.35	0.24	0.46	0.50	0.53	1.23	0.70
Arizona	221,000	345,000	374,000	296,000	[1] 366,000	.89	1.35	1.42	1.09	1.31	.26	.38	.41	.43	.44
Arkansas	277,000	394,000	344,000	285,000	437,000	.16	.17	.19	.16	.24	.33	.32	.39	.42	.52
California	4,009,000	4,362,000	4,652,000	3,569,000	[1] 3,837,000	1.41	1.48	1.53	1.14	1.20	4.76	4.77	5.33	5.22	4.64
Colorado	543,000	657,000	763,000	583,000	679,000	.58	.68	.79	.57	.65	.64	.72	.87	.85	.82
Connecticut	1,645,000	1,623,000	1,455,000	936,000	1,273,000	1.34	1.30	1.15	.73	.97	1.95	1.78	1.66	1.37	1.54
Delaware	172,000	195,000	213,000	269,000	290,000	.81	.92	.99	1.24	1.32	.20	.21	.24	.39	.35
District of Columbia	443,000	340,000	514,000	611,000	408,000	1.23	.93	1.40	1.63	1.07	.53	.37	.58	.89	.49
Florida	486,000	484,000	523,000	363,000	506,000	.56	.54	.58	.39	.53	.58	.53	.60	.53	.61
Georgia	620,000	808,000	799,000	708,000	1,041,000	.22	.28	.28	.24	.35	.74	.88	.90	1.03	1.26
Idaho	243,000	523,000	466,000	233,000	[1] 297,000	.59	1.22	1.05	.50	.62	.29	.57	.53	.34	.36
Illinois	6,739,000	7,704,000	7,188,000	5,049,000	6,159,000	1.11	1.25	1.15	.80	.96	8.00	8.43	8.21	7.38	7.47
Indiana	2,954,000	3,749,000	3,408,000	2,503,000	3,134,000	1.06	1.33	1.20	.88	1.09	3.51	4.10	3.89	3.66	3.79
Iowa	3,637,000	3,918,000	3,507,000	2,334,000	3,402,000	1.64	1.76	1.57	1.05	1.53	4.32	4.28	4.01	3.41	4.12
Kansas	1,765,000	2,164,000	1,992,000	1,418,000	1,857,000	.98	1.18	1.08	.76	.98	2.10	2.37	2.28	2.07	2.25
Kentucky	828,000	878,000	769,000	630,000	770,000	.35	.37	.32	.26	.32	.98	.96	.88	.92	.93
Louisiana	778,000	599,000	613,000	588,000	578,000	.43	.33	.33	.31	.30	.92	.65	.70	.86	.70
Maine	440,000	352,000	376,000	247,000	342,000	.57	.46	.50	.32	.43	.52	.39	.43	.36	.41
Maryland	1,370,000	1,393,000	1,560,000	1,459,000	1,368,000	1.01	1.02	1.14	1.05	.98	1.63	1.52	1.76	2.13	1.66
Massachusetts	2,915,000	2,878,000	2,799,000	2,236,000	2,310,000	.80	.78	.74	.58	.59	3.46	3.15	3.20	3.27	2.80
Michigan	3,954,000	4,818,000	4,400,000	3,244,000	5,013,000	1.31	1.58	1.42	1.04	1.58	4.69	5.27	5.03	4.74	6.06
Minnesota	3,147,000	3,315,000	2,788,000	2,202,000	3,002,000	1.40	1.45	1.21	.94	1.26	3.74	3.62	3.19	3.22	3.63
Mississippi	195,000	246,000	251,000	165,000	257,000	.10	.13	.13	.08	.13	.23	.27	.29	24	.31
Missouri	2,896,000	2,785,000	2,539,000	1,644,000	2,209,000	.85	.82	.74	.48	.64	3.44	3.05	2.90	2.40	2.67
Montana	578,000	660,000	790,000	367,000	456,000	1.30	1.44	1.67	.76	.91	.69	.72	.90	.54	.55
Nebraska	1,253,000	1,439,000	1,466,000	1,072,000	1,451,000	1.00	1.13	1.14	.83	1.11	1.49	1.57	1.67	1.57	1.75
Nevada	43,000	44,000	77,000	34,000	50,000	.42	.41	.69	.30	.42	.05	.05	.09	.05	.06
New Hampshire	343,000	240,000	316,000	223,000	321,000	.78	.54	.71	.50	.72	.41	.26	.36	.33	.39
Jew Jersey	3,502,000	3,405,000	3,112,000	2,909,000	3,160,000	1.22	1.16	1.03	.94	1.00	4.16	3.72	3.56	4.25	3.82
New Mexico	253,000	180,000	175,000	135,000	132,000	.64	.44	.41	.31	.29	.30	.20	.20	.20	.16
New York	10,381,000	10,233,000	8,915,000	6,335,000	7,317,000	1.03	1.00	.86	.60	.68	12.32	11.19	10.16	9.25	8.84
North Carolina	573,000	1,083,000	1,022,000	644,000	774,000	.24	.45	.42	.26	.31	.68	1.19	1.12	.94	.94
North Dakota	247,000	415,000	411,000	272,000	352,000	.35	.56	.54	.34	.43	.29	.45	.47	.40	.43
Ohio	7,081,000	7,603,000	6,992,000	4,861,000	6,415,000	1.39	1.48	1.34	.92	1.20	8.41	8.32	7.99	7.11	7.76
Oklahoma	674,000	1,154,000	1,444,000	1,067,000	1,322,000	.32	.52	.63	.45	.54	.80	1.26	1.73	1.56	1.60
Oregon	539,000	514,000	416,000	323,000	642,000	.67	.61	.48	.36	.70	.64	.56	.48	.47	.78
Pennsylvania	7,328,000	7,486,000	7,770,000	6,606,000	7,717,000	.87	.88	.91	.75	.86	8.70	8.19	8.74	9.65	9.33
Rhode Island	379,000	351,000	332,000	344,000	454,000	.63	.57	.53	.54	.70	.45	.38	.38	.50	.55
South Carolina	273,000	459,000	502,000	710,000	531,000	.17	.28	.31	.43	.32	.32	.50	.57	1.04	.64
South Dakota	433,000	562,000	538,000	419,000	713,000	.64	.80	.75	.57	.95	.51	.62	.61	.61	.86
Tennessee	739,000	943,000	882,000	938,000	767,000	.33	.41	.38	.40	.33	.88	1.03	1.02	1.37	.93
Texas	1,744,000	2,260,000	2,037,000	1,543,000	1,980,000	.40	.51	.45	.34	.42	2.07	2.47	2.32	2.26	2.39
Utah	424,000	468,000	488,000	319,000	[1] 412,000	1.00	1.08	1.10	.70	.89	.50	.51	.56	.46	.50
Vermont	210,000	199,000	180,000	122,000	174,000	.58	.55	.49	.33	.52	.25	.22	.21	.18	.21
Virginia	1,181,000	1,105,000	1,341,000	2,054,000	1,477,000	.54	.50	.61	.92	.65	1.40	1.22	1.53	3.00	1.79
Washington	1,037,000	1,288,000	1,187,000	1,043,000	1,277,000	.70	.84	.74	.63	.74	1.23	1.41	1.35	1.52	1.55
West Virginia	1,070,000	995,000	1,181,000	1,277,000	1,089,000	.79	.72	.85	.89	.74	1.27	1.09	1.34	1.87	1.32
Wisconsin	3,168,000	3,282,000	2,962,000	2,212,000	3,274,000	1.28	1.31	1.17	.87	1.27	3.76	3.59	3.38	3.24	3.96
Wyoming	116,000	170,000	226,000	187,000	301,000	.68	.94	1.22	.98	1.54	.14	.19	.26	.27	.36
Total	84,231,000	91,426,000	87,523,000	68,428,000	82,670,000	.84	.90	.85	.65	.77	100.00	100.00	100.00	100.00	100.00

[1] Partially estimated.

Both the consumer and the producer must make increasing endeavors to stock and store materials, so that not only manufacturing plants but the transportation agencies as well can operate under normal working conditions.

LACK OF COOPERATION WILL INCREASE DIFFICULTIES.

The States which fail thus to cooperate and through secretiveness or lack of business judgment fail to notify the producers of their potential yearly requirements are apt to experience increasing difficulties in securing their supply of cement. Nor is the necessity for such anticipation of the requirements to be avoided by State operation. In fact, the necessity of it would then be greater because of the more restricted market of the State plant, which could not dispose of surplus stocks outside of the State. For the efficient operation of the State plant it would be necessary not only to know the amount of the annual requirement but that the demand should be practically constant year after year; and even then, because of the seasonal variation in the State's requirements, it would be necessary to build large stock houses at the plant or to provide well-built storehouses of considerable capacity on the contracts.

Worthy of mention also as means of stimulating supply are many intangibles, chief of which are the relations of the manufacturer and consumer. The operations of a great industry are often considered by the uninitiated only as fit topics for police court investigations or as the particular prey of official investigation carried out along political or mercenary lines. It would seem that public officials should approach the problem of making available an increased supply of any basic construction material not by treating the industry as a positive menace to society—a profiteering class of business buccaneers who should be hammered unmercifully in order to force them to disgorge unwarranted profits,—but rather it would seem that a public official should and must, in these days of increasing responsibility, take the business man more closely into his confidence. For example, there is no reason why a broad-minded official interested in supplying a certain commodity for use on State contracts, whether the commodity be steel, oil, asphalt, brick, or cement, should assume that it is necessary to gather his statistics behind closed doors. By and large, most of our construction material manufacturing corporations are run on a broad-gauged business basis, and it is but fair to assume that our supply of these materials will be augmented only by close and consistent cooperation with those who make them. All of our industrial plants are business assets to our States, and individual initiative is best fostered by legitimate and friendly cooperation. Such cooperation must result in more efficient service and quicker dispatch of our public works programs.

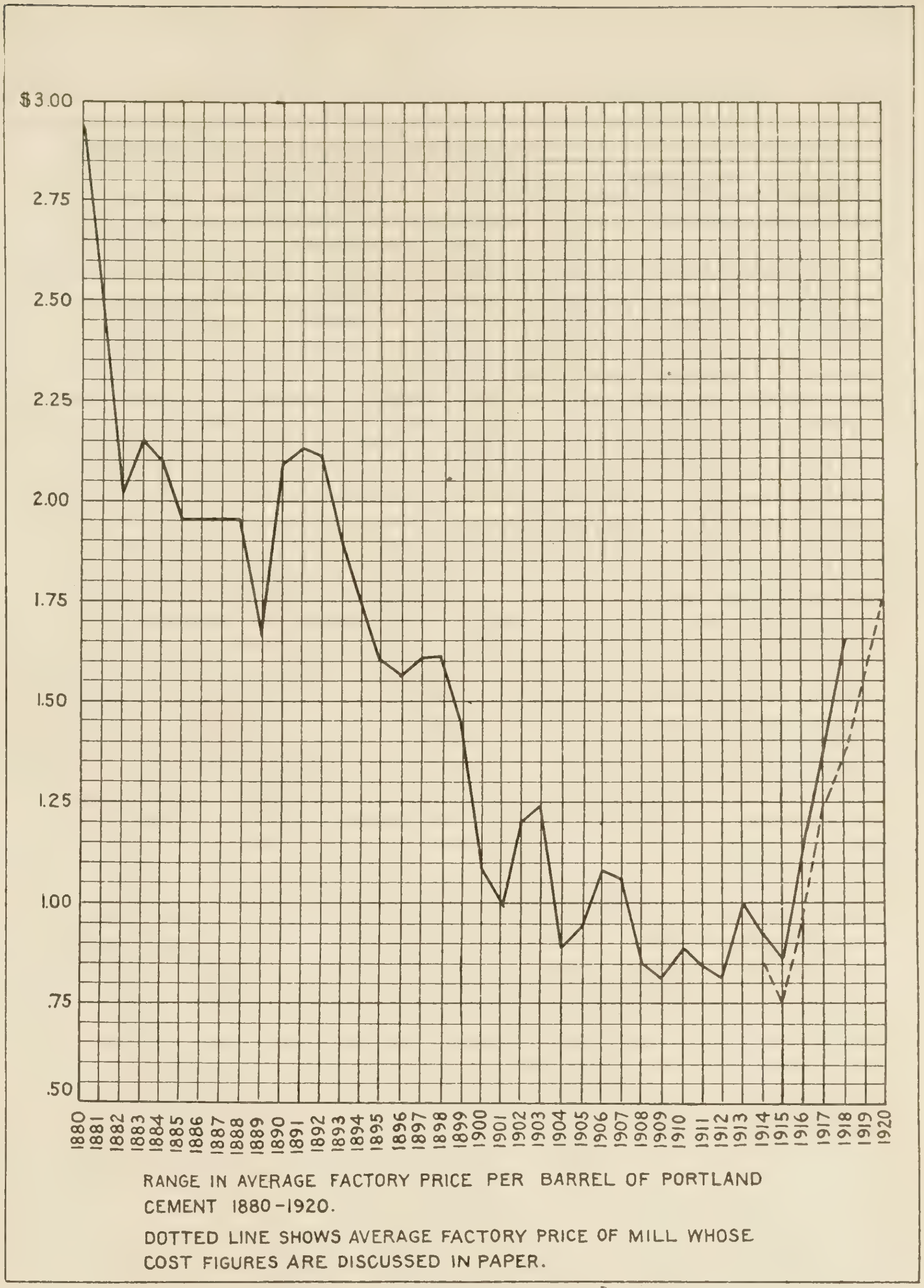


FIG. 2.—PRICE RANGE OF PORTLAND CEMENT.

In the preceding development the author has attempted to show the causes for the unsatisfactory conditions of the cement market and to suggest means by which an adequate supply of this essential material can be assured without turning from the existing commercial sources to the development of new Government-controlled plants. In view of the fact that the producing capacity of the existing plants has never been fully utilized, he is convinced that the difficulties can be ironed out in most cases by close cooperation of producer and consumer.

Where it appears that such is not the case, and that State operation is needed as a solution, there are a number of other facts which should be carefully considered before embarking on the project.

AVAILABILITY OF RAW MATERIALS.

One of the most important of these other matters is the question of availability of the raw materials. In many States all available supplies of the raw materials required are now either owned or under option, and there are several States in which there have been found no satisfactory materials in sufficient quantity to justify the construction of a plant. This is notably the case in the New England States, in Wisconsin, and in some of the Southern States. It is essential, therefore, before taking steps looking toward the construction of a plant, to determine that there is satisfactory raw material available at strategic locations and in sufficient quantity to enable the plant to operate continuously for a long term of years.

This means an appropriation to enable a geologist or cement expert to make an authoritative drill hole and quantity survey of any suggested locations. What is likely to happen if this step is omitted could be illustrated by the results in many cases where promoters of private plants have overlooked its importance in their enthusiasm, thereby making it necessary to transport either shale, clay, limestone, or silica rock long distances at material increases in the unit cost of production. In these days of increased transportation charges, this item might militate against the economical operation of a poorly located plant, inasmuch as over 600 pounds of raw materials and from 150 to 200 pounds of coal are required for the production of a barrel of cement.

DISTANCE FROM MARKETS.

Another feature which must be closely associated with the location of the plant is the distance to the area of largest consumption. The Lehigh Valley mills are adjacent to the New York and Philadelphia markets and tidewater, and the transportation charges to New England points are sufficiently low to enable the Pennsylvania manufacturer to compete with the neighboring New Jersey and New York mills. The western Pennsylvania mills are within easy distance of the Pittsburgh market; the Illinois mills are close to the Chicago market; the Texas mills to the El Paso, San Antonio, and Dallas markets. The California mills are within easy access of the San Francisco and Los Angeles markets as well as tidewater. Were a State-owned plant to be built, it should be located to serve the entire State, and the transportation situation must be carefully analyzed by a traffic expert who is thoroughly acquainted with traffic rates and charges. If this feature be forgotten, a mill might easily be located so that the freight differential would penalize the mill in an amount of from 25 to 60 cents per barrel for transportation. In Pennsylvania this differential for a plant centrally located might result in a loss of at least 30 cents per barrel for shipments to eastern and western points in the State. This element, on close analysis in States of large area, might make it advisable to consider the establishment of two small mills instead of one relatively large one.

The experts in the cement field closely follow the development of prospective sales fields, and every large cement manufacturing corporation employs men who are constantly exploring new territory, both with regard to the establishment of new plants and to increasing the radius of their sales fields. It is essential that every company keep their transportation rate contour investigations up to date inasmuch as this feature enters to a very great degree into the final unit costs and profits. The restriction of sales territory is common in every basic industry which has been susceptible of broad expansion inasmuch as new plants are being constantly established. The cement industry is perhaps the most striking example of this principle, due largely to widespread available raw materials.

COMPETITION BETWEEN STATE AND PRIVATE PLANTS.

Individual initiative would doubtless play a dominant part in the competition of State as against privately owned plants, and the probabilities are that were a State-owned plant to be built it would immediately become the target for intense competition on the part of the private plants in the field, which have through long experience introduced many economies in their process of manufacture. This competition would be particularly dangerous were the private corporations able to materially underbid the State plant. While it would seem unwise to draw general conclusions, still there have been instances where private corporations have been able to accomplish this, inasmuch as their sales field enables them to operate continuously, whereas the municipal or State-owned plant could only operate part time, and therefore uneconomically.

There are many conditions which would justify the construction of a State plant. For instance, there might be cases where existing plants continue to turn out a nonuniform product, due to inferior raw materials, or where due to poor location on the part of the original promoter, the private plant was placed far from available raw materials or the sales field. It must be stated, however, that private capital, conservatively managed, must sooner or later discover these weak private plants and eliminate them by legitimate business methods.

In analyzing competition it is essential that a survey be made of all private plants in the territory and that traffic-rate contours be determined. Further, it is suggested that the business of the competitors be analyzed as to life, volume, and what would be the effect of the State plant on adjusting the sales prices of private plants due to State competition. In the past there have been cases where sales territories of specific private plants have been made the dumping grounds for plants who could afford to dispose of parts of their product which strict interpretation of specifications had eliminated from their immediate sales field. This condition would not govern, however, in the case of the State plant, inasmuch as it must be assumed that all States have well-equipped laboratories, directed by experienced testing engineers, who pass upon the acceptability of the millions of dollars' worth of construction materials used by them every year.

CONDITIONS JUSTIFYING A STATE PLANT.

Were a State-owned plant to embark in business today it would do so in a period of relative uncertainty and of high prices, and the advisability of entering the field must be based on a cold analytical examination which must unmistakably show that:

(1) Competition is lacking.
(2) The existing price scale is too high.
(3) The available product is inferior.
(4) The privately owned plants are woefully lacking in cooperation.
(5) The capacity of the existing plants is not sufficient to supply the demand, assuming transportation facilities normal.

Economically, the broad general condition of the cement industry to-day is conducive to keen competition. As has been pointed out previously, the industry has never been able to market over probably 75 per cent of its capacity, although in specific State fields this percentage may run higher.

While there may be irrational statements given out regarding excessive prices and frozen competition, we must not forget that American business to-day is open to the analytical eye of an omnipresent government, which through its several departments has full authority to not only scan the books of every commercial enterprise, but has also the right to make the most searching investigations regarding the trade relations of all plants turning out a basic product. It would seem that we must differentiate the purposes of such trade investigations as may form the basis of highly colored newspaper reports because many such investigations are not investigations in the true sense of the word. The investigations I have in mind are those of which we hear but little and which are carried out quietly and purposely to correct glaring irregularities either in the financial or trade relations of existing corporations.

Unfortunately, engineers, as a rule, are not always conversant with the cost of manufacturing the materials they use, and I believe that we are safe in saying that generally the engineer has no clear conception of the cost of manufacturing cement. In discussing the price scale, an endeavor will be made a little later to analyze the cost entering into the manufacture of this product, and you may then be able to draw your own conclusions regarding the business hazard encountered in placing this material on the market.

