

Paper delivered by Thos. H. Macdonald, Chief, U. S. Bureau of Public Roads before the Fourth Annual Meeting of the Highway Research Board, Washington, D. C., December 4-5, 1924.

"Financial Value of Highway Research"

It is highly gratifying to those of us who have been interested in the development of this Board for carrying on highway research to see this attendance and recognize the interest of those who are in the audience. I shall try to set a good example. I think we have come to the time when we can deny to the world at large that research and science are tiresome, high-brow and of no financial value, interesting only as a pursuit for those who labor in dusty laboratories or unventilated libraries.

My topic, The Financial Value of Highway Research, ought, it seems to me, to introduce into this meeting a note of the practical application of those scientific principles and facts which we arrive at through research, and it ought to bring out, it seems to me, throughout these discussions, the actual value in dollars and cents to the people of the United States. Therefore, I do not intend to read a paper, because I feel that time is also the most valuable possession that we have.

Research to me is a vital, living thing, a process which we may compare to the process of refining ores. We begin with a rather large mass, some of which is good and some of which is dross, and we select the good and reject the poor. There are two kinds of research, - first, the analysis of problems to segregate them into their major or essential elements, and second, the intensive study of these essential elements in order to develop them to their utmost. It seems to me that the particular function of the Highway Research Board is to analyze the problems and attempt

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to segregate them into their several elements and distribute these for solution, for study, and for investigation among the research agencies of the United States. Speaking on behalf of the Executive Board, and also for the Bureau of Public Roads, I think I can say it is not our ideal that we should build up in Washington a large or overbalanced research agency of any character. The place to carry on research is in every State, in every laboratory, in every State highway commission, and every place else where we can induce men to think. Without vision the people perish, and that vision cannot be segregated in one place or left to a small group of people. It must come generally and universally.

It would be possible to develop out of this topic estimates of the savings that are being effected by highway research that would run into very large amounts of money. When you consider that there were registered the first of July over fifteen and one-half million motor vehicles, and that the consumption of gasoline in the United States amounts to over six billions of gallons annually, that the tire and accessory bill is somewhere in the neighborhood of eight hundred million dollars, and that we have spent for Federal-aid road construction alone a total of six hundred million dollars, there is some indication of the tremendous savings that may be effected by research which tends to refine any one of the factors entering into this business of highway building and highway transportation.

If you think about the question from this angle - that there are only a very few types of roads, and relatively few types of vehicles, you will see that the refinement in the type of road or in the type of vehicle is multiplied enormously. But I am passing over these savings that might

be calculated in general terms, calling attention to this item of a specific character - the use of the thickened edge in the design of concrete roads by which the old sections have been reduced, at a saving, we will say, of some 390 cubic yards of concrete per mile, which at \$10 per cubic yard would mean a saving of \$3900 per mile. There are 24 States that have adopted this policy or this new type of construction. If each of these States constructed 100 miles of concrete roads constructed per year the saving effected would amount to \$9,360,000, in that item alone in a year.

Take another angle. In Iowa the supply of sand is about three times as great as the available supply of commercial coarse aggregate. That makes commercial coarse aggregate and concrete roads built with it expensive. Since 1913 the Iowa State College and Iowa Highway Commission had carried on a systematic survey of the material resources of the State and up to 1920 undeveloped deposits of gravel had been examined in 62 counties, and a number of the more promising deposits were developed with State assistance. Much of this local material contained from 50 to 80 per cent of sand, and was decidedly variable in character. To utilize it and at the same time secure uniformity in the resulting concrete required that the proportions of the concrete be varied with the varying character of the aggregate. The local materials used were subjected to frequent check tests and, according to the indications of these tests, the proportions were varied from 1:2:3-1/2 to 1:2-1/2:1, with the result that the concrete produced with these aggregates was thoroughly satisfactory and surprisingly uniform. During 1920 and 1921 such local sources of material were developed for eleven of the thirty paving contracts completed during

the period. The average price for the 53 miles in which the local material was used was \$39,300 per mile. That of the 111.6 miles let under the same market conditions but using commercial materials was \$42,000 a mile. The Commission estimated, therefore, that the use of the local materials effected a saving of approximately \$143,000 on the 53 miles of road.

