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# 1922 A Banner Year In Federal Aid Road Work

## Over 11,000 Miles Completed During The Year

By H.S. Fairbank, Senior Highway Engineer, Bureau of Public Roads.

Federal-aid road construction reached a new high water mark in 1922 when the mileage of new road added to the growing system of Government aided highways exceeded eleven thousand miles. The exact length was 11,374.7 miles. This was almost twice as much as the mileage constructed in 1921, the best previous year which added only 5943 miles, and it was more than seven times as great as the mileage completed in the first four years of operation under the Federal Aid Road Act.

The total cost of the roads completed in 1922 was over $216,000,000 of which the Federal Government's contribution was more than $90,000,000. This record, both as to total cost and Federal aid payment was nearly twice as great as the accumulated totals for the six preceeding years of operation.

The Federal Aid Road Act was passed in 1916. During the first two years machinery was set in motion for the big work ahead, but not a single mile of road was completed. By the end of 1918 there were 30.5 miles under traffic, and from that time the growth of the work is shown in the table below.

Federal Aid Roads Completed By Calendar Years.

| Year | Miles | Federal Aid | Total Cost |
|---|---|---|---|
| 1918 | 30.5 | $ 197,938.65 | $ 472,044.31 |
| 1919 | 271.2 | 1,084,915.35 | 2,823,836.63 |
| 1920 | 1,229.6 | 6,063,364.03 | 14,037,467.24 |
| 1921 | 5,943.2 | 41,238,012.32 | 94,991,953.93 |
| 1922 | 11,374.7 | 90,643,207.45 | 216,035,582.17 |
| Total | 18,849.2 | $ 139,227,437.60 | $ 328,360,884.28 |

As the table shows the mileage completed up to December 31 was 18,649 miles. These roads were entirely completed and under traffic. The 5,240 miles practically completed at the end of the year is not included. A large part of this mileage was actually completed and it is not included in the total of completed mileage simply because the final payment of Federal aid had not been made. All of it was more than 95 per cent completed, so that it is not far from the fact to say that on December 31 last the mileage of completed Federal-aid roads had reached the total of 24,000 miles.

In addition to this mileage completed or practically completed there was 13,947 miles under construction at the end of the year and approximately 60 per cent complete as indicated by the reports of the Federal district engineers. The reports of progress are made on the basis of projects and it is impossible to say just how much of this mileage under construction is actually complete. A project which is reported as 60 per cent complete may be entirely completed in some sections and in various stages of progress in others; or it may have been brought to an average stage of 60 per cent completion without being actually complete in any part. We do not attempt to enter into this distinction in the gross figures. But as the percentage reported does indicate what part of the work has been finished it is fair to say that work completed on the roads under construction is approximately equivalent to the work necessary to complete 60 per cent of 13,947 miles or about 8,370 miles. Adding this mileage to the 24,000 miles completed or practically completed the work performed on all projects to the end of 1922 may be said to be equivalent to the work necessary to bring to actual completion 32,370 miles of road.

The total of Federal funds appropriated up to the end of the year less the deduction for administration was $388,625,000.00. Of this amount, as shown above, $139,227,437.80 had been paid for completed projects. An additional amount of $70,269,119.08 had been paid in the form of progress payments on projects under construction as part payment of the $149,663,-762.92 allotted to such projects, a further sum of $49,984,248.44 had been allotted to definite projects which had not yet been placed under construction and a balance of $49,749,550.84, was entirely unobligated. Including the newly approved projects, projects for which plans were under way and all projects in the pre-construction stages the total mileage of projects initiated and approved for Federal aid, and in various stages of completion or completed was 45,185.7 miles.

The classification of the 18,849 miles actually completed according to types of construction shows that the mileage of gravel roads is greater than that of any other types. A total of 7621 miles of this type of road had been completed. Concrete with 3542 miles was second in point of completed mileage, and the graded earth roads built in the States which are in the early stages of development reached the total of 3286 miles. The mileage of all types is shown in the following table.

Federal Aid Projects Completed December 1922
By Types of Construction

| Type | Mileage Completed |
|---|---|
| Graded and drained | 3286.4 |
| Sand-clay | 2235.1 |
| Gravel | 7621.3 |
| Water bound macadam | 473.4 |
| Bituminous macadam | 666.4 |
| Bituminous concrete | 681.8 |
| Portland cement concrete | 3542.8 |
| Brick | 310.6 |
| Bridges | 31.4 |
| Total | 18,849.2 |

Omitting the bridges, it will be seen from the above tabulation that what may be called high-type roads, including brick, concrete and bituminous concrete aggregate 4535 miles or about 25 per cent of the total mileage. The intermediate types of bituminous macadam and water bound macadam total only 1140 miles or approximately 6 per cent of the total and the balance of 70 per cent is made up of gravel, sand-clay and earth roads graded and drained.