Eventually an inferior product is eliminated due to lack of confidence in the product on the part of the consumer. It would seem that inferior cement is now the exception rather than the rule, and we should understand that the product in its various stages through the mill is under the direct control of the chemist, and further, that it has been found economical and essential that manufacturing methods be gradually extended and refined in order to cheapen the cost of production and, therefore, the cost to the consumer. Strict control on the part of the chemist elminates the manufacture of an inferior product, and thus eliminates wasted effort and financial loss to the manufacturer. It is a common occurrence for many new mills to run for weeks before the chemist is finally able to control the finished product. Many cases have occurred where it has been necessary to remodel or change the system of manufacture so that conditions which were not foreseen or properly interpreted by the designer might be remedied. Among these might be mentioned the color of the product, its setting qualities, its fineness, and its soundness. It is also common in many mills to find instances where the different units were not properly correlated, the crushing plant would not deliver enough raw materials to permit of continuous operations of all the kiln units, the kiln units would not deliver the clinker fast enough to keep the grinding department in continuous operation, or the power plant was not sufficiently flexible to adapt itself to the changing loads required for economical operation. These conditions in many instances have proved to be financially burdensome.

It would seem desirable again to call attention to cooperation between the manufacturer and the State as a consumer of cement. On the part of the State it would seem that this neglect might be due to a fancied belief that the taxpayers would think that a public official was dominated by certain commercial motives and that he was not actuated by high regards in giving his best efforts in handling the program for which he is held responsible. It would seem that if highway engineers expect to carry out the tremendous responsibility which has been thrust upon them, and which must be carried to a successful conclusion, they must so carry out their work that it will bear the closest scrutiny of the public, and this can no better be consummated than by allowing the manufacturer of all products to know what the State requirements will be in advance. The poorest cooperation that a manufacturer can give consists, first, in poor service; second, malicious promises that he will deliver on contracts which he knows he can not fulfill; third, the sale of his product when he does not know the true cost of manufacture, the last fault being economically the greatest because sooner or later it must result in bankruptcy for his company and the general unsettlement of society. The history of the cement industry is replete with glaring examples of financial failures, and a great many of the companies now in existence have passed through bankruptcy. There have been many cases where promotional schemes have been fostered, plants built, only to pass completely to the junk pile or to become eyesores to those who had invested their savings in them. I repeat, that the poorest cooperation a manufacturer of any commodity can give the purchasing public is that of selling his product at a price below the cost of production or of so running his business as to grant undue extension of credits.

WHAT IS A FAIR PROFIT?

Selling any product at a price which will net an exorbitant profit is economically unsound and will ultimately limit the use of that product. It is interesting to note in this connection that the great war revealed real weaknesses in many of our industrial enterprises.

28302—21——2

During the strenuous times of 1917 and 1918 it became necessary for the Federal Government to closely analyze our producing capacity, and it became increasingly evident that Federal price regulation was essential to our early and successful completion of the great venture. Hearings were held in Washington continuously before the Federal Trade Commission, the War Industries Board, and many other commissions organized to solve our manufacturing difficulties. The books of many manufacturing industries were opened to close scrutiny. It is interesting to note that the hearings as they involved the cement industry developed the fact that there were but four cement manufacturing companies in this country that had fallen within the excess-profits tax provision.

In marketing Portland cement the general practice in many parts of our country is to sell the product to the consumer through legitimate dealers. In opening this phase of the marketing problem it would seem that whenever a dealer does an actual service he is entitled to a fair and just profit. We will all admit that the dealer does a real service by using his yards as a small storage supply base and many times in assuming the consumer's credit obligations until such time as the consumer chooses to pay for the product. In public works, however, this reasoning does not seem to hold. On road contracts very little of the cement purchased through dealers goes through the dealers' yards, and the dealer does not perform a real service in carrying the credit load of a contractor. Many contractors are discounting their bills with regularity in the 10-day period, and they pay net for the product within the customary 30 days. It would seem desirable, therefore, that the States, as large consumers of cement, should be entitled to more consideration from the manufacturers and that cement used for State work should be available at a price equal to that paid by all dealers. On further analysis, we should bear in mind that a complete discussion of the subject would warrant us in assuming that a State should not place upon the manufacturer the burden of carrying an undue credit load or a load of commitments on which he can not hope for financial return for periods of from five to six months. The argument might be raised that this is one of the manufacturer's hazards. If it is a hazard, what would be his fair remuneration for carrying it, or what would be a legitimate method to be used by a State in guaranteeing to the manufacturer the prompt or eventual settlement for materials which he has furnished?

COST OF CONSTRUCTION AND OPERATION OF PLANTS.

Taking into consideration the conditions which have been developed, it would seem that obviously the only justification for the erection of a State-owned plant is failure in the past, or probable failure in the future, to secure sufficient cement for the State's needs and at reasonable prices for the territory in which the plant would be located.

Specifically, the question resolves itself into two parts:

First. Does a real need for a State-owned plant exist in a given State after the subject has been thoroughly analyzed from the viewpoint which has been expressed in this paper?

Second. What will be the cost to construct and operate a plant of the required capacity?

It will be assumed that the development covered in the first topic warrants a close analysis of topic number two, and that it has been decided that close estimates be prepared for the erection of—

(1) A first-class cement plant of 600,000 barrels capacity per year, assuming an operation period of 350 days per year. The plant is to be so designed that there will be minimum maintenance requirements, and to be equipped with raw materials storage bins, up-to-date dust-collecting systems, waste-heat boilers, a central generating plant with all machinery supplied with unit electric-driven motors. It is further assumed that a sanitary system, a pumping station, and a cement stock house of 150,000 barrels capacity, a main office building, dispensary, and sufficient trackage to facilitate train movements, both from and to the mill, will be required. It is further assumed that the mill will be located on property purchased by the State on which there is a sufficient raw material supply to run the plant from 50 to 100 years. The estimates to include, also, general items which are necessary in financing the construction, with sufficient capital to be laid aside to operate the plant for one month. The operation expenses are to include sufficient sack supply for three months' operation.

(2) A second-class plant of the same capacity built with a view to detailed structural maintenance from time to time, and with dust-collecting systems, sanitary system, dispensary, etc., eliminated.

Such an estimate is given in detail in Table 5. This estimate is for plants which will be erected on the assumption that the State believes that the demand for cement has become stabilized and that the industry is one of the major construction industries; that the plant must be prepared to turn out cement which will be subject to intense competition, and therefore, be manufactured at the lowest possible mill cost. This estimate is for a contemplated plant in the north central or northeastern part of our country. The total cost per barrel of production for plant No. 1 is estimated to be $4.865 per barrel; for plant No. 2, $3.483 per barrel.

In order to operate these plants, it is assumed that the inventory given in the table will be necessary. This inventory amounts to $0.365 per barrel capacity. The total cost of construction and inventory is, therefore, $5.23 per barrel capacity for plant No. 1 and $3.848 per barrel capacity for plant No. 2.

TABLE 4.—*Mortality table, being average estimated life of various properties in the cement industry.*

	Average life (years).
Machinery:	
Quarry	
Locomotives	13
Tracks and cars	9
Steam shovels	11
Dredges	11
Drills—Well	9
Drills—Tripod	7
Live stock	8
Carts and wagons	7
Cableway	9
Raw department:	
Crushing machinery	14
Driers—Upright	11
Driers—Rotary	11
Slurry tanks	16
Grinding machinery	13
Clinker-burning department:	
Kilns	13
Coolers—Upright	12
Coolers—Rotary	13
Clinker-grinding machinery	12
Coal mill:	
Driers	11
Grinding machinery	14
Power house:	
Boilers	15
Engines	17
Generators	16
Motors	14
Stock-house machinery	10
Machinery and B. S. shop machinery	15
Buildings:	
Mill—	
Concrete	50
Steel and corrugated iron	20
Steel and stucco	21
Steel and brick	30
Timber	20
General (mill office, laboratory, storehouse, etc.):	
Concrete	50
Steel and corrugated iron	20
Steel and stucco	22
Steel and brick	30
Frame	18
Frame and stucco	22
Dwellings:	
Concrete	50
Brick	30
Frame	20
Frame and stucco	23

TABLE 5.—*Estimate of cost of a 600,000-barrel cement plant (Dec. 9, 1920).*

TABLE 5.—*Estimate of cost of a 600,000-barrel cement plant (Dec. 9, 1920)*—Continued.

	First-class plant—estimate.	Second-class plant—estimate.
General mill expense:		
Clearing, grading, and filling	$5,000	$3,000
Clock house and watchman's shanty	10,000	6,000
Fence, inclosing mill property	10,000	5,000
Total	25,000	14,000
Construction equipment:		
Tools and equipment	50,000	15,000
Temporary buildings	7,500	2,500
Temporary tracks	7,500	2,500
Total	65,000	20,000
Trestle to raw-material bins:		
Excavating and back filling	3,000	1,500
Foundations	10,000	2,000
Trestle	50,500	20,000
Walks	1,500	500
Total	65,000	24,000
Raw-material bins:		
Excavating and back filling	1,500	500
Foundations and floor	5,000	1,000
Building	37,000	7,000
Roof	3,500	1,500
Concrete walls and plastering	13,000	2,000
Total	60,000	12,000
Raw-material mill:		
Excavating and back filling	5,000	2,500
Foundations and floor	30,000	15,000
Building, hoppers, and upper floors	65,000	30,000
Roof	6,000	2,500
Walls, plastering, doors, and windows	15,000	5,000
Crushing machinery	7,000	7,000
Driers, stacks, and coal-burning apparatus	36,000	35,000
Dust-collecting system for driers	15,000	15,000
Preliminary grinding machinery	36,000	36,000
Tube mills	70,000	70,000
Elevating and conveying machinery	40,000	25,000
Dust-collecting system for machinery	15,000	15,000
Total	340,000	258,000
Raw-material storage bin:		
Excavating and back filling	$2,000	$1,200
Foundations, tunnels, and floors	4,000	2,000
Building	10,000	6,000
Roof	500	300
Concrete walls and plastering	7,500	2,500
Elevating and conveying machinery	6,000	6,000
Total	30,000	18,000
Gypsum storage:		
Excavating and back filling	500	200
Foundations and floors	2,000	600
Building, walls, and plastering	10,000	3,000
Roof	500	200
Elevating and conveying machinery	3,000	3,000
Total	16,000	7,000
Cement stock house (150,000 barrels capacity):		
Excavating and back filling	8,000	5,000
Foundations, tunnels, and floor	75,000	50,000
Building and hoppers	20,000	15,000
Concrete walls and plastering	142,000	60,000
Elevating and conveying machinery	30,000	30,000
Packing and loading machinery	15,000	15,000
Dust-collecting system	10,000	10,000
Total	300,000	185,000
Sack-storage building:		
Excavating and back filling	2,000	500
Foundation and floor	12,000	6,500
Building, walls, and plastering	25,000	15,000
Heating, lighting, and sanitary system	6,000	5,000
Bag-cleaning machinery	15,000	15,000
Dust-collecting system	15,000	13,000
Total	75,000	55,000
Machine and blacksmith shop:		
Excavating and back filling	500	200
Foundation and floor	5,500	3,000
Building	18,000	8,000
Roof	3,000	1,000
Walls, plastering, doors, and windows	8,000	4,000
Heating and sanitary system	8,000	6,800
Machinery and equipment	17,000	17,000
Total	60,000	40,000
Coal Bins:		
Excavating and back filling	500	100
Foundations and floors	2,000	1,000
Building	16,000	8,000
Roof	500	300
Concrete walls, bin floor, and plastering	6,000	3,600
Total	25,000	13,000
Coal-grinding building:		
Excavating and back filling	1,500	500
Foundations and floors	8,000	3,000
Building and hoppers	16,000	10,000
Roof	1,500	500
Crushing and drying machinery	12,000	12,000
Pulverizing machinery	14,000	14,000
Dust-collecting system	9,000	8,000
Elevating and conveying machinery	8,000	8,000
Total	70,000	56,000
Burner building:		
Excavating and back filling	3,000	1,000
Foundations and floor	15,000	8,000
Building, hoppers, and upper floors	35,000	25,000
Roof	3,500	1,000
Walls, plastering, doors, and windows	11,000	6,000
Two 10 by 150 foot kilns and stack bases	100,000	80,000
Dust-collecting system for kilns	105,000	....
Elevating and conveying machinery	17,500	17,000
Total	290,000	138,000
Waste-heat boiler house:		
Excavating and back filling	1,500	500
Foundation and floors	7,500	3,500
Building and upper floors	19,000	10,000
Roof	500	300
Walls, plastering, doors, and windows	7,500	3,500
3 boilers, settings, and superheaters (2 waste heat, 1 coal fired)	90,000	90,000
Flues to and from boilers and fans	7,500	7,500
Fans, motors, and switches	16,000	16,000
Boiler-feed pumps, motors, and switches	7,500	7,500
Boiler-feed water piping	10,000	8,000
Boiler-feed water, filtrating, and softening plant	5,000	5,000
Blow-off piping	4,500	3,000
Steam line, supports, and covering	23,500	20,200
Total	200,000	175,000

TABLE 5.—*Estimate of cost of a 600,000-barrel cement plant (Dec. 9, 1920)*—Continued.

	First-class plant—estimate.	Second-class plant—estimate.
Storeroom:		
Excavation and back filling	$500	$100
Foundation and floor	2,500	1,500
Building, walls, and plastering	9,000	6,000
Equipment	3,000	2,400
Total	15,000	10,000
Sanitary installations:		
Excavating and back filling	500	
Foundation and floors	5,000	
Buildings	12,500	
Roofs	2,000	
Walls, plastering, doors, and windows	7,000	
Plumbing, lighting, and heating systems	8,000	5,000
Total	35,000	5,000
Main office, foremen's office, and dispensary:		
Excavating and back-filling	2,000	500
Foundation and floors	10,000	3,500
Building, walls, plastering, doors, and windows	40,000	10,000
Heating, lighting, and plumbing system	3,000	2,000
Furniture and fixtures	10,000	8,000
Total	65,000	24,000
Compressed-air system:		
Air compressor and motor	4,500	4,500
Air receiver and piping	4,500	4,500
Total	9,000	9,000
Track system: Tracks	120,000	100,000
Drainage and sewer system	10,000	3,000
Quarry:		
Steam shovels	30,000	20,000
Quarry car and dinkey locomotive	55,000	40,000
Crushing plant, complete	90,000	90,000
Total	175,000	150,000
Generating station:		
Excavating and back filling	3,000	1,200
Foundations and floor	12,000	5,500
Building and upper floors	19,000	11,000
Roof	1,500	500
Walls, plastering, doors, and windows	12,000	8,000
Motor generator	6,000	6,000
Sanitary facilities	500	300
Turbo-generator and exciter (two 1,000-kilowatt ordin.; one 1,000-kilowatt, spare)	85,000	85,000
Condensor and accessories	10,000	10,000
Condensor piping	9,000	8,500
Air washer	2,000	2,000
Transformers	15,000	15,000
Main switches, switchboard, and wiring	15,000	15,000
Total	190,000	168,000
Electrical work outside station:		
Trenching and back filling	2,000	500
Concrete work and wire ducts	18,000	11,500
Wiring	35,000	25,000
Total	55,000	37,000
Pumping station:		
Excavating and back filling	500	100
Foundation and floors	2,500	1,500
Building	3,000	2,000
Roof	250	150
Walls, plastering, doors, and windows	1,500	1,000
Pumps, motors, and switches	6,000	6,000
Water piping, valves, and fittings	24,000	20,000
Screens	2,250	2,250
Total	40,000	33,000
Clinker storage:		
Excavating and back filling	3,500	1,000
Foundations, retaining walls, and floor	22,500	15,000
Crane runway	15,000	12,000
Clinker cranes, with grabs	34,000	34,000
Total	75,000	62,000
Finishing mill:		
Excavating and back filling	2,500	1,000
Foundations and floor	20,000	12,000
Building, hoppers, and bridge to stock house	60,000	45,000
Roof	2,500	1,000
Walls, plastering, doors and windows	15,000	10,000
Preliminary grinding machinery	35,000	35,000
Tube mills	70,000	70,000
Elevating and conveying machinery	30,000	30,000
Dust-collecting system	25,000	20,000
Total	260,000	224,000
Plant property:		
Stone property, 150 acres; shale property, 50 acres; plant property, 50 acres	125,000	125,000
Total	2,795,000	1,965,000

TABLE 5.—*Estimate of cost of a 600,000-barrel cement plant (Dec. 9, 1920)*—Continued.

	First-class plant—estimate.	Second-class plant—estimate.
General works expense	$30,000	$30,000
Engineering	45,000	45,000
Contingencies	25,000	25,000
Accident and hospital reserve	25,000	25,000
General overhead expense, 4.5 per cent	125,000	125,000
Grand total	2,920,000	2,090,000

$2,920,000 divided by 600,000 equals $4.865 per barrel (first-class plant).
$2,090,000 divided by 600,000 equals $3.483 per barrel (second-class plant).
Estimated cost of these cement plants having a yearly capacity of 600,000 barrels, based on 350 days' operation and on the supposition that the plant site is level ground with water and railroad facilities adjacent to the site. The above first-class plant is equipped with all modern and up-to-date improvements such as waste-heat boilers, dust-collecting apparatus throughout, and modern sanitary facilities.

Inventory needed in the operations of a 600,000-barrel capacity plant.

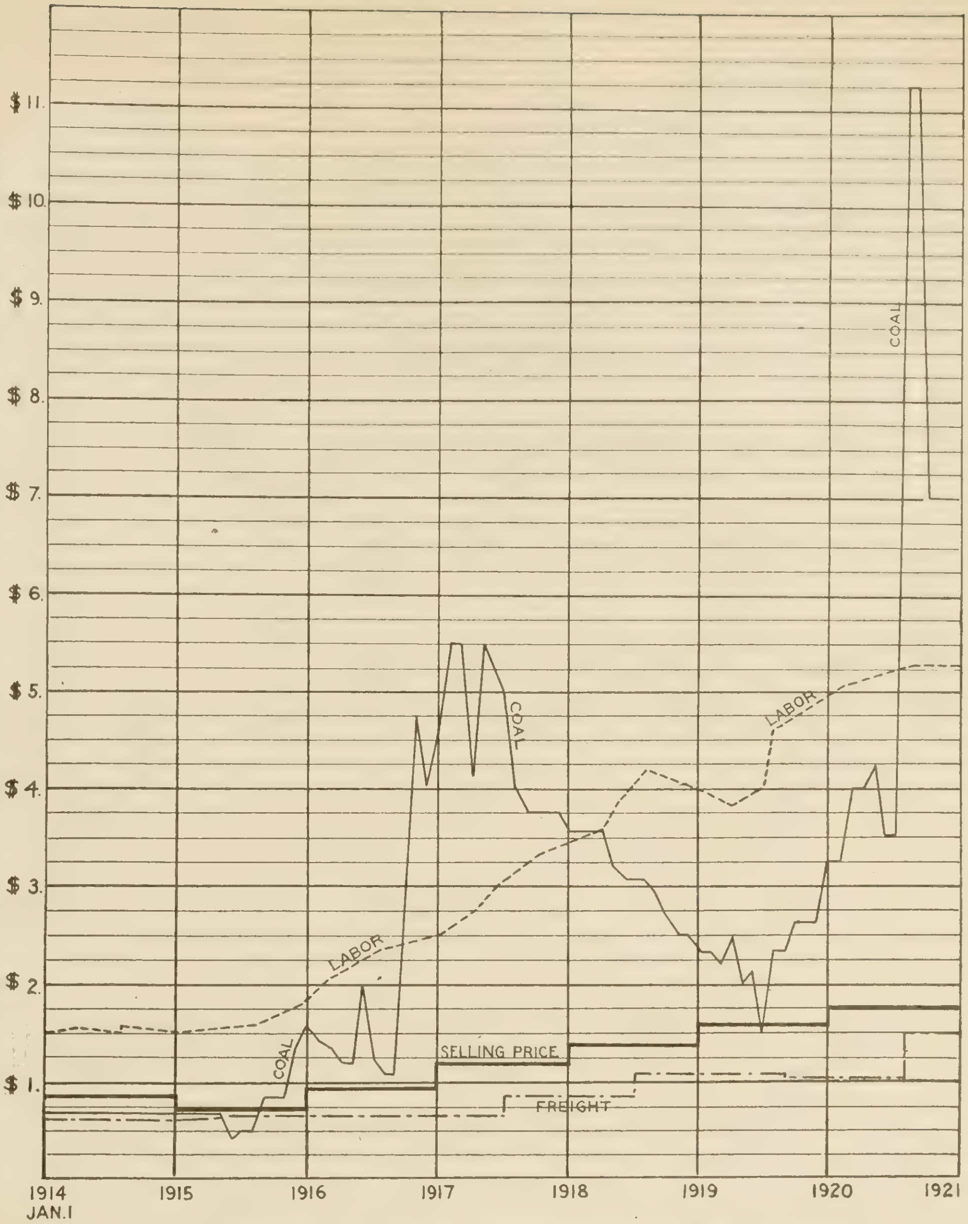
	First-class plant estimate.	Second-class plant estimate.
600,000 sacks at $150 per thousand (6 months' supply)	$90,000	$90,000
Stores and miscellaneous supplies	40,000	40,000
2,500 tons coal at $5 (1 month's supply)	12,500	12,500
250 tons gypsum at $7 (1 month's supply)	1,750	1,750
Raw material, limestone, shale, or clay	5,000	5,000
10,000 barrels clinker (average monthly inventory $1)	10,000	10,000
40,000 barrels cement (average monthly inventory $1.50)	60,000	60,000
Total	219,250	219,250

For larger mills the cost of construction will be somewhat smaller. An estimate for a million-barrel mill of type No. 1 would be from $4.50 to $4.75 per barrel capacity. The estimate does not provide for financing the housing of employees. If the mill is located near a town and convenient transportation is available the housing problem may solve itself. If, however, the mill is at some distance from a town, it would probably become necessary to establish a village which would contain some 500 to 600 people, requiring at least from 75 to 100 houses, with the necessary church, school, stores, and some sort of municipal improvements. No attempt will be made to estimate the cost of this feature, although it must be given consideration in order to insure continuous and economical operation of the plant. Developments durings the years 1916 to 1920 have demonstrated to cement manufacturers that this feature is essential for the economic operation of plants. A State-owned plant must be operated continuously or its operating costs will mount to figures which would not permit of competition.