In Iowa, also, as a result of several years study of the various reported researches into the constituents and composition of concrete, and data secured in the field, the highway commission became convinced that the common method of measuring materials by loose volume was subject to considerable error and variation and that if the aggregates were weighed some of the most important of the variable factors could be eliminated. Accordingly this method was tried in a small way on two contracts in 1923. The results were so satisfactory that the procedure of requiring the aggregates to be weighed was adopted as standard. Some fears were entertained that the costs might be increased on account of the additional equipment needed and on account of the fear of the contractors that their operations would be slowed down. But the results showed that these fears were groundless. The years 1923 and 1924 were comparable in respect to labor, material and transportation costs. In 1923 measurement was by loose volume and in 1924 the aggregates were weighed. Comparative unit costs were as follows:

Let and Built in 1923
Loose Volume Measurement

County	Miles	Price per Square Yard
Clinton	2.79	\$ 2.76
"	1.60	2.70
"	2.80	2.76
Greene	2.01	2.45
"	1.53	2.34
Polk	4.95	2.44
"	4.10	2.48
"	4.96	2.48
Scott	7.55	2.77
"	4.79	2.62
"	5.46	2.62
Average Unit Price		\$ 2.60

Let and Built in 1924
Aggregates Weighed

County	Miles	Price per Square Yard
Black Hawk	13.8	\$ 2.39
" "	4.38	2.44
" "	14.00	2.54
Clinton	14.53	2.58
"	1.30	2.42
Greene	17.22	2.63
Polk	5.22	2.385
"	4.71	2.48
"	1.51	2.42
Average Unit Price		\$ 2.51

This general decrease can hardly be credited to the weighing method for the contractors were bidding without much previous experience, but apparently the price was not affected by the new method.

The data collected in the field this year show that the primary object of this refinement, namely improvement in the uniformity of the concrete, has been in some measure accomplished and furthermore the way to other important refinements has been pointed out.

These facts and others of a similar nature, are matters of record.

They represent specific instances of substantial savings effected through research. I now want to take a few minutes of your time for an attack on an attitude of mind, shall we call it, or, perhaps, a current impression that the building of highways by contractors, is an unsafe proposition. I am sure you have all heard contractors bewailing the fact that theirs is not a paying business. Certainly if any of the men who have been engineers of a State highway department or a county department, or have carried on road construction in any way, have ever heard a contractor admit that he has made any money on a job, he has had an experience that is rather different from my own. We are continually met with this attitude of mind - that every contract job for road construction is a losing job. I know of nothing that this convention can attack to better purpose than this feeling that the engineers are crowding the contractors to the wall, or that the contractors are failing to deliver to the engineers. I am not taking a position of antagonism to the contractors. I merely suggest that the feeling that now exists is an exceedingly unhealthy one, and that if there is any basis for it the facts should be brought to light and a remedy found, and that, in my judgment can only come about through research. We have all heard various and sundry excuses offered for the failure of jobs to go properly. I merely suggest that it is time now to investigate these excuses, and determine, on a basis of concrete facts rather than rumor or feeling or any such intangible evidence exactly what foundation there is for the constantly recurring statement that highway building is a losing venture.

We have lately been doing something of this sort in the Bureau of Public Roads, and this is what we find. From the reports of our district

engineers over a period of 14 months the causes assigned for unsatisfactory progress on current work, reduced to a percentage basis, are as follows: Labor shortage, 7 per cent; material shortage, 3.4 per cent; inadequate equipment, 2.9 per cent; financial, 2.5 per cent; management, 27.1 per cent; weather, 33 per cent; construction difficulties, 2.4 per cent; cause not stated, 19 per cent; legal, 0.5 per cent; and preliminary difficulties, 1 per cent.