From the standpoint of cost the percentages of the highest and lowest classes are nearly reversed. The high-type roads which constitute only one quarter of the mileage involve 52 per cent of the total expenditure and the low-type roads involve only 36 per cent.

The average cost of all types per mile exclusive of bridges for the whole period of operation is $16,800. For the year 1922 the cost was $18,500 as compared with $15,400 in 1918.

How much of the increase shown in these figures is due to higher costs of materials, labor and transportation and how much is due to the construction of wider and thicker roads to meet the more severe conditions imposed by traffic does not appear in these figures.

Probably the increase is due in greater part to the latter than to the former.

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**The Penny Wisdom of Overloading Motor Trucks.**

By H.S.Fairbank, Senior Highway Engineer, U.S. Bureau of Public Roads.

Roads are made to be travelled. A very trite statement that-- but it is well to keep it in mind just the same. Highway builders are sometimes accused of forgetting it. It has been charged that they surround the use of their roads with so many restrictions and regulations as to prevent their effective use.

As one who is fairly familiar with the way the highway official sets about his job, I am sure that he never loses sight of the primary purpose of the road for a moment. He looks upon the roads he builds as merely a means to an end - the end, better highway transportation; the roads as improved avenues of highway transport. His first question, when the improvement of a particular piece of road is projected, is-- "What about the traffic?" That question answered, he proceeds to design the road for the traffic it must carry. He seeks to make it strong enough to carry the traffic with safety, keeping in mind, the while that there is an economic factor involved as well as a physical factor. If it were not for this economic factor his task would be easy. He knows how to build a road that will carry an unlimited number of the heaviest vehicles made, and if it were not for the economics of the problem he would build that kind of road everywhere and all the time. But that wouldn't be good highway engineering.

Such roads are very expensive. Not that he balks at mere expensiveness - sometimes he is accused of spending too much money. What he has in mind is that the road, whatever its cost may be, must pay dividends on the investment. And a road can pay dividends in only one way, and that is by enabling those who use it to reduce their cost of transportation by an amount greater than the cost of the road.

Up in Connecticut the Boston Post Road carries an average traffic of 1140 gross tons of commodities in nine daylight hours. This is the actual observed traffic passing four observation stations maintained by the Bureau of Public Roads. Adding one-third, as a very conservative estimate for the full day, we have 1520 gross tons daily commodity movement, which includes the weight of the commodity and the carrying vehicle. Now, from figures based on experiments conducted by the Iowa Experiment Station, assuming gasoline to cost 24 cents per gallon, the cost of fuel alone for moving this tonnage over an ordinary dirt road would be $26.44 per mile per day, assuming the impossible, that such traffic could be carried over a dirt road. The cost of fuel for moving the same tonnage over a paved road would be $11.70, a difference of $14.74 per day. On the basis of 300 days per year the actual saving in fuel alone for moving this tonnage would be $4,422. Suppose the paved highway costs $40,000 per mile - it will probably cost that much. The average interest at 5 per cent would then be $1000 per year, which, deducted from the saving on fuel, would leave a balance which would retire the cost of the road in between 11 and 12 years.

In other words, the saving in fuel consumption alone for the commodity traffic only on this road is sufficient to pay the cost of construction of an expensive road surface, and the tremendous passenger traffic is carried, on this basis, free of cost. That looks like an economical proposition and it is.

But suppose the road we have under consideration carried only 500 gross tons per day instead of more than 1500. It is obvious that the saving in fuel on such a road will not pay for paving it with a $40,000 surface - nor anywhere near it. If this road is to pay dividends it must be improved with a cheaper type of surface. Of course when you cheapen the surface you reduce the possible saving of fuel. The Iowa experiments show, for example, that on a dirt road a gallon of gasoline will carry a ton 14 miles; on a concrete road the same gallon will carry the same ton 31 miles; and a gravel surface will require a consumption of a gallon of gasoline for a 21-mile haul. In other words the gravel surface lies between the paved road and the dirt road in point of tractive resistance. It also lies between the two in point of construction cost, so the engineer immediately thinks of a gravel road for the solution of his 500-ton road problem.

Using the test results given above he figures that the annual cost of gasoline for hauling 500 tons one mile over a dirt road will be $2570. Over a gravel road it would be only $1710, a saving of $860 per year. With interest at 5 per cent this saving would pay the interest charges on an investment of $10,000 and retire the cost in 16½ years. The ten thousand dollars will pay for a mile of gravel road and the economies in repairs, depreciation, time and tires as well as gasoline will make this type of road pay for itself in much less than 16½ years if the traffic is as much as 500 gross tons of commodities daily. In both these illustrations I am neglecting the intangibles of passenger traffic.