It will be assumed that the next step in analyzing the subject will be to estimate the operating costs of the projected plant, which will be erected following the outline as given for plant No. 1. It should be understood that the system used to figure an estimated unit cost of production must approximate the true cost of production. Otherwise, if the actual operating cost is higher and becomes excessive, the venture may result in either loss of capital or loss of sales. If the manufacturing costs are understated, the profits will be overstated; and, conversely, if the manufacturing costs are overstated, and the mill produces with regularity and economy, the venture will be profitable. True costs must reflect seasonal fluctuation in production, shutdowns, strikes, overproduction of clinker or finished cement, poor transportation, and all favorable or unfavorable developments. A true estimate must also be made of labor efficiency.

Table No. 6 represents a close survey of 51 cement manufacturing plants and demonstrates the relative labor efficiency in both large and small mills.

Having in mind the operation of the projected plant, Table No. 7 gives an estimate of unit costs of operation and Table No. 8 represents the balance sheet of the projected company at the end of the first month's operation, the estimate being for December, 1920. It should be understood that the estimated costs, as given in these tables, are for a particular 600,000-barrel mill in a given section of our country, which will be subject to certain assumed operating conditions. The costs would not be applicable for a mill to be erected on the Pacific Coast or in the Southern States, where the operating conditions and the rate of consumption per month would be entirely different.



LABOR COST—COST PER DAY; TRANSPORTATION COST—COST PER TON; COAL COST—COST PER TON; SELLING PRICE PER BARREL OF CEMENT OF MILL QUOTED IN FIGURES NOS. 18 AND 19.

FIG. 3.—FACTORS IN COST OF PORTLAND CEMENT PRODUCTION.

TRUE COSTS OF AN OPERATING COMPANY.

To demonstrate the fluctuation in operating conditions, costs of materials, increased cost of transportation, and all of the many items which have entered into the true cost of cement during the past several years, Tables 9 and 10 are given for two mills of 2,000 and 3,900 barrels per day capacity, respectively. These mills have operated under the same management from 1915 to date. The company markets a well-known brand under an exceptionally able business management and has accepted its obligations of fulfilling holdover contracts from previous years, even at increasing manufacturing unit costs per barrel.

The smaller mill, with the higher unit cost per barrel, was shut down during 1918 and 1919, when the demand was far below production in this country and when we experienced general unsettlement in the construction industry. It will be noted that in the 3,900-barrel mill the cost of materials jumped from 20.6 cents per barrel in 1914 to 63 cents per barrel for the first 10 months in 1920; labor jumped from 6 cents to 13.7 cents per barrel; supplies from 6 cents to 12.7 cents per barrel; general mill expenses from 11.1 cents to 20 cents per barrel; reserves and packing costs from 17.5 cents to 22 cents per barrel.

A survey of some of the variable items entering into the manufacturing costs is given in figure 3. Freight is the average cost per ton from a given manufacturing plant to an assumed destination at a relatively short distance from the mill; the labor curve represents the average price of common labor employed at the mill; the coal cost represents quotations at mines or of spot coal during the tight period of midsummer 1920. The curve of selling price of cement is taken from the mill referred to in Tables 9 and 10.

TABLE 6.—*Labor efficiency in 51 cement plants, on man-hours per barrel basis, for the year 1919.*

Plant No.	Number of barrels produced.	Number of man-hours per barrel produced.																Number of barrels shipped.	Number of man-hours per barrel shipped.			Number of shifts in plant.
		Quarrying.	Raw department.	Clinker department.	Finishing department.	Power department.	Coal mill.	Yard.	Shops.	Repair gang.	Mill office.	Storeroom.	Laboratory.	Superintendent and general foreman.	Watchmen.	Miscellaneous.	Total.		Packing and loading.	Sack handling.	Total.	
1	855,463	0.112	0.075	0.072	0.048	0.044	0.027	0.030	0.064	0.058	0.030	0.013	0.025	0.037	0.009	....	0.643	932,145	0.065	0.047	0.112	3
2	919,192	.317	.162	.083	.072	.132	.050	.018	.056	(1)	.022	.023	.030	.047	.010	....	1.022	981,072	.102	.029	.131	2
3	406,000	(2)	.182	.090	.105	.034	.072	.052	.046	(3)	.015	.007	.025	.041	.014	....	.683	483,450	.046	.034	.080	2
4	281,811	[4].042	.327	.103	.120	.156	.119	.165	.094	.084	.025	.013	.050	.035	.016	....	1.349	284,686	.097	.023	.120	2
5	645,870	.170	.026	.038	.035	.027	.030	.068	.026	.033	.011	.010	.026	.015	.007	....	.523	657,870	.055	.027	.082	2
6	400,000	.119	.071	.042	.054	.036	.036	.060	.030	.035	.020	.005	.025	.012	....	....	.545	344,000	.045	.022	.067	3
7	601,333	.096	.105	.057	.063	.075	.062	.097	.006	.185	.050	.033	.022	.023	.013	....	.888	611,359	.066	.061	.127	2–3
8	1,414,000	.169	.041	.032	.061	.068	.025	.035	.064	.027	.021	.008	.018	.010	.010	....	.590	1,638,582	.114	.054	.168	3
9	225,118	.426	.067	.023	.058	.038	.037	.047	.023	.023	.023	(5)	.029	(5)	.019	....	.814	182,838	.079	.031	.110	3
10	600,000	.117	.106	.040	.040	.092	.045	.033	.100	.145	.028	.011	.043	.033	.007	....	.840	650,000	.062	(6)	.062	2
11	352,130	.235	.196	.076	.074	.153	.027	.088	.085	.105	.009	.026	.044	.039	....	0.038	1.195	417,896	.073	.019	.092	2
12	200,521	.494	.125	.115	.118	.147	.088	.100	.123	.118	.031	.065	.082	.055	.022	....	1.683	189,668	.115	.058	.173	2
13	498,816	.251	.229	.111	.095	.018	.054	.145	.059	.132	.030	.029	.043	.051	.010	....	1.257	608,707	.106	.080	.186	2
14	278,300	.208	.146	.104	.042	.031	.062	.006	.153	.089	.010	.016	.021	.043	.016	....	.947	270,300	.072	.046	.118	2
15	547,771	.175	.215	.119	.135	.141	(7)	.069	.020	.015	.023	.014	.020	.014	.015	.023	.999	549,310	.083	.120	.203	2
16	498,781	.109	.094	.092	.065	.115	.059	.127	.058	.069	.020	.016	.014	.027	....	.140	1.006	571,055	.071	.021	.092	2
17	838,056	.093	.128	.011	.044	.068	.042	.074	.056	.118	.016	.015	.017	.014	.011	....	.707	998,676	.072	.027	.099	2
18	148,692	.350	.101	.117	.154	.213	.097	.046	.117	.254	.050	.023	.035	.043	.016	....	1.617	180,688	.087	.025	.112	2
19	234,557	(2)	.238	.171	.112	.184	.095	.017	.050	.072	.037	.016	.041	.040	.018	.018	1.109	227,953	.066	.033	.099	2
20	697,286	.232	.081	.033	.067	.085	.033	.024	.026	.245	.008	.014	.029	.009	.006	....	.892	707,836	.059	.071	.130	2
21	176,245	(2)	.196	.056	.132	.018	.097	.044	.073	.173	.016	.015	.046	.057	.013	.002	.938	179,928	.065	.034	.099	2
22	790,583	.135	.057	.052	.070	.110	.033	.033	.183	.187	.008	.011	.029	.012	.006	.002	.940	758,744	.113	[6].005	.118	2
23	1,182,971	.105	.064	.030	.069	.033	.026	.009	.070	.123	.005	.009	.015	.008	.005	.002	.572	1,282,680	.068	[6].001	.069	2
24	265,830	.308	.088	.072	.118	.135	.058	.067	.129	.333	.023	.019	.031	.026	.018	.004	1.429	370,652	.092	[6].008	.100	2
25	513,448	.237	.131	.038	.073	.099	.031	.054	.092	.164	.018	.010	.029	.022	.009	.013	1.020	565,092	.100	[6].008	.108	2
26	847,710	.164	.064	.046	.048	.063	.034	.073	.046	.055	.007	.007	.019	.008	.006	....	.644	878,092	.061	(6)	.061	2–3
27	639,535	.118	.062	.059	.030	.031	(8)	.061	.037	.045	.044	.011	.027	.012	.007	.093	.638	659,642	.049	.016	.065	2
28	327,065	.097	.120	.107	.061	.099	(8)	.054	(9)	(9)	.024	.010	.036	.029	.012	....	.649	355,977	.035	.028	.063	2
29	878,266	.307	.248	.079	.064	.107	.041	.078	.095	(10)	.020	.026	.039	.034	.013	....	1.150	871,966	.067	.034	.101	2
30	1,118,625	.069	.072	.055	.045	.010	.002	.106	.038	.039	.022	.009	.027	.003	.008	....	.551	1,121,400	.082	.079	.161	2–3
31	326,954	.266	.146	.068	.111	.026	.053	.034	.107	.122	.009	.011	.034	.044	.006	....	1.038	357,304	.090	.045	.135	2
32	544,309	.165	.197	.043	.115	.013	.026	.093	.143	.038	.026	.005	.031	.020	.014	....	.930	496,552	.143	.066	.209	2–3
33	377,000	.254	.056	.039	.052	.022	.034	.079	.048	.031	.022	.009	.024	.019	.010	....	.699	379,011	.061	.067	.128	2–3
34	594,000	.199	.127	.056	.122	.015	.049	.025	.069	.011	.014	.007	.025	.013	.009	....	.737	649,384	.058	.034	.092	2–3
35	717,410	.211	.111	.046	.046	.080	.029	.083	.126	.070	.003	.012	.013	.007	.003	....	.840	742,641	.068	.074	.142	2–3
36	768,755	.365	.239	.070	.098	.012	.040	.011	.158	.008	.015	.022	.033	.019	....	....	1.088	946,672	.099	.027	.126	2
37	656,469	.302	.138	.116	.083	.048	.065	.084	.054	.054	.015	.026	.039	.022	....	....	1.047	664,224	.099	.065	.164	2
38	1,671,125	.129	.075	.042	.048	.085	.021	.032	.184	.136	.003	.003	.004	.021	.006	.217	1.006	1,563,161	.135	.078	.213	3
39	532,354	.408	.082	.051	.046	.090	.018	.324	.148	.059	.052	.013	.019	.033	.008	....	1.351	643,535	.066	.078	.144	3
40	1,291,730	.165	.108	.016	.046	.049	.024	.126	.167	.050	.014	.007	.010	(10)	.007	....	.789	1,391,096	.084	.062	.146	3
41	1,103,013	.218	.141	.031	.157	.117	.060	.043	.073	.072	.026	.009	.016	(10)	....	....	.970	1,460,398	.110	(10)	.110	2
42	1,099,399	.110	.080	.044	.038	.082	.031	.060	.096	.028	.020	.007	.017	.016	.015	....	.642	1,299,506	.064	.044	.108	3
43	1,289,482	.133	.056	.028	.048	.057	.024	.030	.072	.084	.007	.007	.007	.011	.003	....	.567	1,541,340	.041	.011	.052	3
44	698,601	.144	.130	.113	.122	.092	.066	.022	.010	(11)	.040	.068	.012	(10)	.013	....	.833	867,526	.042	.005	.047	3
45	311,118	.442	.155	.075	.115	.194	.050	.012	.101	.303	.015	.025	.020	.022	.023	....	1.551	347,481	.037	.010	.047	2
46	641,488	.375	.138	.058	.104	.152	.043	.009	.068	.106	.021	(10)	.015	(10)	....	....	1.091	705,825	.046	.010	.056	2
47	628,386	.353	.160	.077	.076	.181	.063	.056	.046	.204	.036	.008	.030	.010	.007	....	1.309	663,509	.158	.048	.206	3
48	194,153	.148	.152	.063	.049	.014	.054	.038	.144	.046	.049	.013	.046	.063	.015	....	.896	261,120	.047	.055	.102	3
49	333,483	.138	.114	.109	.094	.106	.053	.075	.043	.036	.036	.010	.032	.021	.010	....	.879	338,278	.085	.045	.130	2
50	1,249,500	.059	.103	.039	.048	.039	.019	.097	.040	.114	.017	.004	.015	.021	.015	....	.632	1,245,308	.057	(6)	.057	2
51	390,729	.090	.092	.065	.074	.130	.055	.138	.028	.055	.006	.009	.030	.028	.002	....	.802	429,984	.048	.024	.072	2

[1] Repair gang distributed daily in other items.
[2] Purchase raw materials.
[3] Repair gang included in other departments.
[4] Purchase limestone.
[5] Man-hours for storeroom and superintendence not given.
[6] Bag cleaned by contract.
[7] Oil used for burning; man-hours for handling same insignificant.
[8] Oil used for burning.
[9] Always carried against departments.
[10] Man-hours not given.
[11] Repairs carried by each department.

TABLE 7.—*Statement of monthly costs for December, 1920.*

Element of cost.		Totals.		Per barrel cement.	
		Unit.	Amount.	This mo.	1920
Raw material:	No. 1.				0.11
	No. 2.				.15
	Gypsum.				.05
	Total				.31
Labor:	Operating.				.21
	Repair.				.05
	Total				.26
Supplies:	Operating.				.02
	Repair.				.10
	Total				.12
Fuel:	Drying raw material.				.06
	Burning clinker.				.47
	Total				.53
Power, light, and water.	Total				.15
	Direct cost of production:				1.37
Mill overhead:	Superintendence.				.01
	Mill office and stores.				.02
	Laboratory.				.01
	Miscellaneous.				.05
	Total				.09

TABLE 7.—*Statement of monthly costs for December, 1920*—Con

Element of cost.		Totals.		Per barrel cement.	
		Unit.	Amount.	This mo.	1920
Reserves:	Insurance.				0.01
	Taxes.				.01
	Depreciation.				.10
	Total				.12
	Total bin cost:				1.58
Trading:	Inventory First month.				
	Total Inventory end of month.				
	Cost of sales:				
Profit and loss:	Sack cost.				
	Packing and loading.				.08
	Sack handling.				.02
	Cost on board cars:				1.68
	Selling expenses.				.12
	General expenses.				.08
	Financial expenses.				.05
	Total costs:				1.93
	Net operating profit.				
Sales:	For month.				
Extraneous income.	Net profit brought down.				
Total net profit	Estimated.				

TABLE 8.—*Balance sheet.*

Assets.			
Cash in banks:			
First National			
Second National		$205.250 00	
Petty cash:			
General office			
Mill office		500 00	$205,750 00
Bills receivable			
Accounts receivable:			
Customers'			
Less reserves			
Advances			200,000 00
Investments			
Inventories:			
Cement		60,000 00	
Stores			
Gypsum		40,000 00	
Explosives		1,750 00	
Coal—kiln		12,500 00	
Coal—steam		4,000 00	118,250 00
Total current assets			524,000 00
Deferred assets:			
Shut-down expenses			
Work in process—			
Raw material		5,000 00	
Clinker		10,000 00	15,000 00
Stores			
Capital assets:			
Bags, cloth—new			
Deferred cost			
Bags, cloth—second-hand			
Bags, paper			180,000 00
Mill buildings		1,317,750 00	
Dwellings			
Less reserves			
Mill machinery		1,302,250 00	
Quarry equipment		175,000 00	2,795,000 00
Less reserves			
Land, Quarry No. 1			
Land, Quarry No. 2			
Less reserve			
Land, mill			125,000 00
			3,639,000 00

TABLE 9.—*Comparative costs per barrel.*

(Capacity of mill, 2,000 barrels per day.)

	1914	1915	1916	1917	1920 (10 months to Nov. 1).
Number of barrels cement manufactured	401,727	336,918¼	366,376¼	218,814¾	248,152¼
Materials:					
Raw material No. 1	0.05114	0.04670	0.05257	0.06566	0.10993
Raw material No. 2	.05328	.05313	.05482	.07167	.20582
Unground coal	.11034	.10955	.14389	.24098	.46754
Gypsum	.01440	.01647	.01770	.02366	.03966
Sweepings	.00140	.00218	.00172	.00319	....
Composition	....	.00046	.00028	....	....
Total	.23056	.22849	.27098	.40516	.82295
Labor:					
Operating	.06397	.05467	.06970	.09814	.20566
Repairs and maintenance	.01181	.01526	.01720	.03108	.04198
Total	.07578	.06993	.08690	.12922	.24764
Supplies:					
Operating	....	....	....	....	.01449
Repairs and maintenance	.04561	.03959	.04294	.05059	.09745
Tools	.00007	.00010	.00013	.00016	.00084
Oil and waste	.00351	.00327	.00353	.00462	.00772
Fuel	.00850	.01146	.01357	.02184	.06225
Total	.05769	.05442	.06017	.07721	.18275
Expenses:					
Power, light, and water	.07194	.07070	.09310	.14117	.26203
Laboratory	.00397	.00420	.00383	.00477	.00858
Shops	.00256	.00353	.00446	.00459	.00220
Teaming	.00053	.00081	.00089	.00134	.00149
Mill office	.01195	.01349	.01268	.02026	.01539
Boarding house	.00075	.00034	.00090	.00043	.00317
Welfare work	....	....	....	....	....
Total	.09170	.09307	.11586	.17256	.29286

TABLE 9.—*Comparative costs per barrel*—Continued.

	1914	1915	1916	1917	1920 (10 months to Nov. 1).
Provisions for—					
Depreciation and obsolescence	0.10000	0.10000	0.09999	0.10000	0.10000
Insurance	.00861	.00919	.01264	.01626	.00778
Taxes	.01356	.01479	.01314	.01485	.01002
Contingencies	.01270	.00714	.00891	....	.00364
Packing and loading	.03500	.03088	.03969	.04923	.08154
Sack handling	.00909	.00623	.00764	.01234	.01495
Total	.17896	.16823	.18201	.19268	.21793
Total mill cost	.63469	.61414	.71592	.97683	1.76413

NOTE.—None manufactured in 1918 and 1919.

TABLE 10.—*Comparative costs per barrel.*

(Capacity of mill, 3,900 barrels per day.)