This is the result of an analysis of the sober reports of our engineers as to causes of unsatisfactory progress. I do not want to be understood as saying that all these jobs are failures. The great majority of them have not gone that far, but all of them are making unsatisfactory progress, and our engineers have tried in each case to place their fingers upon the cause. Now, what I want to direct your attention to, especially, is that when these causes are summarized and analyzed the only items that appear as considerable factors are weather conditions and the management of the contracts. Sixty per cent of the unsatisfactory progress is reported as due to these causes alone. Thirty-three per cent is due to weather conditions, over which it may be said the contractors have no control, although I am convinced that more time is lost because of weather conditions than there is justification for. But, it is the 27 per cent that is attributed to bad management that, to my mind, suggests the field in which research can be employed to the greatest advantage, and I believe the contractors themselves will welcome such research.

We have been making some investigations in that particular field, and we have published recently in Public Roads several reports of what we have found. Thus far we have limited our studies to methods of moving

dirt; there has been no attempt as yet to analyze the complicated processes of pavement construction, so we are not yet prepared to offer concrete suggestions for the elimination of all management losses. I should like to refer to a few of our discoveries, however, merely as indicating a method of approach by which such losses may eventually be materially reduced.

From a long series of studies by stop-watch timing it has been found that the average time required to load, unload and turn wheel scrapers at the two ends of the haul is 2.9 minutes. This time is a constant which is not affected by the length of haul, and, as I say, it represents very closely the actual time consumed on the average job in the performance of these operations. But when we attempt to break down this time into the several periods of which it is composed, that is, the time for loading, for dumping, for turning at the cut and at the fill, etc., we find that only about 75 seconds of the total of 2.9 minutes can be accounted for in these essential operations, and the balance of 99 seconds can only be accounted for as miscellaneous delays, most of which must be preventable by persistent effort on the part of the foreman. To illustrate what this loss of 99 seconds may mean on an actual job let us suppose that the average haul is 400 feet. Our studies show that the average time required to make such a haul is 5-3/4 minutes, which includes the time for the actual haul as well as the time consumed in loading, unloading, etc. Of this time, then it appears that 1-2/3 minutes or nearly 30 per cent is expended to no useful end.

To illustrate what may be done by careful management to eliminate

such losses, I should like to mention a specific case in which such a saving was made. On one of the contracts studied by our investigators the contract price for excavation was 43 cents per cubic yard. When our man arrived on the job it was costing the contractor practically the full 43 cents to move the dirt. The foreman realized in that instance that he was losing money and asked our engineer to help him straighten out the job so we made the job a test of the practicability of our theories, and the results were highly successful. Using the same foreman, the same teams, and the same men, and changing only the character of the management we were able to reduce the miscellaneous preventable delays to such a degree that the cost of moving the dirt was lowered to 34 cents - a saving of 9 cents a cubic yard. In my judgment, much of the difference between profitable and unprofitable highway construction is expressed in that operation, and it seems to me that this body, by encouraging the application of the scientific method to our every-day construction operations as in this instance, has the opportunity not only to help the contractors to increase their legitimate profits and incidentally the quality of their output, but actually to decrease the cost of the highways to the public.

When we are spending in this country each year one billion dollars or more for highway construction and maintenance, is it necessary to develop any further the enormous financial value of highway research when on a single operation a saving of between 20 and 25 per cent can be made by the simple use of stop watches and analysis of the problem. Twenty-seven per cent of the delayed Federal aid projects owe their delay to the

management of the projects, the highest percentage attributed to any cause except weather. To me it seems that highway research will eliminate a very considerable percentage of these delays, will improve the quality of our product, and will give us what I conceive to be the whole reason for highway research, which is: "To direct correctly efforts to attain the widest utility and greatest economy of highway transport for the public."

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