And now I come to the point which illustrates the penny wisdom of the overloaded truck. Whether the road be a paved road or a road surfaced with gravel it is designed by the highway engineer to withstand a certain maximum load. For the paved road that maximum is no doubt the maximum legal wheel load - the heaviest load permitted under the laws of the State. So long as that load is not exceeded the chances are that the investment will yield dividends just about as calculated in advance by the highway engineer, but let a few truck owners decide to take advantage of the smooth surface and overload their trucks so that the load applied to the road exceeds the load for which it was designed, and the whole calculation is upset. It doesn't require a great many overloads to ruin a road or run up the maintenance cost so high as to wipe out all the calculated profits. A very few will do it. It is as though you build your warehouse floor to carry ~~200~~ 150 pounds per square foot and then decide to load it at the rate of ~~600~~ 450 pounds. You won't get the chance to do it many times. Just about once will be the finish of the floor.

In the case of the road the results are apparently not so disastrous. The road surface doesn't give way with a loud crash and drop its load ten feet or more. The overloaded truck gets by without suffering the fate it merits, but it leaves a trail of trouble behind - trouble and expense. The operator of the overloaded truck will have to bear his part of the expense, as a taxpayer. Unfortunately his part of the expense will be very small indeed in proportion to the burden he had laid, by his selfishness, on the shoulders of others.

A few years ago the consequences of overloading were very much more apparent than they are now. At that time - during and immediately after the war - we were suffering from the sudden development of heavy truck traffic on roads which had been built in the ante-war years for a far lighter traffic, and coupled with this condition the maintenance of these roads had been neglected during the war because of the mistaken policy which declared road building and maintenance to be non-essential to the winning of the war. Sections of utterly destroyed highway were not an uncommon sight at that time. Such destruction is seldom observed now, because, in the first place the roads are now built to carry heavier loads, and, in the second place, they are more perfectly maintained.

But just because the roads do not give way with a loud crash under every overloaded truck, but appear to go on giving service in spite of repeated violations of the law is no reason for concluding that the piper is not being paid. Listen to Mr. Clifford Older on the cost of overloading. Mr. Older is the chief highway engineer of Illinois. He is a close student of road problems. Under his direction the State of Illinois has recently conducted experiments of the first importance on the Bates Road near Springfield, Illinois. The Bates Road was built to be destroyed in order to determine the ultimate load carrying ability of a number of types of pavement with which it was surfaced. That is simply by way of introducing Mr. Older to ice cream manufacturers and to make it clear that he speaks with authority. I quote now from his remarks at the recent conference of highway officials called by Gov. Pinchot of Pennsylvania just after he assumed office, and he is referring not to any experimental road built to be destroyed, but to one of the most important roads of the State, built to give economical highway service. This is his testimony: "We have a certain piece of highway on which, two years ago, legislation authorized us to employ a highway police force, primarily to control loading. It happens that on that section, about five miles long, heavy hauling has come to stay. Previous to the enforcement of our maximum load limit our maintenance expense on that section was about $12,000 per year. Last year we did enforce our maximum load limit on this one section and the maintenance expense was reduced $10,000 for the year. We did not improve or strengthen the road in order to accomplish this result. It is practically in the same condition as it was before. The difference is due to the enforcement of the law against overloading."

Ten thousand dollars of avoidable expense on five miles of road is $2,000 per mile per year. If we have that expense on the $40,000 paved road in Connecticut that saving of $3422 we counted on to retire the cost of the road would be reduced to $1422, and instead of paying for the road in 11 or 12 years we need the fuel savings of 28 years to retire the debt. That is what overloading means in dollars and cents. However penny wise it may appear to be from the standpoint of the individual truck operator, it is certainly pound foolish from the standpoint of the State - and that means the taxpayers.

What, exactly, constitutes an overload? It is not so simple a matter to answer that question fully. Legally, it consists of a load in violation of the traffic regulations as to maximum gross weight of truck and carried load, maximum axle or wheel load or maximum load per inch of tire width. Actually the maximum gross weight doesn't mean much. Because of the way in which trucks are built and loaded anywhere from 50 to 90 per cent of the total weight of the vehicle and its load may be transmitted to the road surface by the two rear wheels. So a vehicle which with its load may weigh well within the maximum load regulations may still be an overloaded vehicle because its rear axle or rear wheel load may be greater than the law permits. Moreover a truck which violates neither the maximum gross road regulation nor the wheel or axle-load provisions may still have a weight per inch width of tire that is greater than the law allows. For example, let us assume that the legal weight restrictions are as follows:

maximum gross weight 24,000 pounds; maximum wheel load 8,000 pounds; maximum load per inch width of tire 800 pounds. The law in this case would be violated by a three-ton truck (tare, approximately 3 tons) carrying a five-ton load on 8-inch tires, if 45 per cent of the load were distributed to each rear wheel. The gross load of 16,000 pounds would be well within the law; the wheel load of 7200 pounds would also conform to the law; but the weight per inch of tire width would be 900 pounds, a violation of the law.