	1914	1915	1916	1917	1918	1919	1920 (10 months to Nov. 1).
Number of barrels of cement manufactured	355,260	491,239¾	596,081	634,252	705,099½	847,709¾	646,931¾
Materials:							
Raw material No. 1	0.05300	0.05026	0.05756	0.07579	0.08053	0.08074	0.11441
Raw material No. 2	.03023	.04242	.05462	.03882	.05362	.06014	.09159
Unground coal	.10599	.10418	.13594	.21843	.24705	.20224	.38034
Gypsum	.01647	.01474	.01681	.02131	.02672	.03069	.04187
Sweepings	....	....	....	.00032	.00131	.00096	.00194
Total	.20569	.21160	.26493	.35467	.40923	.37477	.63015
Labor:							
Operating	.04467	.04170	.04456	.05990	.07352	.07675	.10885
Repairs and maintenance	.01686	.01568	.01577	.02110	.02066	.02341	.02864
Total	.06153	.05738	.06033	.08100	.09418	.10016	.13749
Supplies:							
Operating	....	....	....	....	....	....	.00996
Repairs and maintenance	.04752	.04553	.04298	.04532	.06005	.06186	.07290
Tools	.00008	.00013	.00048	.00036	.00030	.00028	.00023
Oils and waste	.00448	.00456	.00437	.00471	.00672	.00821	.00798
Fuel	.00767	.00780	.00865	.01388	.01399	.01389	.03588
Total	.05975	.05802	.05648	.06427	.08106	.08424	.12695
Expenses:							
Power, light, and water	.09533	.06623	.07390	.10696	.16358	.13091	.16242
Laboratory	.00354	.00313	.00312	.00322	.00585	.00899	.01094
Shops	.00290	.00225	.00301	.00345	.00642	.00380	.00315
Teaming	.00018	.00002	.00029	.00013	.00064	.00024	.00001
Mill office	.00913	.00990	.01020	.01494	.01959	.02037	.01987
Boarding house	.00052	.00022	.00093	.00072	....	....	....
Welfare work	....	....	....	....	....	....	.00429
Total	.11160	.08175	.09145	.12942	.19608	.16431	.20068
Provisions for—							
Depreciation and obsolescence	.10000	.10000	.10000	.10000	.10000	.10000	.10000
Insurance	.00681	.00652	.00945	.01357	.01693	.01419	.01230
Taxes	.01094	.01047	.00969	.01132	.01691	.01652	.01469
Contingencies	.01316	.01344	.00814	.01565	.01349	.01176	.00243
Packing and loading	.03500	.02731	.03157	.03821	.04274	.04952	.07664
Sack handling	.00901	.00455	.00587	.00425	.00957	.01239	.01376
Total	.17492	.16229	.16472	.18300	.19964	.20438	.21982
Total mill cost	.61349	.57104	.63791	.81236	.98019	.92786	1.31509

TABLE 11.—*Summary of mill cost and overhead.*

	1914	1915	1916	1917	1918	1919	1920 (10 months).
Barrels manufactured	756,987	828,158	962,457¼	853,066¾	705,099½	847,709¾	895,084
Barrels sold (including foreign)	839,584¼	852,099	964,286	933,423	706,837½	893,969½	906,655
Mill cost	0.62474	0.58857	0.66760	0.86627	0.98019	0.92786	1.43958
Overhead (including selling, administration, financial)	.18253	.17543	.19338	.20225	.22805	.29129	.20733
Total cost	.80727	.76400	.86098	1.06852	1.20824	1.21915	1.64691
Average selling price received	.05965	.75140	.96668	1.23709	1.36995	1.54509	1.75422

During the sellers' market of the past few years there have been many obstacles placed in the path of the manufacturing executive, and it remains to be seen what the developments will be in the buyers' market, which is now seemingly at its commencement.

In conclusion, the writer has endeavored to treat the subject from an impartial viewpoint. Using public moneys to develop industrial enterprises which of necessity will compete with private corporations is a hazardous venture. It should be undertaken only under the most extreme provocation and when conferences, investigations, and possibly regulatory measures have failed.

DISCUSSION OF MR. HILTS'S PAPER.

R. J. Windrow, State highway engineer, Texas: As a result of a resolution passed by the Texas Legislature, we have been investigating the proposition as to whether it will be advantageous for the State to own and operate a cement plant of its own. The facts which we have uncovered in our investigation thus far lead us to conclusions similar to those which have been drawn in the paper under discussion.

There were two fundamental principles that we had in mind at the outset of our investigation. The first was that the cement industry which we were considering entering is only incidental to the main business in which we are engaged. Our main business is the construction of highways and in that work we need some cement, a large amount or small amount as it may be. Keeping in mind, therefore, that the production of cement is essentially a side line, we have asked ourselves two questions—first, is our demand for cement large and constant enough to enable us to make a profit on this side line, as you might call it; second, is the present source of supply not reliable enough to enable us to proceed with our main business in an efficient way? The other main consideration that we had in mind was the fact, that we consider has been well established, that a Government-owned plant of any kind can not be operated as efficiently as a privately owned plant.

With these considerations in mind, we went to the cement companies and gave them the opportunity of presenting the facts from their standpoint. They threw open their plants and their records to us, and as a result, we have been able to get a little light on the subject. But the further we have gone into the investigation the more nearly have we come to the conclusion that it is a proposition we do not care to recommend to the State. Certainly, if we can depend upon the cement companies enlarging their plants sufficiently to take care of our future needs, we do not care to enter into the cement business. One of the principal deterring reasons is that we do not know whether a single State plant would improve matters. Our territory is so large that there is no doubt that we could use the entire output of a plant with a daily capacity of 2,000 barrels, but, of course, that plant would have to be located at one point. We could not compete with the five privately owned plants that are scattered throughout Texas, due to the freight rate and transportation problem. Therefore, the territory in which we could economically use cement from our State-owned plant would be restricted, and we would either have to take care of only part of our demand from the State-owned plant or would have to establish several plants in order to meet the competition. Therefore, instead of the investment being two or two and one-half million dollars, it would be several times that. We would be entering into a very large industry and we do not believe it advisable to develop a side line to that extent.

Difficulties Experienced by the States in the Matter of Rail Transportation.

S. E. BRADT, Superintendent of Highways, Illinois.

THE rail transportation difficulties encountered in Illinois have not differed materially from those encountered in the other States of the Mississippi Valley, and probably all of the States attempting to carry on a large program of highway construction are meeting with similar troubles.

Shortly after the signing of the armistice in November, 1918, the States were urged by the Department of Agriculture to proceed as fast as possible with the construction of roads with money made available from the Federal appropriation. This was urged because of the possibility of idle labor due to the slow absorption of the released army into ordinary pursuits and because of the releasing of the thousands of people employed in the war industries.

Illinois, acting in harmony with this suggestion, proceeded to make preparations, and awarded contracts for about 570 miles of hard-surfaced roads, costing some $32,000 per mile. It was hoped that at least 400 miles would be completed during the season of 1919. We were at the beginning of a new era of road building in Illinois; hence, many contractors were obliged to buy complete equipments, and all of them, at least, some additional equipment. The manufacturers, instead of being able to furnish them equipment within 30 days, as promised, required from 60 to 90 days to make delivery. This prevented an early start on the part of the contractors. As soon as the contractors were ready for the delivery of material, a shortage of open-top cars developed. This was followed by the shopmen's strike, which crippled the motive power of the railroads; and later in the season came the coal strike, in anticipation of which all open-top cars were taken from the building industries and sent to the coal mines. The result was that, instead of 400 miles being completed, we ended the season with 170 miles of finished roads and carried over to the 1920 season approximately 400 miles unfinished.

PROGRAM UPSET BY CAR SITUATION.

The bond-issue law called for construction at the rate of approximately 1,000 miles per year. Accordingly, we made tentative plans for putting that mileage under contract for 1920 construction. Because of the handicap placed upon the 1919 construction work through the inability of the railroads to furnish sufficient equipment for the transportation of material, we visited the officials of the Railroad Administration with a view to ascertaining the possibility of obtaining cars if we undertook a program involving the addition of 1,000 miles of roads. We explained to them that the building of 1,000 miles of roads meant the delivery of 1,000 cars of material a day. Figuring that each car would consume eight days in making the round trip, our requirements would be at least 8,000 cars continuously during the highway construction season. We were advised that in the spring of each year, from March 1 to July 1, there was ordinarily a supply of a quarter of a million or more of idle cars, and that if we could arrange to have a large portion of our material delivered before July they would be able to take care of our requirements.

In accordance with these suggestions from the Railroad Administration, we arranged with our contractors for the storage of materials. They began to call for cars in February and March, but instead of the required number of cars being available it developed that the year 1920 was unlike any of the preceding years and that there was no surplus of idle cars available. As a result, few contractors were able to get a supply of material stored in advance of construction.

As soon as we asked for bids on new construction it also developed that, owing to the uncertainty of transportation, the increased price of labor and material, and the uncertainty of the general situation, our bids, instead of averaging $32,000, as in 1919, averaged $44,000 per mile. With all these things facing the department, it was decided to reject bids and to award contracts for only about 50 miles instead of the amount originally planned, putting all of our effort into the completion of the 450 miles. To this end Gov. Lowden called a conference of the producers of materials and the railroad presidents, all of whom pledged the fullest possible measure of cooperation in carrying out the plans of the department, and it is but fair to say that in our opinion this pledge was fulfilled to the best of their ability.

The contractors who were working in 1919 closed the season with approximately 100 paving machines on the ground, ready to start the 1920 construction work as soon as materials were available and weather conditions suitable. At no time during the entire season, however, were there more than 53 of the 100 machines in operation, and the average for the season was much less than 53. This situation was due almost entirely to insufficient transportation facilities.

ORDERS CAUSE DIFFICULTIES.

The first interference with our work came in the shape of a switchmen's strike, which caused a congestion of freight cars in practically all of the centers of population in our vicinity and prevented their movement for a number of weeks. However, the most serious difficulty experienced has been the various orders issued from Washington by the car-service commission and the Interstate Commerce Commission. Early in June the car-service commission issued an order requiring that coal mines should be given 50 per cent of their rated car requirements and that plants producing other commodities requiring open-top equipment should be restricted to the use of the remainder of the cars, whatever that might be, but not exceeding, to any one plant, more than enough cars to transport 50 per cent of its output. This immediately reduced the shipments of road materials. This order was followed on June 21 by another order, issued by the Interstate Commerce Commission, providing that open-top cars could be used for hauling material other than coal only when returning to the mines. This order was to be in force only 30 days, but was renewed at the end of each 30-day period and remained in force throughout the construction season. Perhaps 50 per cent of our contractors were doing work in localities that permitted all of the material for their work to be handled in accordance with this order without interruption. The other 50 per cent, however, were getting material in localities requiring a "back haul," which was in violation of the ruling. Within a short time after the order went into effect material coming to them was stopped. We appealed to the Interstate Commerce Commission and a hearing was called early in July. The result of this hearing was the issuing of special permits, but only after a delay of several weeks. These permits were granted only for the hauling of material for the completion of old contracts where work was being done on sections of important roads. Our work was all being carried on upon the main highways of the State; accordingly, by the middle of August we had secured permits for most of those contractors requiring a "back haul" for their material. These permits were generally put into effect by the railroads, but occasionally some road would get an order from Washington to deliver a certain number of cars to some special plant for a specific coal loading, which, of course, interfered with work in that vicinity.

In September an order was issued from Washington suspending all permits for a period of 10 days. This again suspended the movement of material for road work. At the expiration of the 10-day period road work was resumed, but early in October another order came from the Interstate Commerce Commission canceling all permits and requiring that additional evidence be submitted before those permits would be renewed. We succeeded in securing the renewal of not more than five of the old permits. Because of this interference, mainly through the two commissions mentioned, we have been able to complete only a little more than 300 of the 450 miles. In order to do this, much of the time of the officials of the department, as well as all of the time of experts employed for that purpose, has been given to the securing of car equipment and connecting it up with the producers of road materials so as to keep contractors supplied with as large an amount of material as possible.

TRANSPORTATION LIMITING FACTOR.

During the seasons of 1919 and 1920 we have built 500 miles of high-class hard-surfaced roads. The same effort put forth under ordinary conditions and without the hindrances herein enumerated would easily have completed 1,000 miles of the same class of roads, which would have proved reasonably satisfactory to our people.

As a result of this situation, it will be seen that the people of Illinois have suffered great inconvenience because of the inability of the contractors to finish their work promptly, and that the contractors have been subject to excessive losses because of insufficient transportation facilities.

It will also be seen that the producers of material, through their failure to secure cars for a normal output, will be subject to losses, due to the fact that the overhead expenses remain practically the same under a reduced output as under a normal output.

All of these losses will in a large measure come back to the people in the added cost of construction of future work.

We can not remedy the past; our problem lies in the future.

We have the contractors.

The contractors have the equipment.

Labor has been in fairly good supply this year and the indications are that it will be more plentiful next year.

The money is available.

Materials are in ample supply at their source.

As nearly as we can judge, the one principal limiting factor in 1921 will be transportation. In so far as the railroads are able to solve this problem of transportation by the purchase of added railroad equipment, by the repair of present equipment, by increasing the number of car-miles per day so as to carry on our work without governmental interference, just so far the improvement of the highways of Illinois and other States in the Mississippi Valley will be carried on in an increasing portion. This is the important problem.

DISCUSSION OF MR. BRADT'S PAPER.

M. W. WATSON, State Highway Engineer, Kansas.

The highway programs of Kansas and her neighboring States suffered far more by the inefficiency of rail transportation during the past season than from all other causes combined. Of course, we had some other troubles, such as inefficiency of labor, shortage of cement, and bad weather, but these troubles were Lilliputian in comparison with those arising out of the rail situation. Although labor was inefficient, there seemed to be plenty of help available. What we lacked in quality we could make up in quantity or the substitution of machinery. The cement shortage seemed to be traceable to the unsatisfactory rail situation. The hesitancy of cement companies to contract for definite deliveries was due to uncertainty. While we had more wet weather than during ordinary seasons, there were many ideal days for road building that were lost on account of the nonarrival of materials.

During 1919 and 1920 we placed under contract in Kansas approximately 358 miles of Federal-aid road work, 77 miles of earth roadway and culverts preliminary to surfacing, 69 miles of gravel, 30 miles of macadam, 126 miles of concrete, and 55 miles of brick. Of this amount we had completed on November 9 approximately 13 miles of earth, 24 of gravel, 5 of macadam, 31 of concrete, and 23 of brick. Under normal conditions practically the entire mileage should have been completed at the close of the construction season.

LOCAL CONDITIONS KANSAS FACTOR.

The situation in our State is aggravated by the location of our hard-stone supply so close to our coal-mining territory. There is a decided lack of a well-distributed supply of stone having sufficient hardness to be used in the construction of concrete roads. Our main deposit of material of a satisfactory character is the flint spalls and chats from the zinc and lead mines of the Joplin district in southeastern Kansas, southwestern Missouri, and northeastern Oklahoma. This deposit not only supplies a large part of Kansas but also southwest Missouri, a considerable part of Oklahoma, and a portion of Arkansas. The coal fields which supply a large part of Kansas, Missouri, and Oklahoma are also located in southeastern Kansas and southwestern Missouri, only a few miles distant from the flint regions. The utilization of empty coal cars for the transportation of the flint is impossible, because the road projects are located in the same direction from the coal mines as the markets for coal.

The bulk of our sand comes from the Kansas and Arkansas rivers and in only a few instances are the plants so located as to utilize returning empties from coal shipments.

The producers of materials demanding open-top equipment for their shipments are now discovering that they have overlooked a valuable piece of propaganda which has been of decided service to the coal interests during the past construction season. The general public has been trained to term all cars of the open-top variety as coal cars until even the Interstate Commerce Commission seems to think that there is only one use to which such cars can be put. This fact, together with the apparently well-organized lobby of the coal interests, has been the means of securing embargoes and priority rulings until we become dizzy if we attempt to trace these orders around the circle they have been following. Congress would render a great service to industry in general and especially to the construction activities if it would legislate out of use in the commercial world the three words that have spelled a large part of our grief, "embargo, priority, and permit." It is true that in the end we were obliged to resort to the permit system for the highway shipments, but only to counteract the methods other interests were employing and after all other measures had failed. Such practices during war time may be necessary but after the close of hostilities they should be placed in the discard. They can lead only to one end, that is, preferential treatment for the industry with the best organized lobby.

COMMISSIONER CLARK'S SUGGESTION.

Chairman Clark, of the Interstate Commerce Commission, has recommended to the Senate Interstate Commerce Committee that a differential freight rate be granted so as to distribute the coal shipments throughout the year. The following is a quotation of his statement, in part, taken from Railway Age, March 26, 1920:

Such legislation would obviate very largely the pressing necessity for more coal cars. The present supply of coal cars, while totally insufficient to handle the fall and winter rush under existing conditions, would be fairly adequate to carry all the coal desired by consumers if this equipment could be kept moving with greater regularity throughout the year, as would be the case if the advantage of lower summer and spring freight rates could be held out to induce consumers to receive coal shipments in advance of their winter needs. Under the present system thousands of coal cars lie idle during the spring and summer, while the whole available supply of coal cars is entirely insufficient to handle the fall and winter emergency.

The acquisition of more coal cars does not afford a practicable and complete remedy for existing difficulties. Under the transportation act, recently approved, the Interstate Commerce Commission is given the power to require carriers to provide themselves with sufficient cars. But most of the railroads have neither the money nor the credit with which to buy a supply of coal cars adequate for current needs under the present system of large seasonal shipments, so it would be useless for the commission to order them to purchase this equipment. On the other hand, most of the railroads which have enough money or credit to finance such purchases already possess an adequate number of coal cars to care for the needs of their own patrons, and they could not reasonably be required by the commission to purchase additional cars to take care of the traffic of other lines.

Apparently Chairman Clark does not realize that there are other industries which need cars as well as the coal industry. The concentration of coal shipments has been the solution of our problem in the past. Coal shipments have been greatest when the needs for fuel were greatest; that is, during the winter months. These cars were then available for building materials during the summer months, which is the only time when building operations can be carried on satisfactorily. The clever coal propaganda has done nothing more than secure the increase of price desired by the operators. Part of the time this season when the open-top cars were withheld from stone shipments our mines were idle. It would seem the policy of the Interstate Commerce Commission to reduce the scope of the Nation's activities to the size of our present rail transportation rather than to utilize what we now have to develop our other avenues of transportation.

The other classes of equipment were also scarce, at least for our use. The grain producers of Kansas were unable to secure relief. Grain was piled high in the open in many places throughout the States while the elevators were filled to capacity. When orders were given to ship empties to the West for the relief of this situation we observed that the empty cars were allowed to stand idle in the yards for many days, while our most urgent appeals were of no avail to secure them for loading westward, even though they were to pass empty through points where the materials were needed. Refrigerator and cattle cars hold the same status as box cars in our shipping arrangement. They go eastward through the State when loaded, and empty westward. Long trains of empties passed by the cement and brick plants, but were not available for use.

DELAYS IN MOVING CARS.

Through the cooperation of the State industrial court and our local engineers it was found that empty cars would stand in the railroad yards throughout the State for days and even weeks at a time. In some instances they were moved from one end of the yards to the other and then in a few days returned. When the railroad officials discovered that our men were checking their yards they ordered them to stay out and threatened arrest for trespassing. Why?

The most curious part of the entire procedure is the speed with which conditions changed when the higher rate went into effect and the Government guaranty was removed. It seems a general theory of public utilities operation that when a higher rate is requested the service becomes almost unbearable until the public is willing to try anything for relief. Gas service becomes decidedly improved after the rate is increased, and central will give you the number requested at least a part of the time after the telephone rate is advanced. Records show that the larger railroad lines operating in Kansas and in fact in other States as well are not utilizing their present equipment to its fullest capacity. One of our roads gets from 54 to 86 car-miles per car day out of its freight cars, while another gets from 17 to 22 or not quite as far in a day as the average team will travel.

The investigations of our industrial court brought out that many unaccountable delays occurred at terminals. They followed closely 412 open-top cars used in coal shipment from the mines to destination and return. Of these cars 171 were loaded with company coal. The average number of days consumed in the assembling yards was 4.25. Company coal required an average of 4.29 days to travel to destination; commercial coal, 3.54 days. The total car-days consumed at destination in unloading and delivery to connecting lines amounted to 1,773 for company coal and 760 for commercial coal. The average travel per car-day for company coal was 6.3 miles and for commercial coal 13.4 miles. Of 273 cars unloaded, 4 required 30 days, 11 required 29 days, 4 required 28 days, 9 required 27 days, 10 required 26 days, and 18 required from 13 to 25 days; and the surprising part of the statistics is that the railroad companies seemed to be the ones who were longest in unloading their cars. This does not look as though the grave warnings issued to shippers by the Interstate Commerce Commission were placed in properly addressed envelopes.

Let us hope that conditions will continue to improve, but in the meantime the highway industry, which is the coming industry of the day, should awaken to the necessity of securing adequate recognition from the powers governing the railroad situation and a better understanding with the carriers themselves. Some of our railroads have assumed the policy of fighting highway improvement and seem to look upon the highway, with its improved transportation facilities, as a serious competitor. We know that this country is developing more rapidly than all the methods of transportation, so that the highway program should be aided by the railroads rather than hindered.

If the construction of highways could be worked out so that they would build themselves by allowing the hauling of materials over the newly constructed roads as we go we might be independent of the railroads. But it is not possible in highway work to regulate the places where we are to start as well as might be were it a private enterprise, and in most States we must depend on rail transportation for the success of our highway program.

COMMISSIONER COLEMAN'S VIEWS.

George P. Coleman, State highway commissioner, Virginia: I am sure we have all passed through much the same experiences in our transportation difficulties. A year ago we were told that there would be available 250,000 to 300,000 open-top cars for road-material transportation during the spring months and that it would be advisable for the State highway departments to store all the material possible during those months. I presume that many of the State departments prepared to follow that advice; at any rate, we did make such preparations in Virginia. Then we started looking for cars. We found the cars right in the State of Virginia, but the trouble was to get them loaded and moved. There were thousands of cars standing idle, not for days only but for weeks in some instances, as our records show. Yet in spite of this fact we could not get them. Whose fault it was or why I am not prepared to say. Following that the Interstate Commerce Commission rained down on us priority order after priority order. We came up to Washington seeking relief, but we were practically told by the Interstate Commerce Commission that highway construction was a nonessential. Perhaps it was not put quite so bluntly as that, but at any rate I received the impression that it was considered that highway construction could be held up for an indefinite period. The reason assigned was that New England needed coal. We were glad to let New England have it. Again we were told that the Northwest needed coal. We were glad to let the Northwest have it, because ours is a coal State and we derive our revenues largely from coal. Yet in the face of all this preference given to coal, the result has been very curious so far as Virginia is concerned. We have received and shipped more coal than ever before in the history of the State, and yet to-day there are sections of Virginia that are facing a coal famine.

That leads me to the point which I should like to make, which is that the railroads are unequal to the task imposed upon them, and that highways are needed to assist them in improving transportation conditions; and we should do our utmost to convince the Interstate Commerce Commission of that fact.

I would change the wording of the subject under discussion and make it, "Transportation difficulties and how we are to overcome them, using our experience of the past year in aiding us to a solution." The past is behind us, and we should now bend our efforts toward the improvement of conditions in the future. It seems to me that the principal lesson to be learned from our past experiences is that we must impress upon the Interstate Commerce Commission the importance of the work which we as highway engineers are doing in this country. We must make it clear to the commission that highway transportation is as essential, in many instances more essential, than rail or water transportation, and that we can give valuable assistance in the efforts which are being made to unravel the transportation tangle.

What the Highway Departments May Expect In Service in 1921 from the Railroads.

A. G. GUTHEIM, Car Service Section, American Railway Association.

THERE is no use trying to plead a clean bill of health for the railroads during the past four years. I have talked before a number of different associations throughout the country on somewhat this same subject—the open-top car situation—and I always get down to the same proposition. You can not handle the bituminous coal business of the United States in production peaks of 13,000,000 tons a week and production valleys of 7,000,000 tons a week and reach a total annual production sufficient to meet the country's requirements and still conduct transportation in anything like an ordinary and normal manner.

What we have done in the past two years and to a lesser extent in the preceding two years on coal production—and I speak now of bituminous coal production—is this: We have tried to get for this country all the coal it needs, utilizing a deficient railroad plant that has not grown to speak of for four years, and we have found ourselves compelled to attempt the job with a production some weeks of 13,000,000 tons, and other weeks pretty close to 7,000,000 tons. And it simply can not be done without disturbing other business.

A year ago I was asked to discuss the transportation outlook for 1920 before several associations concerned in road building. I gave it as my opinion that the railroads should do a pretty good job. The roads went back to their owners on March 1. Progress in March was good and we hoped we would do well thereafter, but the switchmen's strike started on the 7th of April. There were probably never more than 25,000 or 30,000 men out on the switchmen's strike out of perhaps 2,000,000 railroad employees, but they went out at psychological points—at Chicago the first day, Toledo the next, St. Louis the third day, Harrisburg the fourth day, New York the next week. I don't know if the points were picked. I don't claim that they were, but the facts are that the points at which trouble occurred were such that, usually, particular harm was done to coal production.

Now, your road-material problem is tied up inevitably and always with the coal problem. You can not get away from it. You must use the open-top cars. There has been no great increase in the ownership of open-top cars in this country for the past four years. The Railroad Administration in its entire career purchased about 100,000 cars, of which 50,000 were open-top cars. That was nowhere near enough to take up the usual retirements. When the roads went back to their owners, March 1, they had just about as many open-top cars as when the Government took them over January 1, 1918. They had a relatively greater bad-order condition. As the new cars purchased during Federal control were way down, and there was no great increase in ownership during Federal control, it follows that the retirements during that control were nowhere near what they ought to have been. Therefore the roads were returned to their owners with a condition of equipment that was worse by far than it should have been.

COAL PREFERENCE ORDER NECESSARY.

But despite all this, if we had faced a bituminous production of about 10,500,000 tons a week we could, without doubt, have handled the job and supplied the country according to its requirements from week to week, permitted replenishment of stocks, and successfully met the aggregate requirements for the year without unduly affecting other industry. But that problem, for reasons beyond our control, didn't come to us in just that fashion. We did get up to 11,000,000 tons of bituminous production in March, and then in the middle of April we got down below 8,000,000, and there we stayed a while. Finally the situation was presented to the Interstate Commerce Commission with the advice that as long as we were in the troubles we were then facing it would be impossible to take care of the country's coal requirements unless some preference in transportation were given to coal. The railroads made that recommendation. I personally framed the figures on which it was based, and I am perfectly willing to accept my share of the responsibility.

The Interstate Commerce Commission evidently agreed with us, and they put in their Service Order No. 7, which merely made more stringent our so-called 50 per cent rule. On the strength of that preference by service order of the Interstate Commerce Commission we have obtained a 1920 bituminous production that up to date is in the neighborhood of 525,000,000 tons. When we were before the Interstate Commerce Commission with respect to Service Order No. 7 in early July and the question was asked, "What coal is needed in this country for the current year?" the answer was, "About 535,000,000 to 545,000,000 tons." We will get just about that figure, and mark you, it is only in the last week that any considerable number of mines have reported to the Geological Survey that they have lost working time for want of market, and it was yesterday that I heard for the first time that coal was standing under load on wheels not billed for want of orders. To my mind, that demonstrates conclusively that our judgment as to the coal needed was right.

CONDITIONS WHICH GOVERNED.

Now, that brings us down to this question of "nonessential" work. I have lived in this war period pretty close to "nonessentials." I have heard them dubbed "nonessentials" and then "nonwar"—probably it sounded better. I am willing to admit that road-building work is essential, but I should like to ask you whether you would want road-building work to go on unlimited at the expense of leaving thousands of communities without coal?

Reference has been made to the fact that conditions changed when the rates changed. They did, but the switchman's strike changed about the same time. You may remember that the Railroad Labor Board gave its decision on the wage increase just about a week or two weeks before the Interstate Commerce Commission gave its decision on the rate advance. The decision on the wage increase settled the labor situation, and that is where we began to get some light toward better operation. The decision of the Interstate Commerce Commission followed, and it wasn't that, but the better railroad operation resulting from the stabilizing effect of the wage decision, that gave us better service about the time the increase in freight rates took effect.

With respect now to this spring and early summer surplus of cars which failed to materialize: You can go back to the years previous to 1916 and you will find that every year the surplus of open-top cars was considerable; in fact, there have been cases in past years where roads that were large owners of open-top equipment had to go to the expense of building temporary side tracks on which to store the cars that were routed back to their owners by other lines that did not want to hold them and pay the per diem rental for them. That situation has not obtained since 1915, except in 1919, when the country was living off of the bituminous stocks, which amounted to 63,000,000 tons on Armistice day, and we lived off these stocks to an extent which, coupled with the coal strike, resulted in what you have gone through the past year. If we can obtain bituminous production at anything like a uniform weekly rate, there isn't the slightest doubt that there will be a regular and good volume of open-top car service for road materials. There will not be in the future relatively the same excess of car service over and above coal requirements that there has been in the past unless the railroads again become overequipped to the extent that they were then, and I don't believe that is likely to happen.

THE CAR SITUATION TO-DAY.

Mr. Willard asked me to discuss the car situation as it is at the present time. We are now approaching a stage where we have the coal situation well cared for. With reasonable winter weather and freedom from labor troubles in the mines we ought to get along without any distress this winter. We don't know just how well the stocks are distributed, so we can't tell individual needs. We do know that low-priced purchasers—the railroads and public utilities particularly—have had trouble. The rates they may charge for their service are fixed and regulated and they are not free to pay any price necessary to obtain coal. On this point let me say that I think there is a lack of appreciation among you gentlemen—it was apparent in one of the papers—of the function of the Interstate Commerce Commission in controlling these emergencies. The commission can force transportation for the benefit of some particular commodity to increase production of it, but it has no control, except very indirectly, over the distribution of that commodity to the consumer, and there is no reason why it should have. The Interstate Commerce Commission has no power, except very indirectly, to compel the distribution of coal to a particular consignee. It did it in a degree this past year in the service orders protecting public utilities, the Lake territory, and New England, but all the time that was going on there was uneasiness about the legality of it. It was strong-arm procedure, and a good deal was done to hold off people who were coming to Washington with their lawyers to attack those orders. It was borne in mind that there was a job that had to be finished before winter, and we were going to get away with it if possible.

As to the attitude of the railroads toward highway work, I think there is no one man who can speak for all the railroads. I understand that in the work of your organization you have had the benefit of the association of Mr. M. S. Connors, of the Hocking Valley.

as a railroad representative. He is a man of large experience in this work. He is a man who knows the coal-car game from a to z, knows the particular coal problems as a result of which you have suffered, and he is a good man to keep in touch with on the general problem.

The individual traffic-man—and the attitude of the railroads toward highway work would be a traffic rather than a transportation or operating matter—I think the average traffic man will fall into one of two classes: First, the one that figures everything should be done to help along highway work, because there must be in the course of years a development of transportation of short-haul commodities over the highways, leaving the railroads to handle the longer haul and heavier freight, and again to relieve the railroads of a lot of intracity haul, which has been much tabooed the last two years through embargoes; second, the class who would feel that you ought to make short-haul rates to beat motor-truck competition just as years ago they made rates to beat wagon competition. Without attempting to speak for the traffic men I can give my personal views. I think the man in the last class is bound sooner or later to fall because he is butting his head against something that is bound to come, and he might as well recognize that now.

GET MATERIALS ON GROUND EARLY.

As to what the highway association can do to secure better transportation by the railroads, I have some hesitancy in advising you. There has been a good deal of fun made about the advice given during the last couple of years. I don't know what better advice we could have given you or where you could have gone to get better advice. Certainly no one in the railroad would have anticipated a switchmen's strike that would upset affairs as the strike did this past summer. But we don't know now what faces us in 1921, or, indeed, in the next few weeks. I have read some articles on the railroad labor situation recently, and if I wanted to permit myself to do so, I could easily get exceedingly pessimistic, but I choose not to. I think that the thing for you gentlemen to do is to go ahead and figure that you are going to get more and better transportation by far next year than you have had the past two years, but keep in mind that the labor problems are bothering the railroads still, and something may break. Everything you can do in the way of getting materials when transportation is to be had and storing them is what you should do. It costs more, perhaps, but I don't think it costs more than finally throwing up the job when it is half or two-thirds done, perhaps, and going into bankruptcy.

Assuming that we have reasonably normal conditions, assuming that the advances in efficiency the railroads have made this past summer continue, you ought to be able to go right ahead with your work. You may have trouble in places, you will have sections where the requirements for coal will be greater than elsewhere, and where there is a tendency on the part of the individual railroads to lean a bit toward coal where by doing so they can stave off nation-wide agitation like that we have gone through the last year. As to that the Interstate Commerce Commission will be the judge of what must be done. What that commission may have in mind for next year I do not know. But I do know that the representative of the Northwestern States, who lived in Washington for two months this past summer in an endeavor to obtain coal protection for his section, came to me three weeks ago and said he had just seen Commissioner Clark, who said to him, "You tell your people back home to go out and buy coal and then see that it is shipped to them, because we don't intend to go through this next year taking care of what would take care of itself if you had bought your coal." That, I think, goes to the bottom of the coal situation. In the last analysis it usually gets down to price. And Commissioner Aitchison has stated that under the provisions of section 1 of the interstate commerce act price does not make an emergency.

One thing further that you might keep in mind with respect to the situation next year is this. Everything that was done in Washington that helped coal and that injured you didn't come out of a clear sky in Washington. You represent officially the different States of this country. I venture to say there isn't a State east of the Rocky Mountains and north of an Oklahoma-Arkansas line and the Ohio River but has sent its representatives to Washington or has sent urgent communicates pleading for the very preference for coal transportation which you gentlemen were arguing against. That rather indicates to me that a good policy for you to pursue in the future is to line up affairs within your own States. I have seen instances where we had in Washington the highway people and the representatives of the governor of the same State, each claiming the situation at home justified their individual claims. If the coal situation in your various States is not, in your opinion, as serious as it is represented to be in Washington, then it is for you to get together on the matter with the folks at home.

The Relative Service Value of Different Types of Rural Pavements.

A. R. HIRST, State Highway Engineer of Wisconsin.

THE term "relative service value" is open to various interpretations. It might be held to cover only the potential power of a pavement to bear traffic of various amounts regardless of cost or economics, or it might be held to include the two latter factors. The author prefers to include the latter.

Among the characteristics usually listed as important in determining the service value of pavements are the following:

Freedom from dust.
Appearance.
Character of foothold.
Ability to clean.
Freedom from sanitary objection.
Character as regards noise.
Freedom from slipperiness.
Low tractive resistance.

Almost without exception, the characteristics cited above are among the least important of the matters to be considered in determining the service of rural pavements. Some, or all of these factors, are worthy of consideration in specific cases, but it has been our experience that one or all of them combined has had no important bearing upon 10 per cent of the decisions reached in actual practice. They have a much larger value in city and village pavements than in rural highway construction.

The predominant factor in determining the relative service value of pavements is whether or not they serve the traffic effectively and cheaply. It may be stated as a truism that given effective construction and proper width almost any one of a dozen different pavements will give good service. The question to be determined by the highway engineer is whether they have or will give good service cheaply.

TRAFFIC THE FIRST FACTOR.

Highway traffic is, of course, the first factor to be seriously considered in connection with pavement economics. Traffic is the thing which makes highway surfacings worth while and the thing which wears them out. Its amount and its characteristics are important and should always be taken into account.

We are going to shock a good many of our more theoretical brethren by saying that a preliminary traffic census is absolutely valueless in helping to determine the type of surfacing to be used. An inspection of the location of a road on the map, a knowledge of its relation to other roads and to the general highway system, and to business centers, together with a consideration of the business tributary to it and probably to be tributary to it, will tell a highway engineer who knows his business whether the construction in question should be first, second, or third class. The traffic on a road last year or last month has absolutely no value in this connection, because when a highway becomes a part of a superior highway system or when one highway is paved with a surface superior to that on the adjacent and competing highways, traffic is so concentrated on that highway that what has been is no indication of what will be. Neither can anyone foresee from the fact that 100 automobiles a day passed over a highway on the 19th of June last how many vehicles will pass over it on the 19th of June, 1932.

Any assumption of what traffic will be is merely an assumption, and the presence on a certain past day of 100 automobiles, 10 trucks, 8 farmers or their wives in single buggies, and 3 babies in their perambulators has really no bearing on the future situation.

Traffic counts have value only as serving to give accurate information as to the constantly occurring changes in traffic conditions and in determining the relative cost of service per unit given by various pavements. The unit cost per ton of carrying traffic is the important consideration and, unfortunately, we have little or no information on this point.

The fact that this type of pavement was maintained for so much per annum and this type for so much per annum means little, unless we know the amount and weight of the traffic served and that it was served adequately.

Even then the information would not be conclusive, because the pavement which gave this unit cost under the prevailing soil and climatic conditions might give an entirely different unit cost under different soil and climatic conditions. A light, sandy gravel on a clay soil will give excellent service value if the rainfall is heavy and well distributed, while it would be totally unsatisfactory under the same traffic in an arid region or in one subjected to only seasonal rains. Similar instances could be cited ad infinitum.

We have been too prone to assume from the results of experience with a limited number of stretches of a certain type of pavement, built and maintained under certain conditions, that the same results will ensue from the use of the same pavement wherever it may be built. This is not the case. Climatic, soil, and rainfall conditions must be considered as well as traffic and general performance.

WEIGHT OF TRAFFIC.

Among the important circumstances affecting the service of pavements is the weight of the traffic which the pavement bears.

American highway engineers have been condemned by the unthinking for having built roads which have not stood up under the intense motor truck traffic of recent years. It would be just as sensible to condemn a railroad engineering department for the failure of railroad bridges under engines weighing 200 tons when the bridges were designed for engines weighing 20 tons. Before new and heavier loads are allowed on any length of railroad, all parts of the construction are examined and, if necessary, strengthened or rebuilt before the new traffic is allowed to pass over them. There has been nothing of this in highway practice. Loads almost without limit have been placed upon highways designed for conditions existing and anticipated a decade ago, and condemnation has resulted when the inevitable failure of the road structure ensued.

It would seem that it would be clear to even the feeblest minded that it is not going to be possible for the designers of vehicles using highways to turn loose upon highways any behemoth their ingenuity may design at any time they feel like doing so. It isn't possible to reconstruct the highway system of America every few months, or even every few years.

It is imperative that the several States adopt uniform standards for the loads to be borne by roads of the different classes of importance. It is going to be difficult to do this, because when a motor vehicle is once started toward its destination its operator will wish it to carry its full load for the whole trip, but it seems inevitable that we must classify highways as to the allowable loads upon them and that traffic on highways must be made to conform to these loads.

It is undoubtedly going to be possible ultimately for the States to finance the construction of roads between their congested centers and on certain through highways, which will carry, every day in the year, loads of 12 or 15 tons or, if the economics of transportation really justify it, even more. But it is just as certainly going to be impossible for the States to finance the construction of any great percentage of their roads so that they will stand such loads every day in the year, and I believe that on the secondary roads and roads of the lower classes much lower load limits must be insisted upon, especially at certain seasons.

The importance of this matter upon the design of pavements and upon the service of the several types can not be overestimated.

CONTINUOUS SERVICEABILITY.

One of the intangible factors in the service value of types of pavement is the factor of continuous serviceability. It goes without saying that given two pavements of equal annual cost, and given one which is out of service for several days each year and probably for two or three months at several times during the assumed pavement life, while the other one allows the passage of traffic during its life with practically no inconvenience and no detouring, the choice would immediately fall upon the one which gives the superior serviceability. Furthermore, if the maintenance of one type demands, annually or semiannually or periodically, the application of materials that prevent the accommodation of traffic during their application or, if they do not completely bar it, that subjects the traffic to possibility of accident from slipperiness and to defacement of vehicles and clothes, then that type is seriously impaired in service value.

I hope I may be permitted to say at this point that one of the strikingly characteristic things about American highway practice has been the almost total disregard for the comfort, convenience, and economy of the traveling public during construction, maintenance, and reconstruction. A "public-be-damned" policy has been quite generally practiced. The traveling public has been considered as an interloper, with no possible business save to pay the bills. The traveler has been estopped from passing through main roads without any option of détours being offered him. He has been not stopped by barriers and has been encouraged to go upon construction and maintenance work which has impaired and defaced his tires, his car, or other vehicle, and his clothes to the extent of hundreds of thousands and, possibly, millions of dollars. Even where detoured he has been only in very few cases properly guided along the whole length of the detour, and even where the detour has been marked, almost without exception it has not been maintained. At best, given a closed road, a well-marked and well-maintained detour (a combination which has been exceedingly rare in American highway practice) the economic loss to the traveling public has been tremendous.

For example: A road carrying a traffic of a thousand vehicles a day is closed for a length of 5 miles, due to construction or reconstruction, for a period of four months, the detour being 8 miles in length, an increase in distance of 3 miles. One hundred and twenty days by 1,000 vehicles by 3 miles gives a total traffic loss of 360,000 miles, which at 12 cents a mile is $43,200, which figure may well have a material bearing upon the type of pavement which one should select. Similarly derived figures will illustrate the importance of speed in construction and reconstruction and demonstrate that it is usually worth paying for.