There are two kinds of overloading recognized by highway engineers and both practices are apt to be destructive to the highways. The more obvious kind is overloading beyond the maximum weight limitation. It is comparatively easy to single out such trucks as they pass on the highway. They are the biggest trucks with the heaviest loads. The other kind is represented by the truck that is "overloaded per capacity"; that is, the truck that carries more than the load for which it was designed. Truck and load seldom exceed the maximum weight limits, but frequently they violate the wheel-load and tire-weight limits, on account of the fact that the carried load is not distributed as is the weight of the vehicle, but is concentrated very largely on the rear axle, and that the tire equipment is based upon the rated capacity of the truck and not upon an overload. Springs and brakes are also designed on the basis of the rated capacity and an overload means abnormal deflection of springs and a heavy strain on the brakes, the first condition imposing higher stresses in the road and vehicle and the second a constant menace to life. But to go into the matter from these angles will be to dig too deeply into the mechanics of the problem. Let us stick to the simple question of weights.

With legal limits as described above, let us consider the case of the 5-ton truck (tare, approximately 5 tons) running on 12-inch tires and loaded with 7 tons of commodity. Here we have an overload per capacity without an overload as to maximum weight. The maximum weight is exactly 24,000 pounds, the legal limit. But as about 90 per cent of the total weight is apt to fall upon the rear axle, the load on that axle would be something like 21,600 pounds or 10,800 pounds per rear wheel; and the weight per inch width of tire would be 900 pounds instead of 800 pounds.

Now let us see if we can form any idea of the effect of this overload on a road surface. The Bureau of Public Roads has been conducting for sometime past a series of experiments to determine the effect of truck loads of various weights on road pavements of different kinds when these weights are applied to the roads with impact, as they are when the trucks are in motion. Pavement slabs of various materials were tested under wheel loads of different amounts dropped upon the slabs from various heights in order to simulate the impact of trucks in motion. In this way it has been learned what thicknesses of concrete pavements and pavements of other types are required to withstand truck wheel loads of various amounts. Taking the concrete road as an example, the simple diagram reproduced on page summarizes a great deal of experimental work, and shows, with a reasonable degree of accuracy, what thickness of concrete road surface is required to carry wheel loads of various amounts. Using curve No. 1 the diagram shows that the center thickness of the road to carry a maximum legal wheel load of 8000 pounds should be at least 5-1/2 inches. Such a road would barely be able to stand the load. It would probably break up under repeated applications of the maximum load after a brief period. Add another inch, so that the thickness becomes 6-1/2 inches and you have a road which will carry the legal maximum wheel load of 8000 pounds with safety. Such a road would fail structurally under the 10,800 pound wheel load of the overloaded truck described above. To safely carry this overload would require a pavement at least 7-1/2 inches thick.

Overloads which are manifested only in excessive weight per inch of tire width are not particularly destructive to paved road such as the concrete and brick types which derive their strength from the concrete slab which serves either as the surface or the base. On such roads the application of the load over a width of 6 inches instead of 4 inches, or 12 inches instead of 8 inches makes very little difference. In either case, so far as the concrete road is concerned, the load is a concentrated load to be carried by the "beam strength" of the slab which acts as a monolith to resist the load. But in the case of gravel and macadam roads, which instead of being monolithic in construction are made up of particles of stone, more or less loosely bound together and free to move with respect to each other when a load is applied, the application of the load over a greater or lesser width is a matter of some concern. The load which, on a 12-inch tire, may be safely carried by a road of this character, may sink into the surface and break the bond of the road if it is carried on an 8-inch tire.

There is another kind of overloading which is not prohibited by the laws of all States. I refer to seasonal overloading. As nearly everyone knows, roads are not capable of carrying the heavy loads in the spring that they carry throughout the rest of the year with safety. This is due to the wet condition of the underlying soil in the spring. It is a condition which cannot be entirely eliminated by any of the means of drainage yet known to the highway engineer. It is a condition which should be recognized in all regulatory laws, and the highway authority should be empowered to make special regulations to protect the roads when they are in this condition. But in the absence of such regulations public-spirited truck operators will be guided by their knowledge of this well recognized condition and reduce their loads accordingly. The amount of reduction desirable can always be ascertained by applying to the State highway department.