RELATIVE COST OF SERVICE.

We have been too prone to select types of pavement on the "say so" of others without very careful consideration of the matter of cost. The minute we commence to discuss the relative cost of pavements we are thrown into the field of economic discussion, or rather the ocean of economic discussion, at a point far beyond our depths.

We are immediately brought into contact with the question, "Should an engineer in weighing the merits of two or more types of pavement consider the factor of interest on the original investment?" Many good authorities say "Yes"; many good authorities say "No." I do not pretend to be good authority, but I am sure that the answer is "Yes." The assumption that public money when once spent is gone, and that the public should demand no return upon its investment, sounds to me like the merest bunk. The statement that the value of the pavement in increased comfort, convenience, saving in hauling, saving in gasoline, tires, etc., far offsets the interest on the investment sounds very nice; but what is one going to do about it when one is considering two types of pavement, both of which do all of these things but the costs of which are very dissimilar?

In addition to this little difficulty with the basic economics of the situation, we have the further trouble that in comparing the unit annual cost of various pavements we must make assumptions as to the lives of pavements, and we have little or no information on which to base these assumptions.

It might be of some value to cite the factors entering into an economic comparison and to show just how far one can get in his figuring:

(1) First cost of the pavement: This is readily determinable within the limits of estimating and causes no trouble.

(2) Interest charge on the pavement investment: This charge should be compounded annually and is, of course, readily determinable.

(3) Annual cost of maintenance of the pavement: By maintenance we mean the keeping of the same kind of surface with which we started out; that is, the patching, repairs, and maintenance necessary to preserve it without reconstruction. The cost of this work can only be guessed because no one can predict with more than a moderate degree of assurance what the cost of the material and labor entering into these repairs will be next year or in succeeding years. Furthermore, no one can guess what unexpected development of traffic may entirely upset the conditions under which the surface exists. Therefore, any estimate of the cost of maintenance per year, or for each year, is a guess.

(4) Interest on the maintenance cost: This interest should be added to the cost of the pavement and should be compounded annually.

(5) Life of the pavement before total reconstruction is necessary: Again we are in the field of theory, because the life of the pavement depends upon the traffic which it will carry through a series of years, which we can only guess at. Futhermore, on many of the pavements which are now being widely used, not enough information is available to determine what the life may be, and even on some of the older types of pavement, built under presumably standard and foolproof specifications, a variation of life of several hundred per cent has been noted.

(6) The summation of items 1, 2, 3, and 4, divided by the number of years of expected life of the pavement, gives the annual cost to the public of the pavement as far as the mere outlay of money is concerned.

Before the division by the number of years of expected life is made, however, there should be subtracted from the total cost the value of the old pavement for use in the new pavement. Here, again, we are in the realm of guesswork. Assuming that a certain type of pavement can be preserved for 20 years and will then need resurfacing or replacement by another type, we are making a grave assumption if we attach any material value to the base, because the change in traffic on rural highways is so rapid that it is very hard for one to say that the alignment or grade or culverts or structures that we are building to-day or the widths that we are using to-day will be of any great value to our successors 20 years from now. On less important roads it is probable that structures today being built will have a very good value as a part of the structures which will replace them. But on roads of the first class there is grave doubt as to whether or not any of the surfacing will be of value to the kind of pavement that will be placed 20 years from now. However, a guess can be made considering all the factors surrounding the situation, and, as stated above, the sum so determined should be subtracted from the total cost in order to arrive at the annual cost.

At the end of this series of guesses and assumptions upon assumptions, one will have some basis—better than no basis—for comparing the annual cost of the types under consideration.

WIDTH AS A FACTOR IN PAVEMENT SERVICE.

We highway engineers in designing pavements have been open to the same criticism that is being made against those who are seeking to concentrate the major portion of the travel on a very minor portion of all public highways. That is, we have been designing pavements too narrow, and have multiplied our troubles of maintenance by confining traffic to one or two very restricted lines.

The conduct of all pavements, especially of the so-called inferior pavements, such as water-bound macadams, gravels, and the lesser nonrigid types, is good or bad in almost absolutely direct proportion as to whether they have been built wide or narrow. We have had a great deal of discussion of the importance of drainage on highways, and I am not minimizing the importance of drainage when I state that I am convinced that many of the faults of the lesser types of surfacing of which we are complaining are due to the fact that we have concentrated traffic upon too small units of area, and that a better distribution of traffic will do away with much of the trouble with these types, probably a larger share than will superrefinement in the treatment of the drainage.

I believe that the superiority under traffic of the macadam highways in England and France has been due in part to superior construction, in part to the age of these highways, in part to lesser traffic, in part to the climate, but more largely to the greater widths used in these countries and the consequent better distribution of traffic.

I am not going to develop this thought in detail, but I believe that highway engineers will find that if they will design the so-called nonrigid roads, that is, all roads without concrete bases, wider and flatter, that very much of the trouble incident to the present use of these structures will be avoided.

We have been too prone to compare rigid pavements of a certain width with nonrigid pavements of the same width, rather than comparing rigid pavements of the same cost (I mean total annual cost per mile) with nonrigid pavements of the same cost.

Concrete or other rigid surface laid on what is supposed to be a two-track road built 14, 15, or even 16 feet wide on a main traveled highway has its service value gravely reduced by its inadequate width because it breeds disastrous accidents and causes worry at all times. The shoulder maintenance is also a constant source of worry and grave expense if traffic is at all heavy. Furthermore, the absolute concentration of traffic and the crowding to the extreme edges brought about by such widths reduce the effective life of the pavement very materially. It is the opinion of the writer that even the rigid types of pavement must provide for a moderate distribution of traffic if they are to hold. The minimum two-track highway is 18 feet, and 20 is better on principal highways. If municipalities can not finance these widths they had better build part of their lengths of a cheaper type, pending the securing of more money, building what they now build of proper widths.

Plastic or viscous surfaces of all kinds must have width to allow for traffic distribution, especially if built in a climate of large total variation in temperature. On these types, especially, traffic must be distributed so as to heal its own marks and not deepen them in heated periods.

On primary highways, unless convenient detours are available, all pavements which from their nature require frequent surface attention embarrassing to traffic, should be constructed wide enough so that they can be maintained and repaired one-half at a time.

DESIGN AND SERVICE VALUE.

The service value of any kind of pavement depends largely upon proper design. It is not only necessary that the pavement be properly drained, that it be built of the proper depth and width, but the materials in it must be properly sized and prepared.

For instance, a gravel road built of uncrushed and unscreened gravel, varying in size from sand to cobblestones as large as one's head, has practically no service value to-day, because it is impossible to maintain such a road so as to give satisfactory service to traffic. On the other hand, a road built of the same width and depth and of the same gravel properly crushed and sized may well give most economical service. We in Wisconsin have reached the point where we don't want any gravel within 4 inches of the surface larger than 1 inch, and we prefer it if there is no gravel in the whole structure larger than 1 inch—the smaller the better, our experience indicates.

The service value of any highway may be seriously impaired by the use of sharp and dangerous curves, poor alignment, narrow bridges and culverts, heavy grades, and unnecessary lengths. A well-laid-out highway of inferior surface will many times give better service value than a carelessly located highway built with the best surface. Expressed in terms of real service value, type means little unless the selection of a proper type is supplemented by proper design and proper layout.

MAINTENANCE AS A SERVICE FACTOR.

I believe that maintenance is the keystone of the entire structure of pavement service. Proper selection, design, layout, performance of construction, must be followed immediately by intensive maintenance if the potential service value of a pavement is to be secured. Any discussion of the service value of any type of pavement has no basis unless the assumption is made that good maintenance protects the pavement and gives it a chance to serve. Types seemingly unsuited for the traffic may well, when properly maintained, give better service than a much more suitable surface left to care for itself. We are all familiar with the necessity of proper maintenance, however, and with this slight mention I will leave it.

TRAFFIC DISTRIBUTION ON SEVERAL ROADS.

I am going to interject just a word or two on this important topic. We are too inclined to view future traffic development entirely upon the assumption that one road between two points is going to serve all traffic between these points for all time. I doubt that this is true. Alternate routes will be developed and traffic thus distributed. This will be good from many standpoints. It will prevent traffic congestion, allow the use of cheaper surfacings, accommodate more local traffic, provide a choice of routes, and allow for repairs and reconstruction without closing all available routes. The road problem of America is not to build a few bouleyards; it is to build, maintain, and keep always open a transportation system.

TRAFFIC AND MAINTENANCE COSTS.

Wisconsin has now maintained her 5,000-mile State trunk highway system for three years and over 2,000 additional miles for one year, and we have gained some idea of the maintenance cost of various types. The condition of the various sections varied so much when they were taken over and the relative service given by the various sections and by the various types is so dissimilar that very little can be determined from an inspection of our figures of maintenance costs.

In 1919 the average cost of maintenance per mile for all types, surfaced and unsurfaced, was $254. The average cost of maintenance per mile by types (taken from a large number of sections) was as follows: Earth, $223; gravel, $212; water-bound macadam, $516; penetration macadam, $252; concrete, $337. Qualifying these figures, it would be only fair to say that the earth road maintenance included much heavy blade grader reconstruction, that the water-bound macadams had been allowed to get badly out of repair, and that all but $62 of the $337 for concrete was used in shoulder and ditch maintenance and in applying gravel to shoulders on 16-foot surfaces that were too narrow for the traffic.

As indicating the possible value of well-maintained gravel roads, we segregated nine very satisfactory patrol sections of gravel road and tabulated at least two separate traffic counts on each, a total of 23 traffic counts. The average count on these roads was 1,059 automobiles, 44 trucks, 21 motorcycles, and 48 horse-drawn vehicles per day. Weight was not taken. No effort was made to get maximum day counts. The roads in question gave excellent service every day in the year. The average cost per mile per section of maintaining these nine patrol sections was $263. These roads were not surface treated.

Our experience with gravel roads indicates that when well built of adequate widths with fine-crushed materials and well maintained their traffic limit is far higher than has been hitherto assumed.

The above figures may be of some interest although we have ourselves not been able to draw more than broad inference as to possible service limits and costs from them and other similar compilations.

THE TRAFFIC PROBLEM AND SERVICE VALUE.

In considering the relative service value of pavements, one can not disregard the matter of expediency. When considering a road problem and when determining an economical type to be used, there are always these factors to be considered:

(1) The expected traffic.
(2) The materials locally available.
(3) The funds available.
(4) The whole financial, traffic, and highway situation in the unit of government to be served.

This last factor is far the most important one in the whole situation and has been too often totally disregarded.

We have thought too little about the basic function of highways, which is, of course, to offer facilities for travel. We have been too prone to concentrate upon the consideration of a specific length of highway and upon an endeavor to economically design and build this length, rather than to concern ourselves with the more important traffic situation as a whole in the unit of government in which we operate.

We have been content to design and build a few miles of highway each year and to look forward into the far distant future with the hope that some day the contemplated system would be completed and traffic would be free to come and go as it pleased. We have closed our eyes to the fact that in the meantime we had on our hands scores or hundreds or thousands of miles of highway which are difficult for traffic at all times and impassable at some.

The highway authorities of each unit of government have before them a traffic problem. That is, they have a certain mileage of highways in a certain condition which now bear a certain amount of traffic, and the legitimate development of this traffic can be partly foreseen. They have available or they believe that there can be made available in a definite period, which they can select, a certain sum of money. Of course, the sum of money which may be made available is contingent upon certain circumstances usually beyond the control of the authorities. However, they can analyze their traffic problem, and their highways, and can assume the sum which they must have, and which they believe they can get, within a definite period of years, and can then determine about what should be done with this money, so as to give their clients, the public in that unit of government, the best result in traffic service during the designated period.

I don't know whether I make myself clear or not, but the point I am trying to drive home is this: Far more important than the mere selection of a truly economical type of construction for assumed conditions on a specific highway is the importance of determining upon that program of improvement which will be of the most benefit to the traffic in a designated area.

We are so obsessed with the schoolman's ideas of so-called true economics in pavement construction that we have been inclined to lose sight of the much more important economics of the traffic situation as it exists and may be expected to develop. We have had drilled into us the importance of economic design of specific stretches to such an extent that many of us have lost sight entirely of economic design for a traffic situation.

If unlimited funds, labor, and materials were always available, it might be possible that the schoolman is right and that we should never build anything but the truly economical surface, but there is always a limit to the funds which can be made available or which can be expended in a specific term of years, and the true economics of pavement design is to find the solution which gives the least cost, not only for the construction and maintenance of the pavement, but in the carrying of traffic in the designated area within the designated period.

I may be able to make my idea clearer by giving a short illustration. Normal County has 200 miles of road of the greatest importance; 200 miles of secondary highways, important from the county standpoint; and 400 miles of strictly local highways, cared for by the local units of government.

Outside of the funds which can be made available for the general maintenance of this 800 miles of highway, it can be foreseen that in the next five years the total funds available for highway improvement in Normal County will be $4,000,000. Of the 200 miles of first-class highway, 50 miles have been surfaced in the past, and are still maintainable; 150 miles are earth, without hope of redemption. Of the 200 miles of less importance, 20 miles have been surfaced and 180 miles are earth. Of the 400 miles of local roads, all are earth. Traffic conditions are at present intolerable in the county. Each rain means a blockade; each spring and rainy season an absolute cessation of traffic, except by team, and that traffic is almost blocked.

The $4,000,000 available in the five years will, it is estimated, build 100 miles of the schoolman's economically correct highway. If the public officials determine to build this type of highway, at the end of five years there will be 230 miles of the first and second class highways (over 50 per cent of the whole) still unsurfaced. Isn't it plain that this answer can not be correct, regardless of the so-called economics of the specific instance? Isn't it plain that the public body controlling the money should most carefully consider the whole situation and spend the $4,000,000 in an effort to make at least passable the whole of the 400 miles of principal highways?

The schoolman will say that some of the money is wasted because a portion of the types selected to be built are not going to exist for 20 or 50 years, but the economic waste incident to the use of (in his opinion) uneconomic types is not a marker to the economic waste incident to the continued use of a largely unimproved system of highways. In other words, the loss to traffic by the prolongation of such a situation is usually infinitely more than the loss to the public due to the construction and maintenance of types requiring renewal after a term of years. The schoolman will say that if $4,000,000 isn't enough $10,000,000 or $20,000,000 should be raised, but our assumption is that the $4,000,000 is all that that community can possibly be sold within the given period, and the limit of selling to a community can be pretty well analyzed and defined by the public officials of the community.

Carried to a logical conclusion some one will say this plan means building largely temporary surfacings and later on building again. It does! And why not if that is the true economic solution?

Most of our railroads have been rebuilt more than once. The old railroad men thought not much further than the traffic there was in sight and the distance they had to build to accommodate this traffic. They then mustered all the money they could get or that the economics of the situation justified and built the best they could build with the funds available, usually using local materials to reduce the cost. But they built the whole way and carried traffic through immediately. As the business grew and intensified, and as the country developed so that it could pay for better transportation, thus justifying larger expenditure and better structures, the railroad was rebuilt. I believe we must proceed along exactly similar lines. First accommodate traffic, building to the money which can be made available, expecting that after the traffic is gotten through and the adjacent territory reaches fuller development the necessary betterments will follow.

From the mere standpoint of mechanical performance alone, only so many miles of high-class highway can be built each year. One can multiply this annual possible mechanical performance by 10 and in the ordinary State the total will not equal the number of miles of primary highways, now partly impassable, which should be made passable. In other words, the economically perfect system required to serve traffic properly can not possibly be built in 10 years in the average State. Are we in the meantime to allow the unbuilt portions to go totally unsurfaced and uncared for because we are crying for the moon of absolute perfection? Wisconsin is not waiting, and I miss my guess if many of the other largely unpaved States are going to wait for that millenium. Traffic must be served.

FEDERAL-AID TYPES AND SERVICE.

There has been considerable criticism to the effect that a large proportion of the Federal-aid construction is going into low-class structures and that therefore the funds are being wasted. (Q. E. D.)

Wisconsin is among the list of States which are summoned to the bar charged with building other than permanent highways with Federal and State money. We have no apologies to offer. About 19 per cent of our total mileage of Federal-aid construction will be concrete, 2 per cent macadam, 42 per cent gravel, and 37 per cent earth, with modifying surfacings to make it passable. Expressed in terms of money, about 40 per cent will go into concrete, the remainder into grading and other types. Every project solved a traffic problem and freed a community from the bondage of years of impassability or danger. No one can tell me, nor can he tell the communities in which the work was done, that the money was wasted. Our critics themselves, if faced with the same problems, would have come to the same decisions.

I assume that other States have determined, as Wisconsin has, to serve traffic, rather than to slavishly adhere to certain so-called "permanent" types exclusively. Much of the criticism has come from those retained by certain pavement interests. Naturally if we do not construct their type of pavement we are necessarily wrong in their opinion.

We hope that all States will hold to safe ground and serve traffic now. Deviation from this policy is more apt to waste money than is adherence to it. Probably more Federal and State money has been wasted in prematurely building unnecessarily expensive types of surfacing than has been wasted in grading and building the lesser surfacings. After all, the one thing that is permanent about road work, the one thing that can not be done too well or too soon, is proper grading on correct locations. Those States that are feeling their way by doing much of this kind of work at places where traffic has been previously halted by grades or drainage conditions are not wasting money—they are truly investing it with profit.

COMMON SENSE VS. THE SLIDE RULE.

It may be inferred from this paper that it would take the brain of a Demosthenes, the genius of an Edison, and the engineering skill of a demigod to determine what pavements should be built given a condition, these theories, and a sum of money. Such is not the case. In four cases out of five a decision can be readily and quickly made when all surrounding facts and circumstances are known. What is required is, largely, common sense plus business judgment sufficient to grasp relative values. It is a matter of experience and judgment rather than of the slide rule and arithmetic. We have used too much higher mathematics and too little common sense. We have sought to set ourselves upon a pedestal of economic perfection and have closed our eyes to many of the surrounding circumstances, until many of us can not recognize a real economic fact when we meet it. The people are commencing to demand results rather than higher economics. They don't know much about pavement economics or relative economy of types, but they know when and where they were stuck in the mud and where they broke that last spring.

There are too many hundreds of millions of dollars invested in means of motor transportation, and too much pleasure, comfort, convenience, economy, and time saving depends upon their immediate, economical, and safe use for us to trifle with the facts as they exist. The owners of these vehicles demand service. They must be given it. This despite the fact that many manufacturers of motor vehicles persist in pursuing the ignis fatuus of highly centralized highway systems and of highly concentrated construction. Automobiles and motor trucks are owned on almost every square mile of territory and use every main highway. They can not serve or attain complete efficiency unless they can get through everywhere—now. Why their producers should deliberately work to limit their use offers to me an enigma impossible of solution.

It would be splendid if we could serve traffic immediately and always with the ultimate perfection of service, but it is mechanically impossible. Until we can so serve it we must meet the situation which exists and get the best result we can with the means at our command. We will not often be divinely right, we may sometimes build highways which our grandchildren will not use, but, after all, the people living right now also desire to live and to be happy and to run and jump and play and work.

Let's not worry so much about our predecessors or our successors; let's do our best for our contemporaries. Service value doesn't necessarily mean the ideal for the next decade; it may better mean service value right now, taking all things into consideration, including the living as well as those who may be expected to come after the living. After all, our children and our children's children will probably be able to take care of themselves. The children's children of other ages always have.

A county or State highway department should not exist merely to design and build a few miles of highway and a few culverts and bridges. It should exist to give transportation to its clients. It should strive to arrange the laws and their practice so as to give it now, not in 1950. The thing which we should strive to serve is highway traffic; we should be purveyors of transportation to His Majesty, the American people. Traffic must be served.

CONCLUSIONS.

I have rambled around without saying more that is worth while than the law allowed and I am ready to call it a day. I did not expect to prove anything definite when I started out, and I am not disappointed that I have not done so, even if you may be.

Summing up very briefly the meat there may be in this article we can say as follows:

(1) Service value must always be considered with reference to service cost.

(2) In comparing the relative service value of pavements, interest on the successive investments should be included in the gross cost.

(3) Soil, climatic, and rainfall conditions have a bearing on service value and should always be reckoned with.

(4) Width is an important factor in service and has a very large bearing on the conduct and maintenance cost of pavements, especially of the inferior types.

(5) Proper design and layout are important regardless of type, and poor design and layout seriously impair the service value of the best types.

(6) Traffic has a grave bearing on service and must be restricted and controlled in advance of construction plans.

(7) States must probably divide their roads into classes and name the limiting load for each class. All roads can not be made 15-ton roads every day in the year.

(8) It is not always possible to build the surface that will give the most economical service on the specific portion of highway, and it is not always advisable to do so.

(9) There can be no comparison of service values without assuming proper maintenance of all types of surface.

(10) Constant serviceability is supremely important, especially on main traveled highways, and will often determine the type and width of surface to be used.

(11) In planning improvements consideration of the traffic problem is of the gravest importance. Before any extensive program is laid out, the executives who control the construction should carefully survey the traffic situation and the highway conditions in their own and the surrounding units of Government and plan to meet them.

(12) We should probably seek to decentralize and spread intense traffic on several roads rather than seek to put it all on one.

(13) Expediency is not always wicked. It may sometimes be another name for common sense.

(14) It is better to travel over an uneconomically designed but passable highway system than not to be able to get through on a theoretically perfect one.

(15) The function of highways and of highway departments is to serve traffic and to furnish means of transportation.

(16) To-day's traffic must be served.

DISCUSSION OF MR. HIRST'S PAPER.

Frederick S. Greene, State highway commissioner, New York: Only two classes of pavement can be built with economy. They represent the two extremes of construction, and may be designated as the low and high type roads. The first class includes roads built of local materials; the second should include the most durable types of pavement known to the engineering profession. Between these classes falls the third class—the uneconomic class—composed of those intermediate pavements which cost a great deal more to build than the types which are constructed of local materials and which do not last long enough to pay for the extra cost. Such pavements, if you build enough miles of them, will bankrupt the State to maintain them.

The actual experience in the State of New York with pavements of this class, which includes water-bound macadam and bituminous macadam construction, is that they last seven and one-half years. We all understand that many of those pavements were built solely for horse-drawn traffic. If we had nothing but horse-drawn traffic to-day I would be a strong advocate of the water-bound pavement, but highway engineers know that the water-bound macadam pavement does not stand up under the action of the pneumatic tire, to say nothing of the truck tire. It has been pointed out that our railroads were built on the principle of the most miles for the least money, but no mention has been made of the fact that a history of our railroads shows that a great majority of them went into the hands of receivers and had to be reorganized. A State can not afford that.

NEW YORK EXPERIENCE.

The experience of New York with gravel roads has not been satisfactory. We have a great many miles of them, especially in Orange County, and the cost of keeping them passable is about $1,200 per mile per year. It has been pointed out that if gravel roads be built with a wide surface they will often give better service than a more durable type of pavement. We will all agree that a wide pavement, which permits the traffic to use it without forming ruts, will last longer than a 9-foot pavement on which, perforce, every vehicle uses the same rut. But the generalization which has been made fails to take into account a number of conditions which prevent the full realization of all the benefits of greater width. Such a condition exists, for example, when the roads are covered with snow. In a great many places it is only possible to clear a 9-foot track, and then, no matter how wide the road is, all vehicles are forced to travel practically in a single rut. Such condition will result in serious damage, even to the more durable types of roads. I have in mind, for example, the case of the road from Albany to New York, which is surfaced with asphalt block. The heavy snows last winter completely blocked this road for about four weeks. Finally a track was broken through and immediately a fleet of trucks began moving. The track was narrow and the trucks were forced to travel in a rut, and you can see to-day where the asphalt block has been worn down by the truck wheels with their equipment of chains. So, while I recognize that there are advantages in the use of wide surfaces, such cases as that which I have described suggest that the general statement of the virtues of width can only be accepted with reservations.

NEW YORK'S NEW TYPE OF PAVEMENT.

There is a type of pavement which we are now building on our main lines which I think worth calling to your attention. It is new and we have not had time yet to determine what it is going to do, but from what we have seen of it, we think it is going to work out. The construction consists of 9 feet of reinforced concrete laid on each side of a center strip of the existing bituminous macadam, 6 feet wide. The concrete sides are built and the bituminous macadam in the center is repaired without disturbing traffic, and the result is a 24-foot pavement, made safe by the division of the traffic, which is effected by the strips. We find that the trucks and automobiles tend to hold to the concrete at the sides; that the center strip of bituminous macadam is used only by overtaking cars in passing the car ahead. For this reason we believe the macadam will last as long as the more expensive concrete. I think we can recommend this type of pavement to those States which are finding that the traffic has outgrown the existing pavements and especially if the roads at present are bituminous macadam. For those who are interested I will say that the first one we tried had 8-foot strips of concrete, which we found about a foot too narrow. We then built one with two 9-foot strips of concrete and a 5-foot strip in the center. This was not entirely successful because the 5-foot bituminous macadam strip in the center could not be properly rolled. To get a tandem roller to roll well the center strip should be 6 feet, and we have now definitely decided upon the 6-foot width for the center strip and the 9-foot width for the sides.

The Analysis and Preparation of Estimates for Road Construction.

H. J. KUELLING, Construction Engineer, Wisconsin State Highway Commission.

IN VIEW of the rapidly changing economic conditions in the past few years and the uncertainty as to future years, estimates have been giving and are going to give highway engineers considerable trouble. There has been and there will be great doubt as to whether or not bids should be accepted. The uncertainties have been very great in recent years and largely against the contractor. Apparently there is a reversal coming and the uncertainties will now be against the States. This means that it is all the more urgent that proper estimates be made on highway work.

The question of estimating will be discussed in this paper from the standpoint of a State department and not from the standpoint of an individual.

It is assumed by the writer that the economical type to be constructed has been previously selected. This statement is made because of the fact that in making estimates factors are very often uncovered which warrant a change in type. Since this subject is properly covered under other papers at this meeting, it will not be discussed here.

ENGINEER'S PRELIMINARY INVESTIGATIONS.

Before any figures are made on an estimate, the engineer must carefully analyze all conditions surrounding the work. In other words, he must spend time in seeking out all local information relative to every feature of the work. This local information may pertain to availability of materials; freight rates; railroad accommodations, as to sidings and train service; camp sites; water supply for these camps; availability of supplies for the camps, whether they come from merchants or farmers; the soil conditions, whether or not they are conducive to a small weather loss; whether the sand is so soft that it will interfere with the movement of his equipment, such as wheelers or wagons; the kind of clearing and grubbing he has, whether the trees are deep or flat rooted; marshes, if there are any, whether it is possible to work horses or equipment on them; the kind of grades that may be encountered in the work, which will have a bearing on the hauling of materials, or the pumping of water; in fact, he must seek information on a great variety of subjects.

In seeking knowledge of materials he must know the capabilities of commercial concerns to ship; whether they are in a position to get cars; whether they have the proper capacity to turn out the amount of material they are liable to contract for; whether their material is satisfactory; the business reputation of the concern, whether they will keep their word or not; that is, whether they will ship in accordance with promises, or whether they will ship to some one that comes along and offers them a higher price at a later date.

INQUIRY AS TO LOCAL MATERIALS.

Seeking information on local materials, the engineer must be even more careful, as he must know the kind of material available, the amount of it, especially if it is a gravel deposit, as these are likely to pinch out; he must know the cost of it, and he should have an option on it, so that one contractor by getting this option can not bar others from bidding.

The mere investigation of materials in present use is not sufficient, as there are many cases where materials are being hauled several miles when there is a sufficiently good supply within a very short distance from the job. Entirely new and unknown sources of supply can be found in any State by a painstaking materials department. The changes of the freight rates, if there are any new increases, should be balanced against the extra distance that local materials can be hauled.

After an engineer has obtained or been furnished with all this local information he is still very much handicapped in making his estimate unless he has had considerable experience in actual construction. He should know the best methods of carrying on the work, what equipment to use, whether it be a grading or surfacing job.

COST INFORMATION FROM FORCE ACCOUNT.

With the amount of work that is being done and will be done by every State in the Union, the simplest, most practical, and only satisfactory way to get this cost information is for the various States to do some of their work by force account. The writer knows that some States can not legally do this, but believes that provision should be made so that they may. It will be surprising to many of you to find out the items that crop up and that must be paid for on a construction job. Some things are hard for an engineer to realize unless he has been through the mill, things which he is apt to criticize the contractor for including in his estimate. The State from which the writer comes has taken this stand for years past and has done a very great amount of certain types of work by force account. Up until the time of Federal construction this force account work was entirely in the hands of the county authorities and only under the general supervision of the State. Since the Federal construction began, the State has undertaken a number of jobs by day labor, and, in fact, in 25 of the 71 counties during the past season part of the work has been done in this way. This does not mean that the majority or even a large per cent of the work is done by force account, but enough is done so that the State will have first-hand and absolute knowledge of costs.

Owing to the variety of work and variety of conditions, it requires several jobs along different lines. For instance, on concrete road construction during the past season one job was run by day labor where the material was dumped on the subgrade and handled by wheelbarrows. This material was shipped in from commercial plants to a special siding; transferred by a clamshell bucket to side-dump cars on an electric railway, which ran along the highway, and dumped directly into the subgrade. In another case a local pit was developed and the material hauled to the road by trucks; it was then mixed and placed, the mixer being loaded with wheelbarrow. In a third case, a local pit was used, the concrete mixed at the pit, hauled in a mixed condition by industrial railway, and placed on the subgrade with a large crane.

In grading operations one job was undertaken in a sandy soil, one in gravelly soil, one in clay soil, still another in very stony ground. Some work was done by steam shovels and some by wheelers and fresnoes.

In a similar manner various kinds of gravel work were undertaken, some with sandy gravel, some with clay gravel, and some with gravel that would hardly be worthy of the name of gravel; in other words, it was really topsoil.

With an accurate cost analysis of all of this work at hand, we feel that we are in much better position to determine whether or not the bids submitted to us are satisfactory.

REGULAR SYSTEM FOR MAKING ESTIMATES.

After progressing this far in the making of an estimate, the writer believes that the States should have a regular system of making these estimates; in fact, he sees no reason why a committee from this organization could not develop a scheme or schemes for having all the States make their estimates in the same manner. This scheme, whatever it may be, should be after the fashion and, in fact, can well take the same form that a contractor should use. There is no reason why the drawing up of such estimate forms could not be done partly by the contractors or in conjunction with them.

This scheme of having the contractors work with the engineers has been tried out during the past year in Wisconsin with more or less success.

A year ago the State highway department called a two-day meeting of contractors, machinery men, material producers, and the engineers of the State. A very open discussion took place regarding the relations of all parties concerned. At this meeting a committee was appointed, which was instructed to draw up a form for making estimates. This committee was composed of five contractors, elected by the vote of the contractors themselves, one man from the aggregate producers, one man from the machinery manufacturers, three men from the county construction departments, and two from the State highway department. This gave a committee of five engineers, five contractors, and two others who were vitally interested in the meeting. The committee held three sessions and I assure you that they were sessions at which work was done. The contractors as a rule were frank in their statements and out of it grew an estimate form for one type of construction which seems to be fairly satisfactory to all concerned. No doubt it has many faults as yet, but it is a start in the right direction. This form is drawn up primarily for a concrete road job, but it can be very easily adjusted to other types of surfacing.

ESTIMATE FOR CONCRETE ROAD CONSTRUCTION.

The form as developed is divided into 16 subdivisions as follows: Cost of sidings, moving of equipment to the job, lost time in moving equipment, cement, clam shell and derrick supplies, fine aggregate, coarse aggregate, surfacing, camp loss, miscellaneous cost, contingencies, compensation and public liability insurance, bond cost, overhead, profit, charges for machinery and equipment. Each of these items is subdivided into as many divisions as were considered necessary by the committee. Most of these items you will readily see are somewhat easy to determine, but others are not. Only a few will be discussed here.

Overhead, the committee finally put on a percentage basis. For instance, in figuring a job the contractor or the engineer would have to estimate the percentage of the manager's time that would be required for the job and then charge up that percentage of his yearly salary to the job. The same procedure was followed with regard to office force, timekeepers, the expense of the manager, his office rent, supplies, etc.

Overhead also includes the corporation insurance, interest on the necessary working capital, and any dues that might have to be paid to associations.

Under the item "Profit" I might say that the committee had a rather heated argument. Naturally the contractors were anxious to obtain as much profit as possible and have the State officials agree to certain percentages. This, however, we refused to do, and the percent of profit was left blank for the contractor to fill in as he desired. What we were seeking primarily was to get everyone to make his estimates along the same line; we were willing to let the contractor be his own judge as to whether or not he could get the job with certain profits added on.

CHARGES FOR EQUIPMENT.

In the last item—charges for machinery and equipment—the committee had perhaps the most interesting discussions. Charges for surfacing, machinery, and equipment were worked out to certain percentages per mile of road constructed. For instance, under concrete pavers, we assume that the paver will build 30 miles of standard 18-foot road, at the end of which time it will be completely used up. The same result is obtained if we assume that it will build 24 miles and at the end of that time have a salvage value of 20 per cent of the original cost. With the 30 miles noted above, and an average per year of 6 miles, the life of the mixer would be five years. Depreciation, therefore, in five years equals 100 per cent. Repairs in five years at 10 per cent would equal 50 per cent of the original cost. Interest, storage, and insurance amount to 30 per cent of the original cost, making a total of 180 per cent of the total cost to be spread over 30 miles, or 6 per cent per mile. In other words, in figuring the charges for machinery for a standard 18-foot road, the contractor would merely multiply the number of miles by 6 per cent and take that percentage of the original cost of his paver as the amount to be charged to the particular job under estimation. In a similar manner, the committee arrived at percentages for various types of equipment used in the surfacing work.

Suggested charges for machinery and equipment used for camps, concrete paving, loading and unloading operations, including depreciation, interest on investment, storage, insurance, and all repairs, but not including fuel, are shown in Table 1.

TABLE 1.

Kind of equipment.	Charge rate per mile of 18-inch concrete.
	Per cent.
Road rollers	2-4
Paving mixers	6
Stationary mixers	5
Finishing machines	7
Sectional storage bins (material)	7
Clamshell crane	4
Stiff-leg derrick (material)	4
2 pumps	6
Pipe line (material)	6
Side forms (steel)	12
Side forms (wood)	27
Iron stakes	15
Automobiles, camp, and service, including operating costs	16
Canvas	10
Hose	16
Wheelbarrows	16
Concrete rollers	20
Mixer loaders (belt conveyor)	12
Wagon loaders	7
Camp equipment	8
Total	....

NOTE.—The above total is to be entered in item 16 of the cost estimate for one-course concrete payment.

The percentage on grading and hauling equipment naturally could not be arranged by miles. It must be worked on a time basis and can not be as accurately determined as surfacing equipment because of the greater variation in quantity and kind of excavation in different jobs. Final percentages have not as yet been arrived at by the committee for these types. The committee did state that including depreciation, interest on investment, storage, insurance, and all repairs, but, not including fuel, the percentage per operating day would vary from one-fourth to one-half of 1 per cent of the original cost, depending upon the kind of equipment.

There is no doubt that a continued use of this form will bring out points of weakness, but the writer believes it is a step in the right direction and that within a very few years standard forms of estimating will be in use for road work, and that there is no reason why the same forms can not be used by the contractors and by the engineers.

There is also no doubt that adjustments will have to be made for certain local conditions which are not covered. Where there is something to guide there is no reason why the contractor and the engineer should not be a little more in harmony than they have been in some cases in the past.

Short cuts in estimating are needed and can be devised by State departments. Care should be taken, however, not to make these too short. No scheme will ever be devised or charts drawn so that a novice can make highway estimates. It is only by the use of brain and knowledge of conditions influencing costs that proper estimates can be made.

WISCONSIN COST ESTIMATE FORM.

Item.	Operation.		Total.	Per square yard.
1. Cost of sidings		$	$	$
2. Moving equipment to job	(*a*) Hauling and loading mixer, clamshell, pipe, pumps, tools, camp equipment, industrial equipment, teams, trucks, etc.			
	(*b*) Freight on above			
	(*c*) Unloading and hauling to job			
	(*d*) Moving overland (other than rail shipment)			
	(*e*) Cost of erection of camp including water supply, storage bins, derrick, etc			
	(*f*) Return of above equipment to storage			
	NOTE.—Item (*f*) is applicable only to job requiring whole season for completion or on last job of season.			
	Total			
3. Lost time in moving equipment	Number of days ...... at ...... per day. Lost time to cover lost time in tranist to job or between jobs or between different set ups on same job.			
4. Cement	Number of barrels in pavement			
	Cost per barrel f. o. b. destination			
	Cost of ...... barrels at ...... per barrel			
	Cost of unloading, hauling, and covering			
	Cost of storing and rehandling ...... barrels			
	Insurance on stored cement and empty sacks			
	Sack loss			
	Freight return on empty sacks			
	Demurrage			
	Total cost of cement			
	Cost per barrel delivered on job			
5. Clamshell and derrick supplies	Fuel, oil, etc., only (Do not include repairs.)			
6. Fine aggregate	Number of cubic yards, including waste			
	Cost per ton at pit or quarry			
	Cost per cubic yard at pit or quarry			
	Freight per ton			
	Freight per cubic yard			
	Hauling cost per cubic yard			
	Estimated demurrage, $........., divided by total yardage, give cost per cubic yard			
	Cost rehandling from stock pile, $..........., divided by total yardage, gives cost per cubic yard.			
	Total cost per cubic yard on job			
	Total cost of ...... cubic yards on job			
7. Coarse aggregate	Number of cubic yards, including waste			
	Cost per ton at pit or quarry			
	Cost per cubic yard at pit or quarry			
	Freight per ton			
	Freight per cubic yard			
	Hauling cost per cubic yard			
	Estimated demurrage, $........., divided by total yardage, gives cost per cubic yard			
	Rehandling from stock pile per cubic yard			
	Total cost per cubic yard on job			
	Total cost of ...... cubic yard on job			
8. Surfacing	Preparation of subgrade			
	Cost of joint material on job			
	Cost of reinforcing metal on job			
	Labor, mixing, and placing concrete, including engineer, fireman, form setters, fine graders, wheelers, shovelers, cement men, puddlers, baling and sorting sacks, curing, covering, uncovering, finishers, water boy, watchmen, pump man, barricades, and lights.			
	Cost of hauling mixed concrete, including fuel, and depreciation on hauling equipment			
	Water supply and pumping, including labor, connecting pipe, setting pump, fuel for pump, disconnecting pipe, and drilling well.			
	Mixer supplies, fuel, and oil only			
	Miscellaneous supplies, such as boots, hardware, etc			
	Total			
9. Camp loss	Including loss on board of men on operating days as well as on idle days, loss on full time men not included in overhead, etc. (Do not include depreciation on camp equipment.)			
10. Miscellaneous costs	(*a*) Cost of hiring and shipping in men	$		
	(*b*) Water rent			
	(*c*) Rent of grounds and buildings			
	(*d*) Cost of building crossovers			
	Total			
11. Contingencies	Delays due to railroad embargoes, strikes at pits, quarry, or job, material plant breakdown, machinery breakdown, failure of water supply, unusually bad weather, freezing of pipe line, etc.			
12. Compensation and public liability insurance.				
13. Bond cost	Personal or surety bonds			

WISCONSIN COST ESTIMATE FORM—Continued.

Item.	Operation.		Total.	Per square yard.
14. Overhead	Per cent of manager's yearly salary	$		
	Per cent of yearly salary of stenographer and clerk			
	Per cent of yearly salary material man and timekeeper			
	Per cent of yearly expense of manager, including railroad fare, hotel bills, bidding cost, auto, etc.			
	Per cent of yearly office rent			
	Per cent of yearly office telephone and telegrams			
	Per cent of office supplies, miscellaneous			
	Corporation insurance			
	Interest on working capital not otherwise included			
	Association dues			
	Total			

SUMMARY OF COST ITEMS—ONE-COURSE CONCRETE PAVEMENTS.

Item.	Total.	Per square yard.
1. Cost of sidings		
2. Moving equipment to job		
3. Lost time of moving equipment		
4. Cement		
5. Clamshell and derrick supplies		
6. Fine aggregate		
7. Coarse aggregate		
8. Surfacing		
9. Camp loss		
10. Miscellaneous costs		
11. Contingencies		
12. Compensation and public liability insurance		
13. Bond cost		
14. Overhead		
15. Profit		
16. Charges for machinery and equipment (Taken from total of Table 1.—Do not include Table 2.)		
Total		

The Study and Treatment of the Different Subgrades and Foundations.

CHAS. M. UPHAM, Chief Engineer, Delaware State Highway Department.

THE subject of subgrade and foundation construction is not a new one for there are many evidences that attention has been given to this detail ever since the art of road building has been practised. In practically every instance, however, this detail of construction was masked under the name of "drainage," a detail always recognized as of great importance, much talked about, but not ordinarily practised .

A few years ago many of the failures in roads were type failures, which meant that the pavement did not have the inherent strength to withstand the demands of traffic, even though supported on a stable foundation or subgrade. In other words, the surface pavement broke down under the loads of traffic.

Although we have now developed road surfaces that satisfactorily carry the present-day traffic, if properly supported, we still find there are failures of these standard types.

During the period of lighter traffic many standard types of road surfaces were developed that carried the traffic satisfactorily, even on the less stable subgrades; but with the coming of the heavier types of vehicles, it was found that these standard types of pavement would carry the heavy traffic only over well-drained and stable subgrades.

While much has been said and a certain amount of research has been made on drainage problems, it is quite obvious that until recently the greater concerted study has been made on pavement surfaces, and comparatively little complete investigation has been carried on relative to stabilizing the subgrade or road foundation.

PROBLEM OF STABILIZING SUBGRADE.

With our present knowledge of permanent surfaces we can, within reasonable limits, compute the strength and resistance to traffic, provided we know the condition and nature of the subgrade, but when we inject the varying factors that influence the stability of the subgrade, the conditions present a new problem, one composed of many variables and difficult to solve. The high first cost of road construction and the heavy cost of road maintenance make necessary a determined effort to solve, if possible, the question of stabilizing the subgrade, no doubt the most complicated problem yet remaining in road building.

Some engineers have recognized for several years that different soils and soil conditions present varying degrees of stability in the subgrade. Various methods have been followed in the subgrade treatment, but, in general, standard pavements have been laid on subgrades of different degrees of stability. In some cases the subgrade has not been sufficiently firm to support the pavement and traffic, and in others it has been of such a nature that a cheaper pavement would have been sufficient. In either case, the result is uneconomic, and the failure to put an end to such conditions is not flattering to the highway engineering profession.

In this paper the pavement is considered the artificial surface, the road foundation as that part of the subgrade that has been replaced or treated, and the subgrade as that part of the road beneath the foundation.

In general, the strength of a pavement is a function of its depth; therefore, any increase in depth will materially strengthen the pavement. The foundation will probably never be as strong as the pavement, but the nearer it approaches this condition the greater will be the strength of the pavement, for the foundation will then act to a greater extent in assisting the pavement to resist traffic forces. The same holds true with regard to the subgrade in stabilizing the foundation, which in turn stabilizes the pavement.

WIDE RANGE OF SUBGRADE MATERIALS.

It would be practically impossible to classify all the various kinds of subgrade materials. The wide range is evident on roads that have failed. Many times a standard pavement has failed in spots or short lengths although the entire road has been subjected to the same traffic. Apparently this is due to the fact that the foundation or subgrade is not as stable in these places that have failed. These failures afford opportunities for the study of subgrade and foundation treatment as well as road-surface design.

An interesting example of this is a bituminous macadam road that has been failing at certain points for a long period. Most of the soil in this vicinity was easily drained, but further investigation revealed that wherever the failures occurred there was an impervious layer of clay, not more than an inch in thickness, and lying in a generally horizontal position which prevented the moisture from draining away from these points. Below this impervious layer of clay which retained the moisture was a sand that was easily drained, and that would have afforded a stable foundation or subgrade condition that would have undoubtedly prevented the pavement from failing.

Such mistakes as this could probably be prevented by means of a subgrade-testing instrument, of which there are several tentative designs. Some of these afford means of securing valuable data, but in general there is a great variation in the results obtained with them when different degrees of moisture are present in the subgrade. The variation may be as great as 200 per cent in some soils when the difference in the amount of moisture is not sufficient to be perceptible to the eye. Until it becomes possible to interpret these varying results more closely than we are able to at present, subgrade-testing instruments will have a very limited usefulness.

METHODS OF STABILIZING SUBGRADE.

At present the subgrade problem seems to resolve itself into a question of stabilizing the subgrade either by draining or excluding the moisture or constructing a foundation course. Whichever method is followed the result is simply to increase the effective depth of road surface or pavement, inasmuch as the stabilized foundation or subgrade will act as increased depth of road surface. The problem consists in deciding just how much should be spent in the drainage and how much should be spent in constructing a foundation.

It seems perfectly proper to assume that the bearing power or stability of most soils is increased by the removal of moisture, so our problem can be more easily solved if we minimize the amount of moisture in the subgrade. The moisture enters the subgrade from the surface in the form of rain; from the sides by seepage or horizontal capillarity; from the bottom by vertical capillarity; or, as in the case on grades, by following along impervious strata which intersect the road surface or foundation.

It is a simple matter to take care of the water that enters the subgrade from above, as this means simply the waterproofing of the surface and shoulders, and the results obtained will be far in excess of the effort and the cost.

The water introduced by side seepage or horizontal capillarity can be taken care of by an intercepting ditch or tile and stone drain. With this removed, the only other source of disturbing water is from below, and this is the difficult portion of the problem to solve.

In many soils capillarity will draw water from 2 to 5 feet in comparatively large quantities. Some authorities claim that the capillary action will extend many feet more. It is quite likely that this capillarity, assisted by the vibratory action of traffic, would cause sufficient moisture to rise to the subgrade to render it unstable. The amount of water which will be thus held against gravity and the rate at which it will be drawn from below depend upon the sizes of the pore spaces between the particles. If these are small the vertical movement of the water will be relatively rapid, and the amount of water the soil will hold against the attraction of gravity will be comparatively great. If the pores are large the movement of the water will be slow and the amount the soil will hold will be small. The knowledge of these phenomena has been applied in the many successful efforts which have been made to defeat the action of capillarity by placing a layer of coarse material of low capillary power beneath the pavement. The tendency is to prevent the moisture from rising above the layer, thereby giving greater stability to the foundation, which is, in a degree, equivalent to increasing the thickness of the pavement.

Another method of preventing the rise of capillary water, which has occurred to some, is to fill the pore spaces with a waterproofing material. A number of experiments of this nature are now being conducted by the Bureau of Public Roads. The results are bound to be of much interest and great importance.

PRACTICAL EFFORTS TO STABILIZE.

Up to the present time, however, the practical efforts to stabilize the subgrade have involved the substitution of sand, crushed stone, or gravel for the unstable material of the natural subgrade. Not only do such materials prevent capillary water from rising, but they also add to the stability of the foundation by virtue of their higher bearing value. Naturally the most effective of these materials are the gravel and crushed stone.

The worst condition we are called upon to meet is that which obtains when the subgrade is saturated with moisture, which usually occurs during the spring thaw. If the ground has been frozen and is suddenly thawed, there is a layer of saturated subgrade directly above the frozen material. That this is the worst condition that may exist is evidenced by the general breaking up of the roads in the spring. Subdrainage under these circumstances is of little value. The condition is best overcome by open ditches allowing the water to run off as soon as the frozen material is melted.

If the conditions are such that the subgrade or foundation can not quickly dry out, the pavement, almost regardless of type, will have a tendency to fail. If the subgrade can not be quickly drained, one of the best methods of stabilizing the construction is to build up a foundation with a material capable of high bearing value and capable of carrying the load.

In some States it is customary to build a foundation using rocks varying in size from 3 to 15 inches. Although this method of treatment is costly, it is very effective, and many roads with these foundations have been carrying heavy traffic although surfaced with only a medium heavy pavement. While a foundation of this sort can stand considerable moisture, still a constant effort should be made to exclude moisture.

There are undoubtedly many other practices that could be followed that would assist in the stabilizing of subgrades. It has been shown that plowing or breaking up the earth will cause it to retain moisture. Therefore, it would seem that the reverse should be true, that to exclude moisture the subgrade should be thoroughly rolled and compacted.

It can not be hoped that a single paper can more than touch the salient facts of this subject, as great questions are yet to be solved. The treatment of subgrades will depend on the results found in the experiments on the bearing power of soils, on experiments to prevent capillary action, on results obtained in underdrain experiments. In other words, there are many questions that must be solved, or partially solved, before the question of economically treating the subgrade and foundation can be completed.

Our present knowledge of the subject assures us that the stability of the subgrade or foundation depends upon the amount of moisture in the subgrade. The sandy or gravelly soils are more stable, but in order to stabilize the clay soils they must be kept dry or replaced with different material. The design of the subgrade or foundation will always depend upon the drainage, and the engineering problem is to decide whether it is more economic to treat or replace the subgrade material, or to provide elaborate drainage, or a combination of the two.

DISCUSSION OF MR. UPHAM'S PAPER.

J. H. Johnston, division engineer, Massachusetts: "Therefore when we build, let us think that we build forever. Let it not be for present delight, nor for present use alone. Let it be such work as our descendants will thank us for, and let us think, as we lay stone on stone, that a time is to come when those stones will be held sacred because our hands have touched them, and that men will say as they look upon the labor, and wrought substance of them, 'See this our fathers did for us.'"

We all hope, with Ruskin, to build for posterity, and our choice of methods will determine whether we shall build roads or only debts. In Massachusetts it has taken 26 years to spend $40,000,000, and I gasp at the thought of the enormous programs now laid out by many of the States. It is easy to fall on one of the two horns of the highway dilemma either by building roads so cheaply that they will not stand or by building roads at such great cost that the interest on the investment will be far more than the cost of maintaining a much greater mileage of serviceable highway.

It has been said that the only permanent features of a road are its alignment and its grade, but this is only a half-truth; for we have seen many lines and grades changed, and the survival of ancient roads has taught us that foundations can be permanent when properly constructed.

A properly built road seldom wears out except upon the surface. We have had many miles of such road torn out because changing conditions make necessary wider surface, less camber, banking of curves, or changes in grade and alignment, and we do not know what the future has in store for us.

The success of a road can not be judged for several years, and in the meantime the designer of the structure may suppose he is on the right track and continue an erroneous practice, building a large amount of work that must eventually fail. If the failure is due to improper foundation, the only remedy is to tear it all out and start afresh. Unfortunately, foundations appear to be so little understood that failure is too often attributed to surface causes and the poor work continued. Long experience and careful thought are essential to recognize cause and effect. For these reasons it has seemed to me a serious mistake to separate construction and maintenance departments, for if the man who built the road maintains it he has a chance to learn from his mistakes. For years I made it a practice every spring to locate all frost breaks and soft places on the roads in my charge. I endeavored in each case to learn the cause of failure, to apply remedies, and watch results. I am, therefore, a strong advocate of the most substantial foundations, and if anything must be skimped, my advice is cheapen the surface, for that is easily repaired.

While it is universally agreed that foundation and drainage are essential to permanency in a road, there is too often a mistaken impression as to what constitutes proper foundations and drainage.

PREFERABLE TREATMENT OF SUBGRADE.

The preferable treatment of subgrade and foundation under a concrete road depends largely on whether or not cracks are considered a serious detriment and what outlay is thought justifiable to eliminate them. In western Massachusetts the frost penetrates the ground to depths of 6 feet. The soil conditions are so variable that very uneven frost distortion occurs, and to treat a subgrade to insure a bearing so uniform as to avoid cracking a rigid concrete surface would require a bed of clean gravel, sand, cinders, stone, or similar porous material at least 24 inches deep, using side drains with pipe at bottom to carry off the ground water and deep gutters or ditches at each side of the road to take care of the surface water. Such construction would cost from $3.50 to $4 per square yard for the foundation and drains alone, and for the concrete, about $3.20 more, making a total of from $6.70 to $7.20 per square yard, or about $90,000 a mile, including grading and culverts, for an 18-foot roadway.

Even then you could not entirely eliminate, but would only minimize, the cracks. Is it worth the price to get rid of cracks that are objectionable only from an aesthetic standpoint? We have a concrete road in the Berkshires built over only 2 inches of gravel (and this was used merely to insure a clean subgrade on which to place the 6-inch concrete slab) which has cracked badly, but after four years rides as smoothly as the best new surface. We have other concrete roads where the foundation of the 6-inch slab consists of 12 inches of cinders, gravel, or stone, with 2-foot side drains on the edges. There is no apparent difference in the amount of cracking over these various materials, and though, in places the surface is badly cracked, the road is smooth to ride upon. The concrete road problem seems to me, therefore, mainly a question of the value received for the money expended.

While there is a very broad field for the concrete road, the road problem as a whole must be solved by utilizing any suitable local materials that may be available, and using a minimum amount of such more costly imported materials as may be needed.

EXPERIENCE IN MASSACHUSETTS.

Perhaps a résumé of our experience in Massachusetts may be of interest. The Massachusetts highway commission started its first State road construction in August, 1894. In October, 1894, I began my career as a State highway official. In those days water-bound macadam was thought to be the acme of perfection for State road construction, and it was built 15 feet wide, 6 inches at the center and 5 inches thick at the edges after rolling. Later we reduced the thickness to 4 inches at the edges. All loam pockets were excavated to a depth of 12 inches below subgrade and back-filled with gravel. Over soft clayey soil we laid a Telford base 8 inches in depth, with a sub-base of gravel 6 inches deep, and over the Telford surfaced with crushed stone 4 inches deep after rolling. At the edges of the Telford we constructed a French drain 3.5 feet deep. Where the Telford and drains were properly built the road stood well, and many such sections are in excellent condition to-day, after more than 20 years' service. It was thought, however, that such construction was too expensive, and to reduce the cost we first cut down the depth of the Telford to 6 inches of stone, over 2 inches of gravel sub-base, and later built without Telford base, except in the most extreme conditions, on the theory that if the macadam cut through it could be readily strengthened by adding more crushed stone on top. There never was a greater fallacy. I have added 12 inches of fresh stone over a 6-inch macadam and within three years have seen the traffic cut through, and this was in the old days, when 3 tons at 3 miles per hour was the greatest strain put on the road. This was tried not merely once, but many times, and never with success. The same experience and failure was repeated by the Army engineers during the late war. They were obliged to abandon the practice and use heavy stone for foundation purposes. It is therefore proved that ordinary crushed stone up to 2½ inches in diameter has very little value as a foundation. I desire to emphasize this because I find the practice still has followers, and they are surely wasting the public money.

We thought French drains would dry out the subgrade and result in sufficient added stability to permit the soil to bear up a 6-inch macadam without additional foundation. We built many miles of such roads but did not get the desired result. We tried gravel, 6 inches to 12 inches in depth, under crushed stone and with French drains, but such roads did not stand except in locations where the natural soil conditions were favorable. Gravel is an uncertain material; gravel suitable for this purpose is scarce and expensive—in many parts of our State more expensive than stone—and though excellent when used in proper combination with large stone will not give permanent results with only the ordinary crushed stone sizes over it.

TRYING THE V DRAIN.

We then tried the V drain, using stone up to 8 inches in largest diameter and building the drain 18 inches deep at the center and 4 inches deep at the edges, and over this we placed 4 inches of crushed stone. The drain was not always the full width of the hardened surface. Such a base held up the roads but resulted in uneven frost action, as, of course, the deep center would not heave as much as the edges; and at times such roads would have a concave cross section. This action was not a serious detriment with a water-bound macadam surface under horse-drawn traffic, but when the motor vehicles made necessary a more rigid surface, that would be broken up under the unequal distortion of the base, we were obliged to change our methods. It had been supposed the V design (the deep center) was necessary to act as a drain to collect the water, which was then tapped off at convenient outlets; but for the last 10 years I have been building, with a subgrade of level cross section, a stone foundation (using the same large stone), 6 inches deep at the edges and 10 inches deep at the center, the voids filled with gravel and the whole rolled until absolutely firm. Where soft bottom is found we use a sub-base of 4 to 6 inches of gravel; where extremely bad soil conditions are met these dimensions are increased to make the punishment fit the crime. For the stone base it is specified that over half of the mass shall consist of stone fragments not less than 4 inches or more than 8 inches in their largest diameters, with the largest stones at the bottom, laid on their broadest bearing, and smaller stone on top to chink the voids. Such foundations are holding up our roads under a present traffic of 2,000 to 2,500 vehicles daily, with loads as great as 20 tons hauled at 20 miles an hour, and without distortion serious enough to break up the bituminized surfaces placed over them. Except where there are springs, we do not use French drains with this stone base, but place outlets to drain the base at suitable places.

We have built many miles of road with such a base, filled the voids with gravel and placed over it an average of only 2 inches of crushed stone, bound with 1 gallon of tar per square yard, and such roads have stood up since 1913 under traffic which has constantly increased to a present daily average of 1,500 to 2,000 vehicles, with a maintenance cost averaging less than $100 per mile per year. There are, of course, places where field stone is scarce and good gravel plentiful. In such regions we have roads built with 12 inches or more of gravel as a base, covered with 8 inches of crushed stone, but such construction is much more expensive than the heavy-stone base and will not stand as well.

NO STANDARD TREATMENT.

I. W. Patterson, chief engineer, Rhode Island: In discussing the subject, I believe that we must first acknowledge that, on account of varying natural conditions, there can be no standard treatment of subgrades. We have, as in New England, the condition where the subgrades are entirely variable; they may vary decidedly at intervals of from 50 to 100 feet in places. In certain sections of the Middle West, on the other hand, we have a uniformly bad subsoil; and we have the road builders' paradises of New Jersey and Florida, where subsoil troubles are almost unknown. It is useless, therefore, to attempt to arrive at uniformity of subgrade treatment. Each section must work out its individual problem to the best of its ability.

Where a uniform subsoil prevails the failures in various places may be of distinctly different types. They may be complete failure of comparatively long sections, or they may take the form of the frost boil, which is not known in the South.

Whatever the form that the failure takes, there are particular reasons which cause it to take that form, and a study of the conditions is necessary to determine the cause before the condition can be rectified. It seems to me, therefore, that it would be well to give some attention to methods of diagnosing troubles.

DIAGNOSING THE TROUBLE.

The practice we employ is to make an inspection of our roads during a period of thaw in the winter months and again during the spring. The winter investigation is made for the purpose of ascertaining the effects of frost, which are in evidence then and at no other time. The purpose of the examination in the spring is to study the conditions which exist when the subsoil is completely saturated with water, which is not always the case in the winter.

In making such examinations we must not confine ourselves to the consideration of the soils alone. Oftentimes our troubles are not due to qualities inherent in the soil but to other causes. In New England, for instance, some of our worst troubles are due to ledges of rock which outcrop in the subgrade. We often find that what is apparently a perfectly stable soil will give all sorts of trouble locally during the winter months. A diagnosis of the trouble in a great many cases discloses bars of ledge which prevent the flow of water from the high points to the low, and cause areas of the soil to become thoroughly saturated. Such areas are especially liable to give trouble in winter and spring. But whatever the cause of the trouble, it seems to me that the best chance of discovering it is by means of thorough examinations at the two seasons I have described.

Having located the trouble we should consider whether it is better economy to attempt to design a pavement which will bridge across the weak places where the conditions are not uniform, or whether we should develop the subgrade by the use of cheap materials so that a pavement which can be built at a minimum cost will hold up over it.

Another point which should be considered is the very intimate relation between the establishment of grades and the elimination of subsoil troubles. There are places where serious subsoil difficulties might be eliminated in the grading at minimum cost by simply superimposing over the troublesome section a layer of permeable material of low capillarity excavated from some near-by point. It seems wrong to me always to attempt to decide definitely upon the grades and then plan the foundations. The two operations should be carried along together to secure economy.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1916. 5c.
*Report of the Director of the Office of Public Roads for 1917. 5c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul. *105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913. 5c.
*136. Highway Bonds. 25c.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 15c.
*373. Brick Roads. 15c.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A summary.
*393. Economic Surveys of County Highway Improvement. 35c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
*537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
*724. Drainage Methods and Foundations for County Roads. 20c.

Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

* Department supply exhausted.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads.
505. Benefits of Improved Roads.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. 727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. *89. Progress Report of Experiments with Dust Preventatives, 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act. 5c.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
*77. Experimental Roads in the Vicinity of Washington, D. C. 5c.

Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States. 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
*Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918. 15c.
Vol. II, No. 15. State Highway Mileage and Expenditures in theUnited States in 1918. 15c.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D- 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cement.
Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D- 4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D- 6. A New Penetration needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted