U.S. DEPARTMENT OF AGRICULTURE

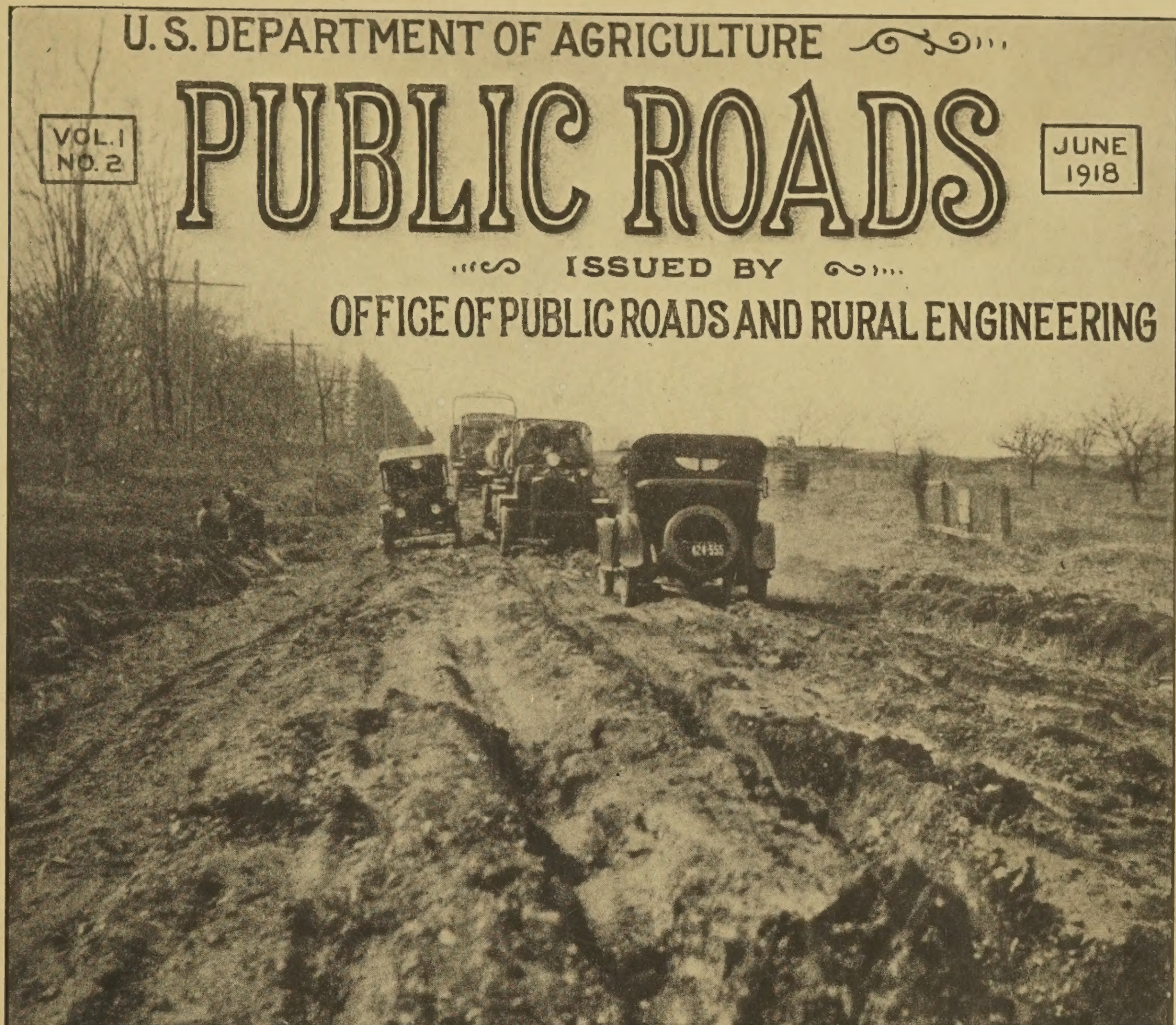
VOL. I NO. 2

PUBLIC ROADS

JUNE 1918

ISSUED BY

OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING



THIS PHOTOGRAPH WAS TAKEN NEAR CANANDAIGUA, N. Y., AND SHOWS WHAT AN EXCESS OF ABOUT THIRTY 7-TON UNITS ABOVE NORMAL TRAFFIC CAN DO TO A MODERN HARD-SURFACED HIGHWAY. ABOUT ONE AND A HALF MILES OF THIS ROAD IS IN LIKE CONDITION

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1918

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

THE U. S. HIGHWAYS COUNCIL

ALL functions of the various Government agencies so far as they relate to streets and highways hereafter will be coordinated in a body called the United States Highways Council, composed of one representative each from the War Department, the Department of Agriculture, the United States Railroad Administration, the War Industries Board, and the Fuel Administration. These representatives, under designation by the heads of their respective departments, held their first meeting June 8, and selected Logan Waller Page, Director of the Office of Public Roads, Department of Agriculture, as chairman, and J. E. Pennybacker, chief of management of that office, as secretary.

The council was formed primarily to prevent the interminable delays, financial loss, and the uncertainty incident to the method of taking up each highway problem in its turn with a separate and distinct Government agency. This council utilizes the efficient organizations of the 48 State highway departments with their trained personnel and their knowledge of local conditions as a medium through which the highway needs of the country may be brought to the attention of the Federal Government. It provides a single agency in the nature of a clearing house, where all highway projects calling for governmental action of any character, whether it be a question of finance, of materials, of transportation, or of war necessity or desirability, may be considered and appropriate action taken thereon.

The complexity of the highway problem can best be understood by a statement as to the manner in which each of these Government agencies is directly concerned:

The War Department constructs hundreds of miles of roads in cantonments and posts and is frequently interested in the highways connecting these cantonments and posts with cities and shipping points. It is also interested in the conditions of great through highways over which Government truck trains are transported. In short, any highway which affects any of the numerous war activities of the Nation is of interest to the War Department.

The Department of Agriculture, of which the Office of Public Roads is a part, has a most direct and far-reaching interest in highways, as the Secretary of Agriculture is intrusted with the administration of the Federal aid road act, which carries an appropriation of $85,000,000 during a five-year period, and calls for an expenditure of at least an equal amount by the State in conjunction with this Federal appropriation. The Office of Public Roads also expends a number of small appropriations under authority to make scientific investigations and to give out information concerning highways. In this educational work, as well as in the Federal aid highway work, it is in constant touch with the highway departments of the 48 States.

The Railroad Administration, controlling as it does all of the facilities of rail transportation, can influence vitally by its action the construction and upkeep of public highways, as vast quantities of crushed stone, gravel, sand, cement, brick, reinforcing and structural steel, and bituminous materials are required to be transported by rail. The acute shortage of open-topped car equipment on account of the needs for shipment of coal, coke, and ore renders it necessary that highway needs be met in a selective manner, so that really urgent work may be done and less important work be postponed. This situation has been met by the issuance of an order by the Car Service Section of the United States Railroad Administration (C. S., dated May 24), which order provides for appeal to the Director of the Office of Public Roads, through the State Highway Departments, where the needs are urgent and the local railroads can not handle the situation. The director in turn brings the appeal before the United States Highways Council for appropriate action.

The Fuel Administration, through its control of fuel, including fuel oils, finds it necessary in order to conserve the supply of fuel oil for the needs of our fleet, our allies, our merchant marine, and our munitions plants, to restrict the use of road oils, asphalts, and tars in street and highway work to really essential needs. In consequence, these materials for highway purposes are delivered by manufacturers and refiners only on a permit issued by the Fuel Administration based upon a recommendation by a committee representing the Office of Public Roads and the Oil Division of the Fuel Administration, this committee forming part of the United States Highways Council.

The War Industries Board, by reason of its control of many of the materials entering into highway construction and maintenance, including cement, crushed stone, gravel, sand, structural and reinforcing steel, and its power to establish priorities, allocate materials, and fix prices, enters very prominently into the field of highway work. Where questions falling within the province of the War Industries Board are brought before the council appropriate recommendation is made through the War Industries Board representative.

The Capital Issues Committee, while not represented in the council, still is interested in highway construction in that under the act approved April 5, 1918, it is required to pass upon bond issues involving $100,000 or more. As there are hundreds of millions of dollars annually voted and sold for highway and street purposes, it is evident that the Capital Issues Committee thus possesses a decisive influence upon the conduct of highway and street work.

The Highways Council has provided a definite form on which application to it for relief may be made and has placed a supply of these forms with the respective State Highway Departments. The council emphasizes the great need of conserving money, transportation, labor, and materials by restricting highway and street work to the most essential needs. It considers the maintenance of existing streets and highways logically should rank first in importance and that the reconstruction of those sections of improved highways and streets which have become too defective for maintenance should next receive attention. New construction is justified only where the highways are vitally important toward the winning of the war or for the movement of essential commodities.

OIL, ASPHALT AND TAR SUPPLY.

ONE of the many striking examples of the manner in which war necessities react upon the routine industrial life of the Nation is afforded by the order recently issued by the Fuel Administration restricting oils, asphalts, and tars for road purposes. The maintenance of the various forms of bituminous construction takes up a large percentage of the normal output of the oil refineries and of the plants producing coal and water-gas tars. Fuel oil has become an increasingly vital necessity for the operation of our fleet, and for the various war needs of ourselves and our allies.

Essential fuel oil requirements at this time necessitate withdrawals from the supply of such bituminous materials as would otherwise be converted into highway material. Hence, the order issued by M. L. Requa, the Chief of the Oil Division of the Fuel Administration, requiring that deliveries of bituminous road materials be made only on permit based upon the recommendations of a committee representing the Fuel Administration and the Department of Agriculture and coordinating with the United States Highways Council, of which Mr. Page, Director of the Office of Public Roads, is chairman.

The question has been asked repeatedly why asphalts and refined tars are classed as fuels. It is true that most of these products can not be used directly for fuel as can many of the fluid oils and tars. It is quite possible, however, to flux or cut back these semisolid or solid products with distillates so as to convert them into fuel oils. Moreover, it is recognized that the use of a considerable tonnage of the heavier products is of vital importance in maintaining roads absolutely essential to war needs. By limiting the use of present stocks of these products the supply of fuel oil is increased by the amount which would be required to replace the heavy products if they are used on roads which, under present war conditions, can not be classed as important. Owing to different and constantly changing production, storage and transportation conditions in various parts of the country, no hard and fast rules can be laid down as to the issuance of permits for the release of bituminous road materials and every application must therefore be considered in the light of its importance and the existing fuel conditions at that time.

The limitation in the bituminous materials for road and street purposes renders it absolutely necessary that the small available supply be so allocated as to take care of the needs of highway and street construction and maintenance in the relative order of their importance. Manifestly, the maintenance of streets and highways is as a general rule of primary importance, and in consequence, the committee carefully scans all applications with a view to giving preference to those which call for material for maintenance purposes, and these maintenance applications are in turn regrouped so that the most heavily traveled and most necessary highways shall receive first place in the approval of the committee. Dust prevention only and the treatment of earth roads with bituminous materials is considered as of least importance, and application for release of materials for these purposes should not ordinarily be made.

After the maintenance needs are met, the next class of highway improvement is the reconstruction of sections of important highway partially or wholly destroyed by traffic, and last will come new construction. In this latter class, preference is given to the filling up of short gaps in main highways and in meeting military needs.

For important work involving the use of large quantities of bituminous materials, permits are frequently granted for a supply which will cover immediate needs, usually for not over 30 days. If conditions warrant, a further release is made.

To the end that a simplified working plan should be put into operation and the most careful scrutiny given to all applications, it was provided in the instructions issued by the Fuel Administration that all the applications for highway work should be made on forms supplied by the Office of Public Roads and should be certified by the State highway department of the State in which the work is located, and the application then forwarded to the Director of the Office of Public Roads. The procedure is set forth clearly in the letter from the Director of the Oil Division of the Fuel Administration, as follows:

"In order that the fuel oil requirements of our Allies, as well as our own Army and Navy, and essential war industries may be fully satisfied, it is found necessary to limit the use of petroleum and coal in the manufacture of road projects, such as asphalt, road binders, road oils, tar binders or dressings.

"The United States is now being drawn upon to an ever increasing extent for petroleum products, especially fuel oil. It will be appreciated that this demand must be satisfied. Commencing this date we request that all highway work in your State of any character, including municipal work, involving the use of the above-mentioned materials, be passed upon by your State highway department. A special permit of the Fuel Administration, Oil Division, will be required before delivery of purchases will be authorized.

"Inclosed you will find forms on which all applications for the above-mentioned road materials must be made. Preference will be given to material for maintenance and repair work. The supply of the above material for road work is so limited that it is requested that all new construction involving these materials be deferred this year except in cases where such work is necessary toward the winning of the war. These forms should be filled out, covering maintenance, reconstruction or new construction, and certified to by the State highway department as to the vital necessity of the work under existing war conditions and the quantity of the material involved. They should then be mailed to Mr. L. W. Page, Director, Offices of Public Roads, Washington, D. C., Mr. Page acting as chairman of a committee which will consider the necessity of the material being supplied and make their recommendation to the Oil Division of the Fuel Administration, which will issue permits in accordance with the recommendation when the necessary material is available.

"It is requested that you give this matter full publicity, so that all parties concerned will be familiar with the procedure necessary to procure supply of these materials.

"Additional supply of inclosed forms can be procured on application to Mr. Page."

THE HIGHWAYS OF THE COUNTRY AND BURDEN THEY MUST CARRY.

APPARENTLY the point has been reached where the demands of traffic have exceeded the strength of the average road to meet them. Highways designed to withstand the pounding of ordinary loads, that have stood up under imposts they were intended to sustain, no longer appear to be adequate to meet the present-day conditions. Congestion on our railways, possibly more acute in some sections than in others, has put upon our roads a transportation burden never expected and consequently not provided for by the engineers who designed the highway systems of the States. Roads have been designed with the same care as given to other structures and with the same regard for the purposes for which they were constructed and the burdens they were called upon to bear. Widespread failure is demonstrative of the fact that roads can not carry unlimited loading. Their capacity is limited. If it is exceeded habitually and constantly, then they can not survive.

The products of our farms and of our factories must be moved. The wants of our urban dwellers must be met. But the needs of our country involved in this great conflict are paramount to the needs of single communities, and thus when avalanches of freight destined to fill the greater necessity made imperative the partial closing of our vast system of rail transportation to the smaller, the relief appeared to be in the motor truck and the highway. Single light units expanded into great fleets, then grew into heavier units that, in turn, developed into long trains. From horse-drawn vehicles with concentrated load of probably 3 tons at most, traveling at the rate of 4 miles an hour, sprung almost overnight the heavy motor truck with a concentrated load of from 8 to 12 tons, thundering along at a speed of 20 miles an hour. The result? The worn and broken threads that bind our communities together. The solution? That is the problem that confronts the men who will be called upon to meet the ever-growing demands upon our highways and to devise regulations fair to those who pay for their construction and to those who pay for their use. State highway officials have been asked to give their views. In the articles that follow they have discussed the problem.

New York Advocates Placing Reasonable Limit Upon Total Load of Motor Trucks.

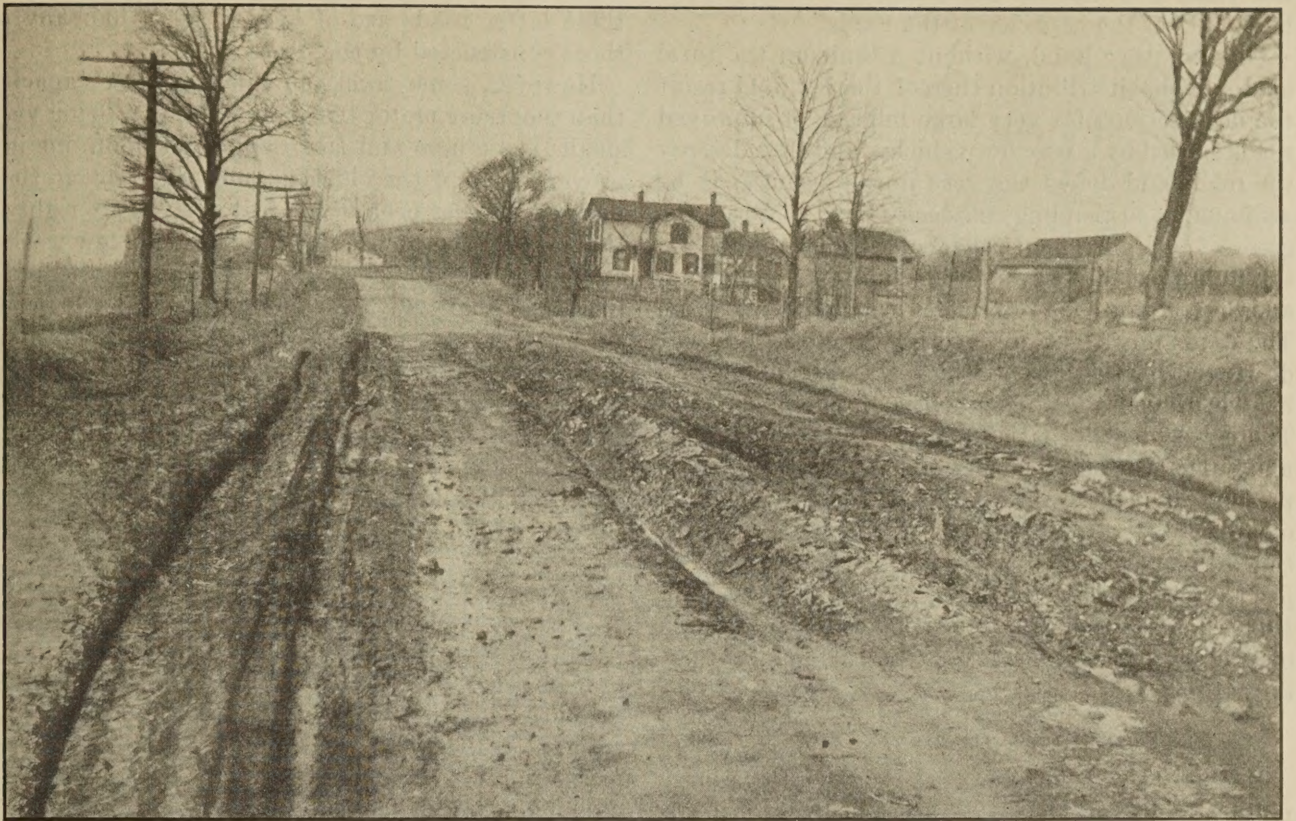
By EDWIN DUFFEY, Commissioner of Highways, New York.

IN common with other States called upon to bear a heavy and almost unforseen increase of traffic inlarge units, New York highways have suffered. No traffic in previous years has equaled the traffic in the critical period of this year.

As examples of what the highways have borne, three stretches of road can be presented. The first, section of water-bound macadam, oiled, constructed 10 years ago at an approximate cost of $10,000 per mile, between Victor and Mendon, has been broken, as shown, by the heavy traffic during the period of frost and the softening of the subgrade, which is of clay. The condition, as shown, prevails over several miles of this road and at present prices would cost about $20,000 per mile to repair. The second example is that of a bituminous macadam road taken about 2 miles east of Lima, Livingston County. This road was built in 1912 at a cost of about $11,000 per mile. During previous seasons this road stood up under all the traffic it was called upon to bear. This year, under probably thirty 7-ton units per day, it has reached its present condition. This extends for probably 14 miles, and it is estimated that it will cost $32,000 per mile to repair.

The third example is town macadam, water bound west of Canandaigua. This has been called upon to carry about thirty 7-ton trucks per day, with the result shown. (Cover.) About 200 feet are shown in this photograph, but altogether there is approximately about 1½ miles in similar condition. The probable cost of repair will be $32,000 per mile.

What can or should be done equitably to meet the unusual repair bills and insure highways capable of carrying the growing burdens is problematical. Prior to 1917 the only law providing for taxation or license of commercial motor vehicles was one that required an annual license fee of $5 per vehicle, regardless of size. In 1916 the legislature appointed a commission to inquire into the subject of license fees which should be paid by commercial and passenger-carrying motor vehicles. An extensive study was made by that commission, but its sole function was to determine in the end upon the fees which should be paid, and in my opinion (for I was a member of that commission) a schedule of fees was adopted and approved by the legislature which was very conservative as to the rates imposed.



MOVING VANS, PRODUCE, AND FREIGHT TRUCKS PUT THIS MACADAM ROAD BETWEEN VICTOR AND MENDON, N. Y., INTO THE CONDITION SHOWN. ESTIMATED COST OF REPAIR IS $20,000 PER MILE.

As far as taxation or license fees are concerned, it seems to me that such taxation or fees should be substantial, but not prohibitive. There is not likely to be much issue at any time over the fees to be charged for the lighter vehicles of either class. The important question will pertain to the heavy vehicles only. I do not see how it is practicable or advisable to attempt to assess to such vehicles their share of the cost of upkeep of highways, without reaching amounts that in effect will be prohibitive.

None of our old roads have been constructed for the extra heavy trucks with trailers. In many cases, especially under favorable conditions, we find our old roads successfully carrying trucks of the 4 and 5 ton capacity, even though it can be scientifically demonstrated that they are not built to do so. We must face the advent of the heavy motor truck. We must permit its use to the greatest weight possible, short of prohibitive injury or wear upon all the roads heretofore built. A reasonable limit upon the total load must be placed, however, and we must at the same time require a proper distribution thereof, or the rapid destruction of our old roads will be the result. We feel that there should be a limit, and if possible a limit that would remain unchanged for a number of years, so that our new roads might be designed to withstand the weights provided for, and our old roads reconstructed in like manner.

DEPENDS UPON LIMIT OF TOTAL LOAD.

There is a tendency on the part of highway engineers to say that the road of the future must be of the heaviest design and of a rigid type. However, if there can be a reasonable limit as to total load, it is quite possible that we can build of heavy design the bituminous type of road without concrete foundation. Such a road, if built, would require perfect drainage in our State, where heavy frost has to be contended with. The concrete type, as far as its carrying qualities are concerned, doubtless would answer the demand. The mixed type of bituminous pavement laid on a concrete foundation would also meet the traffic requirements. The concrete type, as near as a cost estimate can be made under the conditions now confronting the State, will cost for several years to come approximately $25,000 a mile. The bituminous mixed type with concrete base will cost several thousand dollars more. The bituminous type, penetration method, without concrete base but with a well-laid stone base 10 to 12 inches in depth, would cost at least $20,000 a mile. It is essential, if highway building is to proceed along scientific and rational lines, that highway engineers be furnished with the total maximum load and the kind of load which is to be provided for during the useful life of the road. Otherwise we may proceed to build a much heavier type of road than that now generally built throughout the land, and in a very few years find that the loads almost without notice have outrun the capacity of the roads.

On the other hand, without a limit on the total load and the distribution thereof there would result the destruction of a very large mileage of improved roads caused by a very few vehicles, and thus destroy the roads and defeat the very purpose sought to be attained by suspending rules as to limit. Surely the greatest amount of miscellaneous traffic should use the improved highways of the country at all times, and destruction by a few vehicles should be avoided. The roads must be preserved for the many and not destroyed by the few. I think this whole question has been much misunderstood in the popular mind. There is a belief that any restriction of excessive motor loads is selfish in its object and that at the present time these heavy vehicles are serving in a most useful and well-nigh indispensable way. As to the ordinary wear and tear that they cause, the subject may be considered as fairly open for discussion. But when the point is reached where destruction instead of wear is the result a wholly different question arises.

FEARS HEAVIER THAN 5-TON TRUCK.

In this state during the past four months a large number of United States Army trucks crossed our State from Buffalo to New York by way of Albany. The maximum truck that the Government sent to the seaboard is of the 5-ton capacity. The State undertook to provide for this service, regardless of the result. We have at the present time considerable information at hand as to the extent of the injury that has been caused. In some places destruction has been the result. This has been mainly confined to those sections where the oldest and most worn roads were encountered. The greater portion of this route, which is 450 miles long, has up to the present time withstood this heavy service—and that during the spring break-up. This has led us hastily to the belief that possibly we could provide for a truck of this capacity by making heavy appropriations for the repair of our old roads. It has in the same hasty way led us to the hope, at least, that if the Government motor truck were the heaviest vehicle that we had to provide for, our problem, financially and otherwise, would not get to a point beyond our control. If vehicles of greater weight, which would destroy, should be permitted to use all the improved highways of this State, now some 7,000 miles in extent, in such numbers as to bring destruction over a large mileage in a single year, the cost of meeting the situation would be burdensome beyond reason and the work of rebuilding would be so great in extent that it could not be done in the limited time which the public use of our highways would require. In addition to the 7,000 miles of improved highways throughout the State, it should be borne in mind in this connection, from the standpoint of this State, that the counties and townships have improved a mileage of over 10,000 miles, and these latter roads are of lighter type than any of those constructed by the State.

However, some trucks of much greater capacity than the Army motor truck—the number being very small—have here and there appeared upon our improved roads of the old type, and the damage they have caused has been very great. If we are right in this view, based upon the experience of a few weeks, namely, that in some way we can cope with the 5-ton truck and financially bear the burden, and as a result get a restriction as to load of trucks of this capacity, we shall have made much progress. Surely, if the heavy Government truck answers the requirements of our Nation in a time of war, it is fair to assume that it ought to be in maximum capacity adequate for peaceful pursuits.

WHAT REBUILDING WOULD MEAN.

Assuming in case there is no restriction that the number of motor trucks, say, in excess of the 5-ton truck and its load, will in a short time become large, there is much prospect of extensive destruction over the entire system above referred to. In a few years, without restriction, the number of these heavy trucks would be very great. Of course, some of them might reach such a weight as to break through the road at the outset and the amount of damage thus be limited because of the inability of such huge trucks to make progress over roads entirely unable to bear them. The scope of their activity would also undoubtedly be materially limited by the inability of the bridges to bear their loads. But between trucks of such abnormally large size and the truck of 5-ton capacity are undoubtedly many, whose number will constantly increase and whose weight will be such, if unrestricted, as will result in most serious damage.

The improved system in this state constructed up to the present time has cost in round numbers about $100,000,000, and the counties and towns have constructed roads, the cost of which is about $40,000,000. The extent of the financial loss can be estimated in a rough way only, but it is easy to see that, without restriction and with the great increase in the number of vehicles, the actual injury would amount to between one-quarter and one-third of the investment already made. A thing overlooked to some extent at least in a discussion of the matter is the fact that extensive rebuilding and reconstruction would mean for several years an interruption of traffic which would be most deplorable. The system now constructed in this State took nineteen years to build, and if we were to face a general rebuilding of the whole system within the next five to ten years, the maintenance of traffic during such building would be a very serious loss to the counties of the State.

It can not safely be said that the improved road systems now in use in this and many States can, from a scientific standpoint at least, carry loads

THIRTY 7-TON UNITS PER DAY BROKE UP THIS BITUMINOUS MACADAM ROAD IN LIVINGSTON COUNTY, N. Y. IT IS ESTIMATED THAT REPAIRS AT PRESENT PRICES WILL COST $32,000 PER MILE FOR PROBABLY 14 MILES.

greater than the 3-ton truck with load. Large expenditures in the way of strengthening and reconstruction must be made to meet the 5-ton-truck problem. We can not hope to restrict the use of the present improved highway system to those loads which highways engineers could properly say were the maximum the roads could stand, without serious injury and with ordinary maintenance and repair. Again I say that while we expect that we must provide for something greater than this, we must know the maximum load we are to face before either the engineering or the financial question can be met in any sane way.

MANY THINK 3-TON TRUCK BIG ENOUGH.

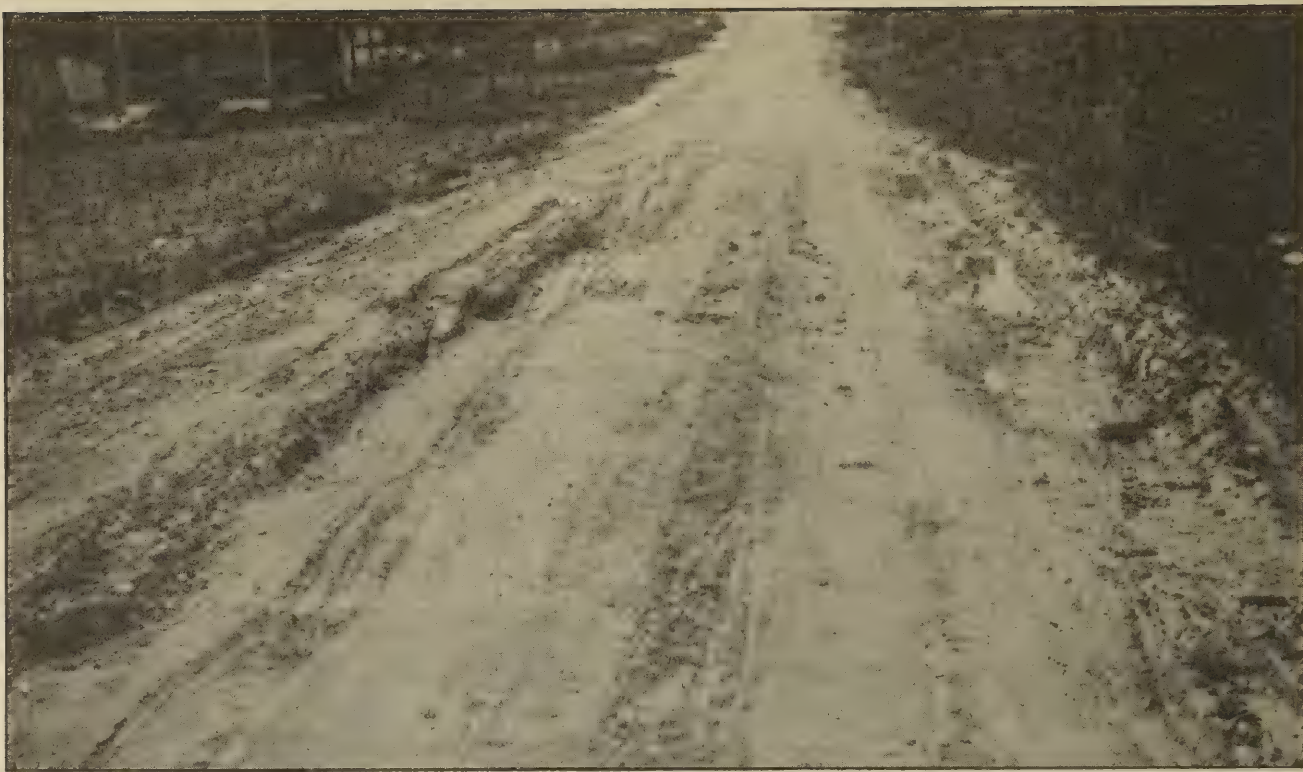
It is the belief of many that the 3-ton truck answers nearly all of the present day requirements. After recent conferences with persons representing truck manufacturers I found that there was quite a general opinion that the 5-ton truck might well be considered the maximum. If the 3-ton truck, or possibly the 4-ton truck, were to be the maximum truck in use, the problem from the standpoint of the highway engineer would be to a large extent solved. We feel that in some way and without revolutionary conditions such a vehicle could be provided for, and all the highways kept continuously open to public use.

In the State of New York during the year 1917, 55,401 motor trucks were licensed, of which 23,462 were registered for use outside of New York City; of this latter number, trucks having a capacity of five tons or over comprised only 6½ per cent, as will be seen from the following tabulation:

Capacity of truck.	Registered in New York City.	Registered for use outside of New York City.
2 tons	15,817	16,547
3 tons	3,963	2,881
4 tons	2,707	1,408
5 tons	2,102	1,081
6 tons	1,610	488
7 tons	1,004	280
8 tons	1,104	292
9 tons	683	115
10 tons	1,261	264
11 tons	953	86
12 tons	455	10
13 tons	116	3
14 tons	79	5
Over 14 tons	85	2
Total	31,939	[1] 23,462

[1] These include trucks used in the cities of Buffalo, Rochester, Syracuse, Utica, and Albany, as well as in 50 other smaller cities.

The whole problem is being considered by this State from the standpoint of the rural improved highway. What shall be used within city limits, where adequate pavements are provided, is another question, and probably should be determined from the standpoint of the city only, and kept wholly separate from the problem as to the rural improved highways.



ON THE BELAIR ROAD AT CHURCHVILLE, MD. THIS ROAD, 14 FEET WIDE, 6 INCHES THICK, MACADAM, CLAY SUBGRADE, WAS CONSTRUCTED IN 1913 AT A COST OF $12,000 A MILE. IT IS WELL DRAINED AND WAS IN GOOD CONDITION PRIOR TO THE SPRING OF THIS YEAR, WHEN THIS PHOTOGRAPH WAS TAKEN.

Abnormal Traffic Causes Maryland To Ask $500 Fee for Heaviest Trucks

By J. N. MACKALL, Chief Engineer, Maryland

THE matter now commanding the attention of the highway officials in almost every State is that of keeping their present roads in repair for the duration of the war under conditions which are abnormal in every way. This is especially true in the State of Maryland.

The road system of Maryland has been constructed during the last 10 years, during all of which time the roads have been built of a higher character from year to year to take care of the almost daily increase in kind and character of traffic. The original roads constructed in Maryland were principally of waterbound macadam, with a width of 12 feet and a thickness of 6 inches. Later the depth was increased to 8 inches and the width to 14 feet, and still later to 16 feet. Within the last few years the roads have been built principally of concrete 14 feet to 16 feet in width, with an average thickness of 6 inches. These roads stood up well with normal maintenance under the traffic which they were called upon to bear. In the spring of 1918, however, the roads began to be subjected to a traffic which it was never intended they should bear, and under which they were unable to stand.

Say! Have You Done Your Share? Well, Do More. Go Over the Top. Save and Keep on Saving W. S. S.

In addition to the abnormal movement of motor trucks over these highways, the weather conditions during the spring of 1918 were probably the worst in many years. The snow and frost during the winter were unusually deep, and a complete thaw came immediately after this frozen condition, rendering the shoulders and subgrades very soft. The abnormal motor-truck movement over these highways has been caused by three conditions, first, the movement of materials to the proving grounds and contonments; second, the tie-up of the railroads required that a great deal of private hauling be done over these roads by motor truck; and third, by the transportation to tidewater of a large number of motor trucks intended for service in France. These motor trucks came loaded with parts, which made the total load in the neighborhood of 10 tons.

VIEWS OF TWO SECTIONS OF THE WASHINGTON-BALTIMORE BOULEVARD IN THE VICINITY OF SAVAGE, MD. THEY WERE CONSTRUCTED IN 1912, COST $12,000 A MILE, ARE OF MACADAM ON A CLAY SUBGRADE, 14 FEET WIDE, 8 INCHES THICK, WITH 5-FOOT SHOULDERS, AND WELL DRAINED. THEY STOOD UP WITH ORDINARY MAINTENANCE UNTIL THIS SPRING.

SEES MAXIMUM IN 10 TONS.

It is well established that the roads shall be preserved for the greatest good to the traveling public, and this presents the question of extraordinarily large trucks and heavy loads. Is the policy of the highway departments going to be one of permitting manufacturers to send over their roads any kind of truck load which they propose to design, or is there going to be a tendency to try to keep these trucks to a size which the roads of the country can stand? It seems to the writer that it is absolutely imperative for the proper care, preservation, and maintenance of the existing roads that the size of motor truck and kind and width of tires shall be controlled to such size as the roads can stand. Just what this size is at this time the writer is not prepared to say, but he does believe that certainly a maximum of 10 tons for a loaded truck is all that should be permitted and probably this will have to be reduced.

It is hardly reasonable to expect that a very few individuals who profit by the use of large heavy trucks should be permitted to destroy the roads which would ordinarily be used by an infinitely greater number of truck and pleasure vehicle owners who desire and have a right to use these roads. It is also well established that the persons who derive the benefit from the road should be the ones to stand the expense of maintenance, and equity would dictate that the charge be directly in proportion to the damage done.

The roads have in most cases originally been built from the general fund of the State, and the general fund should not be called on to pay the expense of maintenance. It would seem, therefore, that the pleasure vehicle and motor truck should pay probably a large portion, if not the entire part, of this maintenance. The pleasure-vehicle owner in the past has gladly and willingly paid his proportion, but the truck owner has in a large measure escaped his share of the burden.

ACTUAL TRIAL TO DETERMINE FEES.

The Maryland Legislature at the 1918 session passed a bill prescribing motor license fees as follows:

Pleasure vehicles, per horsepower	$0.60
1-ton motor truck	20.00
2-ton motor truck	40.00
3-ton motor truck	60.00
4-ton motor truck	100.00
5-ton motor truck	150.00
6-ton motor truck	300.00
7-ton motor truck	500.00

It will be seen from this that the license for large trucks is heavy. Whether or not it is too heavy or heavy enough can be determined only by actual trial.

In Maryland the boulevard between Washington and Baltimore and the road via Belair and Havre de Grace to the Delaware line has failed in a number of places on account of the continued heavy traffic and will require complete rebuilding. To do this and at the same time widen the boulevard, the State plans to expend $350,000.

It would seem that we are justified in drawing the following conclusions from our experience in this State during the past winter and spring:

First. That the size of motor truck should be regulated to such size as improved roads built in the best manner which local conditions will permit, are able to withstand.

Second. That the cost of maintaining these roads should be paid by the traffic using them in as near as possible a proportion to the damage which they do.

Massachusetts Sees the Solution in Limit Upon Capacity and Loads of Trucks.

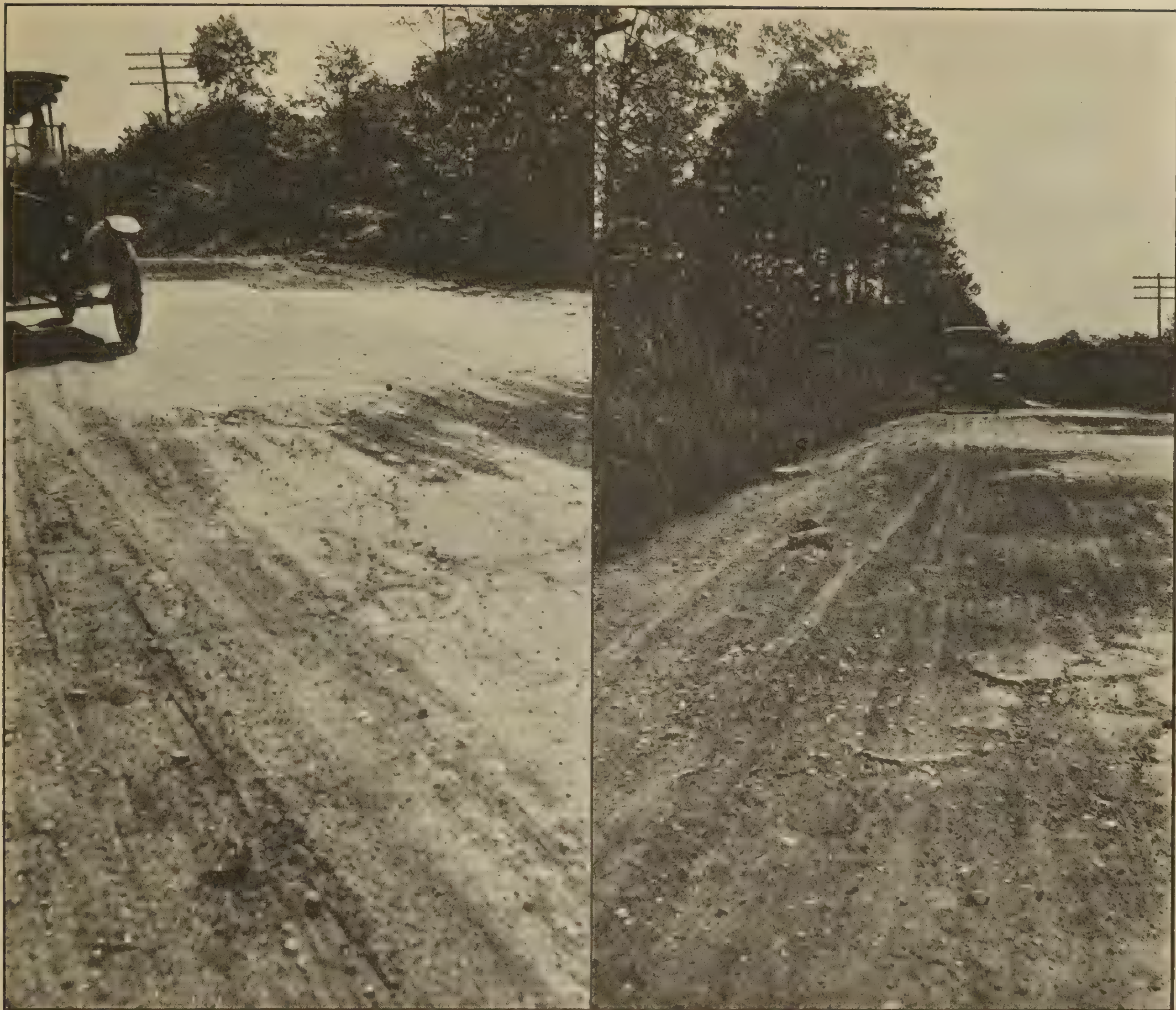
By WILLIAM D. SOHIER, Chairman Highway Commission.

THE road situation in Massachusetts might be summed up as follows:

There are some 1,200 miles of State highway and 800 miles on the same main through routes which have been built under the supervision of the State, but where part of the money was furnished by the counties and municipalities. Besides this there are probably five or six hundred miles more highway on main routes that have been built and are cared for by the towns.

The tremendous increase in motor-vehicle traffic since such vehicles became so numerous has made necessary a very large expenditure, the amount increasing each year, to even reasonably maintain these roads in passable condition. Ten years ago the amount available for the maintenance of State highways was about $100 a mile a year. At that time our engineers estimated that something over $300,000 was necessary in addition, to resurface certain worn-out sections of main road. Two years after this, when the motor vehicles continued to increase, we were actually spending over $300 a mile a year for the maintenance and resurfacing.

The motor-vehicle fees were made available for the maintenance of State highways, but the traffic has increased so fast, especially the truck traffic on the main roads, that while we have nearly $2,000,000 available, it was not nearly sufficient



AT TOP—FAILED SECTIONS ON CONCRETE ROAD BETWEEN ABERDEEN AND ELKTON, MD. AT BOTTOM—THE WASHINGTON-BALTIMORE BOULEVARD AT MUIRKIRK MD., COST \$15,000 A MILE TO BUILD IN 1913. IT IS 14-FOOT MACADAM, 8 INCHES THICK, CLAY SUBGRADE, 5-FOOT SHOULDERS, AND WELL DRAINED. LIKE OTHER ROADS, IT WAS IN GOOD CONDITION UNTIL THIS SPRING.

WATER-BOUND MACADAM, OIL SURFACE TREATMENT, AT WAYLAND, MASS. SURFACING 6 INCHES, BLANKET COAT 90 PER CENT HOT OIL ONE-HALF GALLON PER SQUARE YARD IN 1910, ONE-HALF GALLON HOT TAR PER SQUARE YARD 1909. REBUILT IN 1916, BERMUDEZ ASPHALT PENETRATION, 5 INCHES BROKEN STONE BASE OVER 12 INCH GRAVEL FOUNDATION, WITH 2 1-2 INCH BERMUDEZ ASPHALT TOP.

to resurface and strengthen the various old and weak links in the main routes where some 800 miles of water bound macadam or gravel roads were being rapidly destroyed by this heavy traffic.

Last year the commission spent over $2,000,000 in this maintenance work on State highways alone, and spent about $1,250,000 resurfacing and strengthening about 85 miles of road on main lines and widening 26 more miles.

The average cost for putting on a bituminous surface and patching the road was nearly $500 a mile on the old roads, and this was outside of the resurfacing.

REPAIR COST MAY BE DOUBLED.

To maintain our roads this year will require an expenditure of from 50 to 100 per cent more money for the ordinary maintenance, patching, and bituminous surface treatments on the older roads, because of the increased cost of materials and labor. An average of 100 per cent is a low figure if our main through routes in the country districts are going to be used for long-distance traffic with heavy trucks.

Out of the 1,200 miles of State highway alone in this State, something like 600 miles are 10 years old and have not been strengthened or resurfaced. They are old water bound macadam or gravel roads, the hardened surface being 15 feet and the shoulders 3 feet. They all need resurfacing and widening to at least 18 feet with 3-foot shoulders; but under present conditions this can not be done for less than $20,000 a mile, even if we can secure the necessary bituminous materials.

If heavy trucks carrying loads are used in large numbers, over 2,500 miles of improved water bound macadam and gravel roads in this Commonwealth will be very much injured and quite rapidly destroyed unless very large amounts are spent on them in constantly maintaining them. This can not be done unless the necessary bituminous materials can be secured, because with our main roads having from 500 to 1,000 motor vehicles a day—and it seems likely that they are going to be used by over 100 trucks a day, which is entirely new traffic out in the country—they will certainly go to pieces in a few months and become practically, if not entirely, impassable.

The crops along the sides of the roads, especially the hay crop, for a long distance would be destroyed by the road materials blowing over them. In actual experience we have found during the last eight years that the money was absolutely thrown away on any main highway that we built, if it were water bound macadam or gravel and we could not prevent its being destroyed by the use of some bitumen. A week or two of this heavy truck traffic would disintegrate any water bound macadam we have.

If we are obliged to allow these roads to deteriorate because of this traffic, all the sections which are

A Dollar in the Pocket is a German Dollar, a Dollar Spent Unwisely is a Traitor Dollar, But a Dollar Invested in United States Government Bonds is an American Dollar. W. S. S.

NEAR SUDBURY, MASS. WATER-BOUND MACADAM 6 INCHES THICK, BLANKET COAT ONE-HALF GALLON OF 90 PER CENT OIL IN 1910 AND 1911; ONE-HALF GALLON TAR IN 1909. ROAD BROKEN UP UNDER TRAFFIC, REPAIRED WITH ROAD SCRAPER BEFORE PHOTOGRAPH WAS TAKEN.

not built in a permanent modern way will certainly be destroyed in a few months. It would be a low estimate to say that it would cost from $40,000,000 to $60,000,000 next year to replace them with any type of road that could be built to stand this traffic, whether of concrete or otherwise. Meantime the traffic would be congested and the highways could not be used by the through traffic, because, certainly in wet weather, they would be impassable and at all other times they would be almost impassable because of the holes and ruts that would develop in a month or two.

PLANNED TO USE LOCAL MATERIALS.

We had planned that all of our work this year, whether our own or in combination with the towns, should be confined to the main through routes of great importance, say not more than 10 per cent of the roads in this State. We had also planned to use local material and save car shipments, even when the local materials were of inferior quality but could be used if proper bitumen could be secured. A softer stone or poorer gravel can be used in combination with bitumen. While the roads would not wear as long, we felt that in these times as this work could be done without closing them so they could still be used by the traffic, and as four carloads of bitumen would be sufficient to construct a mile of road which would require 40 carloads of cement or from 70 to 80 carloads of imported stone or gravel, that this would save rail shipments and thereby help the general traffic situation.

We are receiving to-day substantially $2,000,000 from the motor vehicle fees. Without this money not only our roads but a great many miles of town roads that we use these fees on would be destroyed.

The trucks are not now paying their fair share, as our fee is only $5 for the first ton and $3 for each additional ton. In my opinion a much higher fee is necessary unless the Government is going to put very large sums of money into the roads. The States and municipalities could not in these times afford to increase their road appropriation very largely.

England's experience, as well as ours, has shown conclusively that the cost of maintaining a water-bound macadam road, even when the surface had a bituminous treatment, has always been a half a cent a ton a mile, and quite often it has been a cent and a half a ton a mile, and these tables included all classes of vehicles, pneumatic tires as well as trucks. Undoubtedly the cost of repairing the damage done to a road by trucks alone would be vastly greater than that done by the small cars, and would amount to more than one and a half cents a ton a mile. One can readily see that the 1-ton truck which makes 60 miles a day costs for the upkeep of the road 60 cents a day, and for 300 days a year it would be $180 a year. A 5-ton truck damages probably five times as much, or even more, as many roads which would carry a 1-ton truck reasonably well have not a strong enough foundation to carry the 5-ton truck.

SECTION OF THE LENOX, MASS. STATE HIGHWAY. TRAP 15 FEET BY 6 INCHES BY 4 INCHES. RESURFACED WITH TRAP, 10 TONS TO 100 FEET IN 1908. PATCHED IN 1911 STANDARD A ONE-HALF GALLON PER SQUARE YARD, ONE-FOURTH GALLON PER SQUARE YARD LIGHT OIL IN 1914 AND ONE-FIFTH GALLON IN 1916.

URGES USE OF LIGHTER TRUCKS.

Of course it is realized by all road builders, and it should be by the general public, that the country roads built of water-bound macadam or gravel can not withstand city traffic which requires granite block or other pavement, usually upon a concrete base to stand up. Consequently heavy motor trucks will rapidly destroy these country roads that were built for entirely other uses. The rebuilding of them to withstand the tremendously heavy motor truck traffic would be an enormous task and would cost much more than my estimate of $60,000,000 for 2,000 miles of road in this State.

Consequently I hope they will not concentrate too much heavy traffic on these main lines. I would suggest that smaller trucks be used, with lighter loads, 2 or 2½ tons in place of 5 or 6 tons, because with heavier vehicles it would not take a great many of them, in my opinion, to destroy the road, because it has not been built with a sufficiently strong foundation or of sufficiently strong materials to maintain this traffic, and this without any regard to the amount of money that might be available for maintenance.

We should soon be in the condition that the roads are back of the French Army, where they have a man every few feet back of the fighting line constantly spreading material on the road and letting the traffic roll it in, and even at that in wet weather the mud is ankle deep.

An army officer in charge of the roads back of a single British regiment, Maj. Mackendrick, wrote that he had used as much as 2,000 tons of crushed stone in one day in his division, and had 10,000 to 12,000 men at work.

Connecticut Restricts Loads on Roads But Plans to Strengthen its System

By C. J. BENNETT, Highway Commissioner.

THE State of Connecticut, through its highway department, is faced, as are all other States, with the problem of taking care of motor trucks of increased weights. More damage is done by this heavy traffic in the spring, when the frost is coming out of the ground, than at any other season.

Vivid examples of the tremendous increase in traffic and its result are illustrated in two roads, photographs of which are presented herewith. The first, on the Berlin turnpike between Hartford and Meriden, a half mile of which is broken as shown. This road was built of water-bound macadam, cold-oil treated in 1912, has a 7-inch trap rock surfacing with a clay subgrade. The adequacy of the drainage probably is questionable. In 1915 there was practically no heavy truck traffic over this highway.

ON THE BERLIN TURNPIKE, BETWEEN HARTFORD AND MERIDEN, CONN. THIS ROAD HAS BEEN CALLED UPON TO CARRY 200 5-TON TRUCKS PER DAY. THE RESULT IS SHOWN.

In the present emergency there are probably 3,000 vehicles per day, of which 200 are 5-ton trucks. The other example is an earth road with crushed stone top, built in 1913, on the Waterbury-Southington highway. This road is surfaced with 3 inches of trap rock on a clay base and subgrade. Three-fourths of a mile of it is now broken as shown in the illustration. In 1915 the heavy traffic units going over this road did not exceed 50, now out of a maximum of 2,500 vehicles about 250 are of the heavy truck type.

The State roads, when originally built, were not built to carry the excessive truck loads which are now passing over them, and the weakness of these roads develops particularly during the bad subsoil conditions when the frost is coming out of the ground.

There are two remedies for this ill: First, the restriction of weights of trucks and the stopping of truck traffic when the damage is greatest; and, second, the construction of roads sufficiently strong to carry reasonable loads.

It is, of course, impractical to prohibit the use of roads by trucks, even for a short time, however great the damage, and it is also manifestly impossible to construct the roads sufficiently strong to carry any load which may pass over them. Consequently, a compromise must be reached, and this compromise in Connecticut, at least, has taken the following course:

THIS HIGHWAY, BETWEEN WATERBURY AND SOUTHINGTON, CONN., BEARS A DAILY TRAFFIC OF 2,500 VEHICLES, OF WHICH ABOUT 250 ARE HEAVY UNITS.

Loads on four wheels are restricted to 25,000 pounds, except that in special instances which may be designated by the highway commissioner, heavier loads are allowed. License fees are out of proportion, as truck weights increase, which tends to discourage the purchase of extremely heavy truck units and to provide for the purchase of additional trucks or the use of rubber-tired trailers. The effect of these regulations is to limit the truck capacity to that of a 5-ton truck with a reasonable overload.

On the other hand, the State Highway Department has been working along definite lines, looking toward the strengthening of its road system so that little, if any, damage will be done to the roads, providing the above restrictions are followed.

A system of pavements has been designed and is being constructed, in order to allow of the use of motor trucks within reasonable limits. These pavements must have a strong foundation, preferably of Portland cement concrete, and be so designed as to stand the wear and tear on the surface, so that gradually the State highways through the rural sections are becoming of the same character as city pavements.

With the above policy it would appear that eventually a compromised solution of the difficulty would be reached. If all restrictions as to weights of vehicles were removed, the result would be the breaking down of many long sections of highway which have not already been strengthened, and result in the entire stagnation of traffic at certain periods in the year, which must not be allowed. Certainly a 5-ton truck with trailers distributing the load over the surface of the road, rather than centering an extremely heavy load on four wheels, would solve the difficulty.

Solution of the Growing Problem May Be Found in Cooperative Action.

By CHARLES M. UPHAM, State Highway Engineer, Delaware.

WHEN pleasure autos were first introduced the percentage of improved roads was very small; the roads that were improved were generally radiating from business centers, and there were very few improved trunk-line highways. At that time macadam was the universal improved highway pavements. The autos quickly demanded that not only should the mileage of improved roads be increased, but the type of pavement should be changed to something more substantial than the water-bound macadam. Both of these demands have been answered and the mileage of improved roads have been increased and types of pavements have been produced, at moderate cost, that could withstand the passenger auto and light truck traffic.

For a time the new roads stood up under the traffic and certain localities enjoyed good roads; with moderate maintenance the old roads were kept up, and for reasonable cost new roads that could withstand the ordinary traffic had been constructed.

A few medium heavy auto trucks were produced and operated in or near large cities. The city pavements were constructed on good foundations, and no great damage to the pavement was noticed.

The trucks in themselves were a great success. Without any thought or regard of the highways the capacity of the trucks were further increased and their number grew rapidly. They were operated not only in the cities, but in every part of the country, and their effect on the roads was soon felt. It was found that on many of the roads which had been standing up under the ordinary traffic with moderate maintenance the new upkeep was doubled and trebled, and in many cases it was necessary to reconstruct the pavement. The passenger auto demanded that the roads be improved; the trucks are now demanding not only improved roads, but pavements of tremendous strength. This means that thousands of miles of the present roads are not strong enough to withstand the heavy auto trucks, and a large part of the vast amount invested in roads to-day will be lost unless conditions are modified.

There are many roads now being damaged and broken up by auto trucks on which the bonds that paid for their construction have not been retired. The auto truck has made it necessary that a stronger pavement be constructed on these roads, and now, because the traffic demands have surpassed the strength of the road, a new and stronger pavement must be constructed before the expected life of the old one has expired, and thus two roads must be built and paid for while the benefit from only one will be realized.

WOULD LIMIT LOAD ON SINGLE TRUCK.

Just at the present time among the heavy trucks the 5-ton truck is the most numerous. If all pavements were brought up to the strength of withstanding the demands of these 5-ton trucks, what assurance is there that the truck capacities will not be increased after the roads are brought up to the 5-ton standard, and that our roads will not be torn to pieces by still greater trucks? It seems that in order to prevent great economic loss the loads on

ON THE PHILADELPHIA PIKE, FROM TOP TO BOTTOM, 1, 2, AND 4 MILES NORTH OF WILMINGTON, DEL., MACADAM SURFACED, 16 FEET, WITH BITUMINOUS MATERIAL, 1914. SUBGRADE—SAND—ROCK—CLAY. DRAINAGE GOOD. THIS ROAD CARRIED THE ORDINARY TRAFFIC WITH MODERATE MAINTENANCE. ITS CONDITION AS SHOWN IS THE RESULT OF THE PASSAGE OF A FLEET OF 100 HEAVY TRUCKS.

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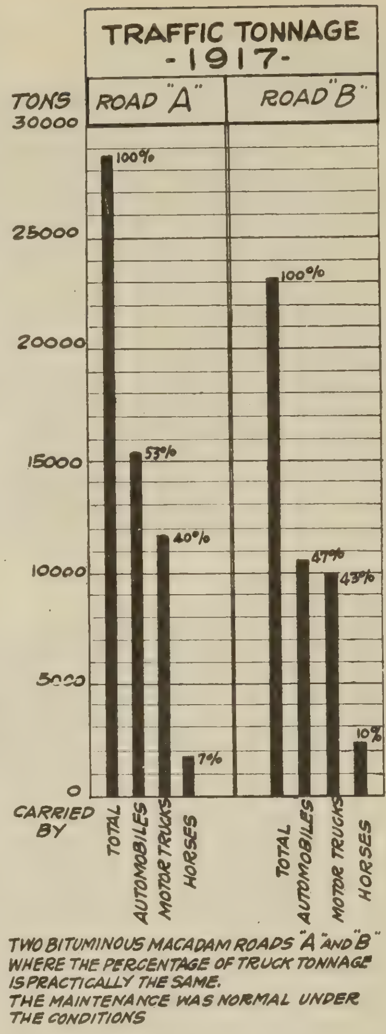
the single] truck should be limited and any load over a certain amount should be carried on trailers, thus distributing the weight.



FACE CHART 1.

Until recently the problem in highway construction has been to build roads that would withstand the various kinds of ordinary traffic. This no longer seems to be the case. We are fast approaching the time when the problem of road construction will be to provide roads that will meet the demands of heavy auto-truck traffic. It seems quite obvious that roads which will carry heavy trucks will stand up under any of the other types of the present-day traffic; therefore it is the truck traffic that should command the attention of the highway engineers.

Now the question arises, if the States, counties, and municipalities have been called upon to invest larger amounts of money in order to build satisfactory pavements, or to provide excessive maintenance to those pavements that have already been constructed, and if this high cost of construction and high cost of maintenance is due to the heavy truck traffic, just what would be a proportionate arrangement and just how much of the road upkeep should the heavy motor truck share as its part in maintaining the highways?

It is readily acknowledged that the large increase of motor trucks has been primarily due to the war, and the greater percentage of the heavy maintenance is due to the damage done by these large motor trucks. If heavy motor trucks were to remain in use only during the period of the war, the problem could be treated in some temporary manner; but the motor truck which has been developed during abnormal times has shown that it has solved an economic problem, and this solution assures us that not only for the period of the war will transportation be affected by motor trucks but that after peace is declared the heavy truck will be utilized in transporting freight and express within expanding limits. Therefore, we should not plan for the truck traffic merely during the war period, but we must build and maintain in such a way that our roads will withstand, as permanently as possible, the demands of the future heavy truck traffic.

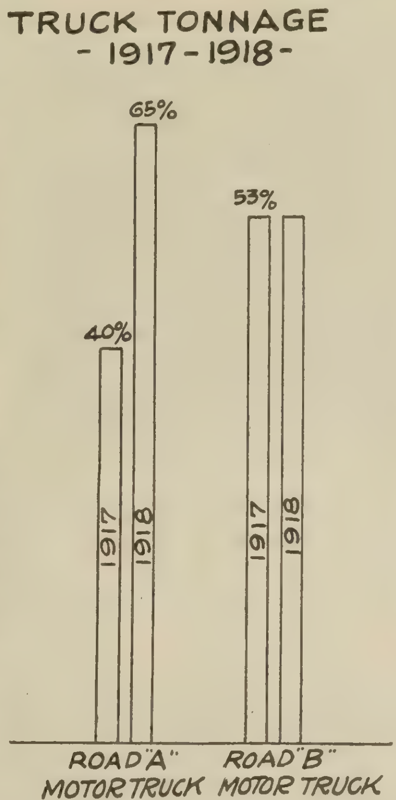
ROAD TAXES AND HEAVY TRUCKS.

In Delaware, previous to 1915, a license for a 20-ton truck would not have cost more than one for a motorcycle, although it can readily be seen that the truck would cause more maintenance than the motorcycle. In 1917 a law was passed which, although far from perfect in making the various types of vehicles pay their proportionate share of the maintenance of the roads, is, however, a step forward in adjusting the tax that should be levied on the various vehicles. This 1917 law is based on the tonnage basis of the vehicle and the expected load. It does not take into account the fact that one truck might be owned by an express company or freight company and be operated day and night, while another of the same rated weight might be used only occasionally. It is evident that the first would cause far more damage to the roads, but both must pay the same license fee.

This points in the direction that heavy trucks should pay the larger part of the road taxes, and this is shown further by data that has been collected relative to this subject, and the experiences of not only Delaware but practically every State.

An example of the damage that the heavy trucks are doing is shown in a road adjacent to Wilmington. This road has been standing the ordinary traffic for three or four years with a moderate amount of maintenance. A manufacturing company purchased a 5-ton truck, loaded it with approximately a 6-ton load, which made the gross load about 11 tons. After this truck began making trips between the factory and the city of Wilmington, the road very soon began to deteriorate, and with the constant hammering of this truck, commenced to break up. As soon as the truck had completed the destruction of the first road and made it too rough to travel, it laid its course over a parallel road between these two points. This road happened to be of lighter construction than the first, and the truck first went over it in the spring when the frost was coming out of the ground. While this road had withstood the demands of light traffic for several years, the first trip of the heavy truck broke it up from one end to the other. A single trip of this truck cost hundreds of dollars of maintenance besides putting the road in such condition that it was too rough for the passage of ordinary vehicles.

Delaware has many miles of macadam road that were constructed and allowed to deteriorate slightly before bituminous coverings were applied. Some of the macadam surface was worn away and the remaining portion was covered with bituminous material. This means that there are now in Delaware many miles of thin-surfaced macadam covered with a bituminous material. This material has been satisfactory for the horse-drawn and light motor-vehicle traffic, but as soon as heavy trucks appeared, these roads which were not capable of standing such heavy loads quickly broke up.



ROAD "A" AND "B" SHOWING THE INCREASE IN TRUCK TRAFFIC ON ROAD "A". MAINTENANCE ON ROAD "A" HAS BEEN EXCESSIVE. TRUCK TONNAGE ON ROAD "B" HAS REMAINED IN THE SAME PROPORTION AND THE MAINTENANCE HAS REMAINED PRACTICALLY NORMAL.

DESTRUCTION BY A SINGLE TRAIN.

A section of the Army transport route between Buffalo and Washington lies in Delaware. On some days as many as 400 trucks have passed over this section which was macadam pavement resurfaced with bituminous material. During the winter, while the road was frozen or covered with snow, trucks had no trouble whatever and apparently did very little damage to the surface. One of the truck trains, however, passed over this section while the frost was coming out of the ground. This one train caused thousands of dollars of damage, and left the road broken up, as shown by the accompanying photographs, which were taken soon after the train had passed. The surface of this road before the trucks had passed was practically smooth and had the appearance of a smooth bituminous macadam. It had been standing up under ordinary traffic with a moderate maintenance. This shows that while these lighter roads are capable of taking care of the lighter traffic, they will not meet the demands of heavy trucks, and we must construct truck roads capable of withstanding heavy truck traffic.

While it has been known for some time that it is the heavy motor truck that is causing great damage to roads, this fact is brought out more clearly by the accompanying charts, which represent the traffic condition on two roads of similar construction.

On Chart 1, Road A, the traffic for an average week showed a total of 11,977 vehicles of all kinds. Road B shows the traffic for an average week ot total 12,411 vehicles of all kinds.

While the number of trucks on each of these roads was practically the same, the truck tonnage hauled over Road A amounted to more than the tonnage over Road B. The percentage of truck traffic over A amounted to 40 per cent, and the amount of truck traffic of the B Road amounted to 43 per cent. Both roads remained in good condition as long as the traffic remained in these proportions.

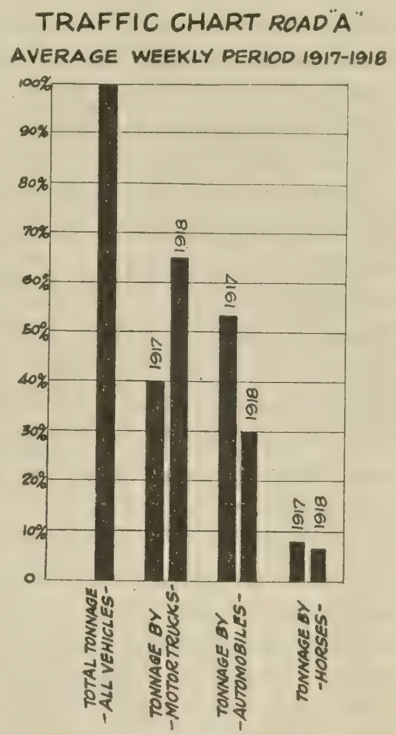


CHART 3

By referring to chart 2, it will be seen that during the spring of 1918 the truck tonnage on B Road remained practically at the same percentage as during the spring of 1917. The truck tonnage on Road A increased to approximately 65 per cent of the total tonnage. The increase in heavy truck tonnage on Road A practically broke up the road for its entire length, and has caused excessive maintenance that has amounted to reconstruction. The maintenance on B Road has remained practically the same for a number of years.

In chart 3 it will be noted that the 1917 traffic shows a greater tonnage of horse traffic and pleasure vehicles than the 1918 traffic, but the heavy truck traffic is greater in 1918 than in 1917. The cost of maintenance thus far in 1918 is considerably more than for the entire year of 1917, or years previous, and this clearly shows that, inasmuch as the horse traffic and pleasure autos have decreased in tonnage, and the heavy auto trucks have increased, that it is undoubtedly the heavy auto truck that is responsible for the high cost of maintenance.

GREATER TAX FOR HEAVIER TRUCKS.

Some have advanced the theory that the license fee for auto trucks should be based on the ton-mile basis. This in itself would be far from satisfactory if no limit were placed on the size of the truck and the maximum load. If there was a limit to the size of the truck and the maximum load, then the greater loads would be distributed over trailers, in which case the ton-mile basis might work to perfection, provided there were some satisfactory means devised for reporting the ton-miles. If there was no limit to the size of the truck, the ton-mile basis would not overcome the great menace, the heavy concentrated loads, for it can be seen at a glance that one 20-ton truck would do infinitely more damage than twenty 1-ton trucks, though the ton-mile tax would be the same. This again shows the reason why the heavier trucks should pay a higher proportionate amount of the road tax.

To stop the building of large auto trucks seems to be standing in the way of progress, but if the cost of maintenance and repair that is made necessary on account of the heavy truck were charged to these trucks themselves, the taxation would be so high that it would be prohibitive, and the use of the heavier trucks would necessarily stop. A large truck can do thousands of dollars' damage to a light road, but we could not expect a truck to pay a license of thousands of dollars.

In view of the fact that there are millions of miles of light pavement throughout the country that will sooner or later be subjected to the demands of truck traffic, it will readily be seen that there will be a great economic loss unless the size of the truck is kept down and made light enough so as not to break down the average pavement we have at the present time.

The problem of truck control is one too large to be handled entirely by the States alone; it is a problem that should not be handled by the truck manufacturers alone, but it should be dealt with in cooperation between the Federal Government, in the control of roads, the State highway departments, the truck manufacturers, and the truck users themselves. From this cooperation and through its sources of information suitable data could be obtained by which the economic maximum size of trucks, the types of satisfactory roads, methods of truck taxation, and traffic regulation could be determined.

It seems quite evident that the width of the truck should be restricted to a certain limit. The excess length, however, does not seem to cause as much concern as any increase over the average width. To allow the width of trucks to expand without restriction, would mean that we would soon be obliged to widen our present-day roads, or reconstruct very wide roads to insure the same safety that now prevails.

The truck trailer has greatly overcome the concentrated loading, and it is quite likely that a more universal application of the trailer will greatly assist in overcoming the heavy loading. To restrict the weight of trucks to a loading that would not injure any of our roads would mean to decrease the size considerably; to allow trucks to go unrestricted over all our roads is going to be very uneconomic; to allow unrestricted trucks the use of all roads and make them pay license fees in proportion to the damage they do would soon prohibit the use of larger trucks; to allow trucks to be constructed larger and larger removes the foundation upon which highway engineers make future plans. A cooperative adjustment of the above factors should present an economic solution of the problem.

There are some roads capable of standing up under 5-ton trucks; others will stand 3-ton trucks without serious maintenance; others will carry the 1-ton truck. Railroads would not send heavy trains over light rails, and why should highways be subjected to loads many times in excess of the loads intended for them?

Until such a time as our trunk-line roads could be brought up to the demands of a standard truck the different highways could be rated, and then any truck in excess of the load that was intended to pass over the highway would not be allowed on that particular road. This would allow heavy trucks on the better roads, and lighter loads on the lighter roads, and would prevent excessive damage to the lighter roads by a few heavy trucks and thus prevent a great economic loss and the destruction of our lighter roads.

New Jersey, One of the Great Sufferers, Plans to Meet Needs of the Future.

By W. G. THOMPSON, State Highway Engineer, New Jersey.

When it is said that New Jersey highways suffered greater damage during the past eight months than during the preceding two years, the statement is hardly exagerated, as roads which for several years presented very good surfaces, became almost impassable under the unprecedented weather and traffic conditions of the past winter. Especially is this condition noticeable along the avenues of heavy motortruck traffic, between the great industrial centers and leading to the seaboard.

It is generally conceded that the geographical position of New Jersey, situated as it is between the great manufacturing States of Pennsylvania and New York, imposes upon it the burden of caring for a greater volume of vehicular traffic than is imposed upon any similar area in the United States. Its seashore resorts attract hundreds of thousands of pleasure and commercial cars during the summer months, while its own enormous industry plus that of its neighboring States pours a never ending stream of heavy motor trucks upon its highways 24 hours per day and 7 days per week. With the entry of our country into the war, this traffic was augmented by thousands of Government motor trucks. All of these classes contribute to the destruction of pavements which were never designed or constructed to bear such heavy, swiftly moving vehicles.

BITUMINOUS CONCRETE ROAD ON THE PHILADELPHIA-NEW YORK MAIN LINE BETWEEN NEW BRUNSWICK AND HIGHTSTOWN N. J., THIS ROAD WAS BUILT IN 1916.

The deterioration of sections of our main trunk highways has been so rapid that the several communities through which they pass have been unable as yet to readjust themselves to enable financing of such a type of construction as will meet the new requirements, though plans and construction are under way by which the counties with their own funds, plus State aid; and the State through its Highway Commission will make strenuous efforts to keep pace with the new and ever-increasing demands.

SUBFOUNDATION DRAINAGE PRIME REQUISITE

The extreme temperature conditions of the past winter have proven beyond any doubt that subfoundation drainage is the prime requisite in maintaining the integrity of foundation and pavement. Ninety per cent of foundation and pavement failures during the past season are directly attributable to lack of, or inadequate, drainage facilities. This is evidenced by the fact that in many instances where, on contiguous sections of road the types of construction were identical, the sections on fill, or well drained, maintained a perfect surface throughout the winter; those sections inadequately drained, heaved and blew up, due to the frost expansion, and in many cases rendered stretches of highway impassable for several days at a time. This condition was unquestionably

ON THE MAIN ROAD, PHILADELPHIA TO NEW YORK, NEAR WINDSOR, N. J. WATERBOUND MACADAM, BITUMINOUS DRESSING, BUILT IN 1915. GOOD IN FALL OF 1917 AND CARRYING 172 HEAVY UNITS A DAY.

aggravated by the continuous motor truck traffic, inasmuch as while light cars and wagons might pass safely over such places, the heavy truck would break through the crust, and immediately upon being extricated would be followed by others, until there was formed a veritable quagmire.

What is the remedy or answer to this very vital question? Shall there be formulated regulations or restrictions as to the size, weight, and speed of these vehicles, or should the several States permit an unlimited development of this traffic and provide for the construction and maintenance of such roads as will carry it, by the imposition upon it of a tax commensurate with the destruction wrought, and based, perhaps, upon the annual income derived from its use by the owners and operators of such vehicles? It is a question which should be viewed and studied only from the most open and broadminded standpoint, as with the increasing inability of the railroads to meet the transportation requirements, the question of highway transportation is becoming one of the most vital this country has to face. Had it not been for the great volume of freight carried by motor trucks on the highways during the winter of 1917-18, the suffering in the congested centers of population would have been incalculably greater, to say nothing of the facilitating of operations of the military establishment, by this rapid and convenient means of inter city and State communication.

MOTOR TRUCK BUSINESS IN ITS INFANCY.

It is realized by all concerned that as regards volume, the motor truck business is but in its infancy. In New York State the increase in number of trucks during the past three years exceeds 300 per cent. What, then, may be expected during the next five or ten years? Maintenance charges on roads are monthly becoming heavier, and to some communities are rapidly becoming unbearable. It would, therefore, seem that since their number can not well be restricted, their weight and general dimensions should be regulated to a point consistent with the ability of the several States and communities to provide highways and bridges of the requisite strength and width to accommodate them.

In February, 1918, the writer was asked by an operator of a motor truck fleet—who at the moment had two heavy trucks stuck in what under ordinary conditions was a very good road—if he could secure redress from the State for the expense and loss of time occasioned by failure of the pavement to carry his loads. When he was advised he could not, his comments were not complimentary to the system which could not keep its roads in condition to carry the traffic. He saw the matter from his own viewpoint only, and while his was possibly an extreme case, it is indicative of the attitude of many on his side of the question.

Although the motor truck business has its tribulations, it is at the same time a very profitable one, and should assist in defraying the expense of maintaining the highways which, more than any other factor, it helps to destroy, and will continue to destroy, even after heavy foundation and proper drainage facilities have been provided on all the main arteries of communication.

It would be hardly proper or fair at this time to attempt to fix an arbitrary amount which should be paid, based upon the tonnage operated by each owner; as sufficient statistics to enable a proper determination of this matter are not available. New Jersey has a varying scale of fees, effective January 1, 1918, and based upon tonnage, the highest amount being $67 for a vehicle and load weighing from 29,001 to 30,000 pounds. In the writer's opinion this is a very reasonable fee, looked at from the viewpoint of effect of such weight running at speed upon the highway, as the cost of repairing damage resulting from the daily use of the highways by such vehicles will amount to many times that sum during the year.

PLANS FOR NEW CONSTRUCTION.

It is manifest to all who have to deal with the problem that none but the highest type of construction will successfully meet the demands of the traffic to come. As an instance of what may be looked for, there is cited the case of one company now operating a fleet of trucks on regular schedule between Baltimore, Philadelphia, and New York, which will within the year operate no fewer than 60 5-ton trucks over New Jersey highways. This company has a regular repair outfit in a light car, traversing the routes traveled by these trucks, lending assistance and making repairs to such of its fleet as may be stalled on the road. The institution of the "return loads" system will tend to decrease the number of trucks returning empty, thus providing for a greater utilization of the available tonnage, and increasing tonnage to be carried by the pavements.

An expression of opinion as to the kind, cost, and general design of highways is apt to be influenced by the local conditions in any particular region. Generally speaking, the greatest care should be exercised in preparing the subfoundation, and no foundation or pavement should be laid where any doubt exists as to the adequacy of the drainage facilities. In many places, these will cost almost as much as the pavement. On main through routes, it is believed none but concrete foundations should be laid. In New Jersey these will be from 6 to 10 inches in thickness. In many places concrete will be used as a wearing surface; in others, bituminous concrete, laid on a concrete base. Pavements should be not less than 18 feet in width plus a 2 or 3 foot stone shoulder on each side. The New Jersey State highway pavements will in no instance be less than 18 feet wide, will have 3-foot stone shoulders on either side, and a graded width of not less than 30 feet. Maximum grades will not exceed 5 per cent or maximum curvature exceed 6 degrees, except in extreme cases. Pavements of this type will cost from thirty to fifty thousand dollars per mile, exceeding the higher figure in some cases where heavy grading is encountered.

BELIEVES REGULATIONS REASONABLE.

It is difficult to say to what extent existing regulations governing motor truck traffic could be suspended. The operation of large trucks is making it increasingly difficult and dangerous for passenger cars and wagons to use some of our routes, due to the unwillingness of drivers of heavily loaded trucks to keep to the right side of the road, as the fear of overturning or running into the ditch causes the truck drivers to keep to the center of the road. It is the writer's experience that such drivers, due to the noise made by their own machines are often unable to hear the horn of a vehicle approaching from the rear, and will keep to the center of the road, thus preventing lighter, faster cars from passing.

On this account it is believed the New Jersey regulations as to weight and dimensions of trucks are not unreasonable, these limits being: Maximum width, out to out, 96 inches; maximum height, 12 feet 2 inches; maximum length, 26 feet 6 inches; maximum weight at present, 30,000 pounds. But one trailer is allowed for each motor truck, though all bridges on State highways will be designed for 20-ton loads.

It is believed that builders should not be restricted to construction of trucks which existing roads can carry, as but few existing pavements will for long carry the loads now being imposed upon them, but rather that builders should be allowed to put out trucks which would come within the limits prescribed above, and that highway departments should build roads to meet these demands.

The illustrations herewith will give a fairly adequate idea of conditions of the New Jersey highways and the traffic they are called upon to bear. On the main road to New York from Philadelphia between New Brunswick and Hightstown there is a bituminous concrete road 18 feet wide with a 2-foot macadam shoulder. This was constructed in 1916 at a cost of $24,450 per mile. The surfacing is 2-inch bituminous concrete on a base of 6 inches of waterbound macadam, with a clay subgrade. It is not well drained. The condition of the shoulders is fair. Although this road is very heavily traveled, traffic uses the shoulders but little, and this would seem to indicate that 18 feet of pavement is about the proper width for two lines of vehicles. The present traffic over this road averages about 760 vehicles per day, of which 115 are of the heavy-truck type.

Another example on the main road from Philadelphia to New York is a waterbound macadam with bituminous dressing on the road near Windsor. This was constructed in 1915 at a cost of nearly $13,000 per mile. The surface is 3-inch waterbound macadam and 1½ inches of bituminous dressing on a 3-inch macadam base, the subgrade being mostly clay. This road was good in the fall of 1917, but at present is in very bad condition. The surface is worn and pitted, the pavement and foundation being broken through in many places by heavily loaded trucks. Out of an average of 682 vehicles per day traveling over this road, 172 are heavy units.

Four Reasons for Saving and Loaning to the Government: For the Safety of Womanhood, For the Protection of Childhood, For the Honor of Manhood, and For Liberty Throughout the World. W. S. S.

The Higher Type of Construction in the Middle West States Also Fails.

By J. L. HARRISON, Office of Public Roads.

IN the middle West the development of truck traffic in increasingly large units has been more of a city than a country problem. This may probably be traced, first, to the fact that large cities are farther apart than in the East and, second, to the fact that there has been less freight congestion and fewer embargoes to force manufacturers to send their goods long distances in trucks. In studying the effect of the increasing truck traffic in this region one must, therefore, supplement the observations made on country roads by observations made on city streets of the same types commonly used on country roads. In the notes which follow there are references both to city streets and to county highways which are near the cities. Both have suffered severely, and, as nearly as can be observed, no type of pavement is immune from rapid deterioration in the face of the heavy traffic many streets now carry.

Washington Boulevard in Chicago presents a wonderful illustration of the effect of heavy truck traffic on roads having a mixed bituminous top laid on a macadam base, a general type of construction widely used on high-class country highways, as well as on many city boulevards and residence streets. This particular street is a part of Chicago's boulevard system, and no heavy teaming is ordinarily permitted to pass over it. However, after the blizzards of last winter this street was cleared of snow sooner than the regular heavy traffic streets, and in order to assist in the movement of traffic a portion of the street was thrown open to heavy traffic for a period of about three weeks. Before this happened the surfacing was in splendid condition, but as a result of the truck traffic which passed over it during this period much of the surfacing has been damaged, and there are considerable areas where the asphalt top has entirely disappeared and where the trucks have removed the macadam base to a depth of a number of inches. The present appearance of the street justifies the impression that the major trouble was in the macadam base, which, though thick enough,to carry the loads, was not stable enough under heavy load to properly support the asphalt top. This pavement is singled out for special comment because the type is a common one, and the results of a brief period of very heavy loading gives an unusually fine opportunity to judge what effect heavy loadings may be expected to produce on such pavements, whether laid in the city or on country roads.

The larger part of the mileage of the county roads around Chicago is macadam, and the truck traffic over them has not yet reached the proportions now to be observed in many other parts of the country. However, West Lake Street and other main outlets all showed the absolute inadequacy of the macadam pavement in the face of heavy truck traffic, for in spite of careful attention and heavy expenditures for maintenance, repairs, and reconstruction, the surfaces of many of these roads were full of pot holes. In the region around Chicago many of the roads are as much as 18 inches thick, but in spite of constant resurfacing fail to stand up in the face of severe truck traffic simply because the heavy loads wear out, grind up, and crush the stone in the surface of the road at such a rapid rate. Moreover, the internal wear in a macadam pavement, always high, is greatly increased by heavy loadings. The load is transmitted downward largely by the friction between the points and edges of the stones which are in contact. Heavy loads overstress these points and edges of contact, which are consequently crushed, the result being that there is constant internal movement in a macadam pavement subjected to heavy loadings, constant abrasion, and much crushing of particles lying even at some distance below the surface.

As a result of this it is natural to expect that such coverings as bituminous mats, penetration tops, and even mixed tops will fail rapidly under heavy traffic when laid on macadam bases. Washington Boulevard has already been mentioned. The Cook County highways which have been surface-treated reveal the same tendency. In general, there is little evidence of poor foundations, but a great deal of evidence of the fact that macadam as a pavement or as a base under a pliable top has a definite load-supporting limit which is dependent upon the hardness of the stones of which it is composed but which, for most classes of stone can be and, in fact, is being exceeded by the loads now permitted to operate freely over the public highways.

The conditions in and around Indianapolis lead to much the same conclusion. The macadam county roads which were inspected were uniformly in bad condition, due to the evident crushing of the surface material accompanied by the grinding action which takes place under the wheels of heavy vehicles and, of course, by dissipation of the dust and binder. For the most part there is no evidence of raveling, which is the usual method of failure where the stone is hard enough to resist crushing strains and abrasion, but where the dust is drawn off by fast traffic and dissipated by the wind. The difficulties ob-

BRICK ON 4 INCHES OF CONCRETE ON THE CLEVELAND-AKRON ROAD NEAR ADSON, OHIO. AT TOP: PAVEMENT STILL IN GOOD CONDITION. BOTTOM: NEAR TWINSBURGH, BASE HAS FAILED, THOUGH BRICK ON THE TOP ARE STILL IN GOOD CONDITION EXCEPT WHERE DAMAGED BY FAILURE OF THE BASE.

served here, as in Cook County, showed themselves in pot holes and indicated the crushing of the surface material under heavy loads.

Detroit is, in a peculiar way, the home of the automobile. No other city in the world makes as many motor vehicles and probably no other city of anything like its size has a street traffic composed so large of motor vehicles. This also applies to Wayne County, in which Detroit is located. Furthermore, owing to the peculiar street layout, the greater part of the city traffic is concentrated on the avenues which radiate from the center of the city much as the spokes of a wheel radiate from the hub and is delivered to the county road system over the county's extensions of these same avenues. Some idea of the intensity of this traffic may be gained from the fact that a recent traffic count showed a daily average of 6,203 autos and teams on Gratiot Avenue and 8,920 on Jefferson Avenue. This count was taken in the city, but the traffic on the county's extensions of these avenues is almost as heavy. The head of the street repair department is authority for the statement that of trucks alone the number passing along some of Detroit's business streets runs into the thousands every day. It is not surprising, then, that the city streets show the effect of this traffic. In many places bricks have been placed in holes on bituminous surfaces as a temporary expedient pending proper conditions for repairs. Wood block pavements show marked indications of over strain and even hard surface pavements show the effect of excessive loadings. Thus on Michigan Avenue, as far out as the new Ford plant, a concrete pavement, built some years ago by Wayne County, and which was in good condition when seen some months ago, has been so badly broken up during the past winter that it is to be resurfaced, and the results here and in other places observed have led the Wayne County officials to plan on an increase in the thickness of their concrete pavements to 7 inches at the edges and approximately 9.2 inches at the center for their standard 18-foot surface.

The same general conclusions seems to have been arrived at by the city's engineers for it is understood that in Detroit 8-inch concrete bases will hereafter be used under the pavements on all heavy traffic streets. To farther protect the highways of all sorts it is planned to secure legislation requiring that all trucks must be provided with rubber tires. It is thought that in this way the gross weight of truck and load can be kept down to about 12 tons. That some remedial action is necessary is evident; but whether this is the proper course or offers adequate remedy remains to be seen.

In Cleveland, as in the other cities, there is plenty of evidence that pavements are being overloaded. However the most picturesque illustration of the effect of overload is not in the city itself but is found on the highway between Cleveland and Akron. This is a well constructed, modern highway connecting Cleveland and Akron. Most of the highway is of brick on various kinds of bases, but there is one section of some 2 or 3 miles which is a mixed bituminous top on a 1–2½–5 concrete base 5 inches thick on the edges and 6 inches thick at the center. This pavement has been broken up and broken through in considerable stretches throughout its length. Illustrations show the nature of these failures. In some other places along this road a 4 inch concrete base under a brick pavement has failed so extensively that it has been necessary to tear the old base out entirely and lay a new base to carry the brick surfacing. The brick have not been damaged by the traffic but the base has been badly broken up.

The loads hauled over this highway are very heavy, in isolated cases being reliably reported as reaching 16 tons on a truck weighing 6 or 7 tons, or a gross weight of about 23 tons. Much of the traffic is in units the gross weight of which will run from 10 to 15 tons. Beside this there is a heavy automobile traffic over the road and much lighter trucking.

In this case the trouble differs from most of the other cases observed for here there is no particular evidence that the traffic is damaging the surface of the road where the base and the sub-base are solid enough to support the loads. In fact many sections of this road are still in good condition, though most of the heavy traffic being through traffic, all of the pavement has been subjected to practically the same amount of heavy traffic. The utter failure of some sections of this highway is patently due to the fact that they have been overloaded and the heavy concrete bases literally smashed to pieces by excessive loads.

Experimental Roads Break Down Under Pounding of Excessive Loads

EXPERIMENTAL roads constructed in the vicinity of Washington by the Office of Public Roads and Rural Engineering, have undergone an experience no different from that of roads in other parts of the country. The Rockville, Md. pike, built in 1913, is a water-bound macadam road 6 inches thick, covered with various types of bituminous mats. It has been carefully maintained and, until this spring, has given good service at a reasonable maintenance cost. Within the past three months, however, the motor traffic over this road has increased rapidly with the result that many holes have been formed in the surface and that maintenance costs have increased greatly. The

BITUMINOUS MIXED TOP ON A 6-INCH CONCRETE BASE. PORTION OF THE CLEVELAND-AKRON (OHIO) ROAD. 1—SHOWS FIRST STAGES OF FAILURE; 2—SAME PAVEMENT, FAILURE COMPLETE BUT NOT YET BROKEN THROUGH; 3—SAME PAVEMENT, TYPICAL COMPLETE FAILURE SHOWING RUTS IN THE SUBGRADE. IN THE FOREGROUND—REPAIRS HAVE BEEN STARTED.

ROCKVILLE (MD.) PIKE. SHOWING FAILURE OF MACADAM

nature of the holes indicates that in some places the loads are crushing the stone under the mats and that in other places the excessive weight of the loads has driven the stone down into the subgrade thus causing rutting and then breaks in the surface.

So far as can be determined, the mats on the surface of this road have all resisted destruction under truck traffic in about the same manner. All have protected the underlying surfacing to some extent but none has prevented its destruction.

ALEXANDRIA-GUM SPRING ROAD

The road from Washington to Alexandria was built in 1915 as an experimental road, the purpose of its construction having been to determine the efficiency of certain forms of bituminous construction. The sections are all bituminous macadam and bituminous concrete, and bituminous gravel concrete tops on gravel and macadam bases and include some twenty types. (For a full description see Bulletin No. 407 U. S. Department of Agriculture.)

The road from Alexandria to Gum Spring was originally improved during 1914–15, having then been surfaced with 7 inches of gravel 14 feet wide. During 1916–17 this road was reshaped and covered with experimental surfacing to a total length of 25,100 feet. For a distance of 24,500 feet a bituminous gravel concrete top 2 inches thick was then laid over the prepared gravel base, and for a distance of 600 feet an earth-oil asphalt top was laid. A detailed description of these tops and the methods of laying them is contained in Bulletin No. 586 of the United States Department of Agriculture.

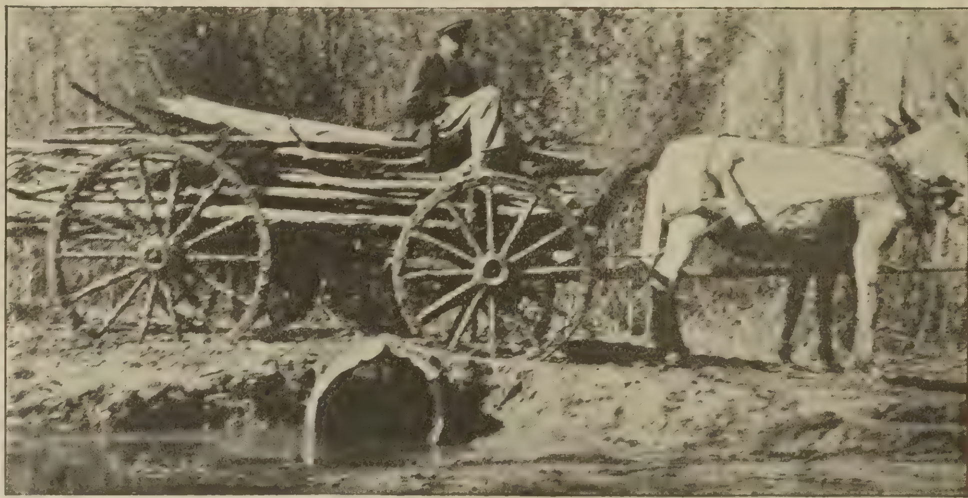
About the first of the year the construction of Camp Humphries led to the transportation of a large amount of building material over these roads especially between Alexandria and Accotink. Traffic records show that as many as 508 trucks per day used the Accotink road. As a result of this traffic the road failed rapidly and so completely that it was abandoned as an experimental road and turned over to the Army engineers for maintenance and repair, as it is being used almost wholly for military purposes. The failure of this road has been so complete that no effort is being made to maintain it as a bituminous road. It has been converted into a plain gravel road and is now maintained as such by the War Department.

The road from Washington to Alexandria did not fail as completely as the traffic over it was not as heavy. However, it was broken through in so many places that in order to prevent its complete destruction the driving of trucks over it has been prohibited and there is now a fine of $100 for violating this order.

ONE OF THE EXPERIMENTAL ROADS IN THE VICINITY OF WASHINGTON—THE ALEXANDRIA-GUM SPRING ROAD—SHOWIMG EARLY FAILURES AND CHARACTER OF TRAFFIC THAT CAUSED THEM.

FEDERAL AID PROJECTS APPROVED.

"MODERN" DRAINAGE ON AN ALABAMA FEDERAL AID PROJECT.



The accompanying photograph, taken on a Federal aid project in Alabama, shows some existing drainage conditions and the great need for road improvement in this section. The "modern" drainage structure portrayed consists of a hollow gum log, which it is proposed to replace by an 18-inch tile pipe with concrete head walls. The present condition of the road is clearly indicated by the appearance of the wagon.

The present location is through a swamp filled in with logs and sawdust from a near-by mill and is practically impassable for any but the lightest loads.

This is a fair sample of conditions existing on many roads in the South and is the cause of widespread interest in the securing of Federal aid.

IN March and April of this year the Secretary of Agriculture approved 212 Federal aid projects submitted by the States. Sixteen plans, specifications, and estimates covering as many of these projects also were approved. The total mileage involved was 2,530.13. To make these improvements the States estimated that they will have to spend $15,651,112.72, toward which Federal aid to the extent of $5,332,336.34 has been allowed. Including projects acted upon up to March 1, the grand totals are: Projects approved, 475; mileage, 5454.84; estimated cost, $34,337,600.34; Federal aid allowed, $13,215,745.55.

Texas leads in the number of projects approved, in mileage, and in the amount of Federal aid allowed. The State has 41 projects passed upon favorably covering 545.195 miles. It estimates that it must expend $2,275,194.13 with a Federal aid allowance of $1,007,350.39. In point of expenditure, however, Texas is outstripped by Kansas, which proposes in six projects of brick, concrete, and macadam construction covering 108.2 miles to expend $2,336,286.85 under Federal allowance of $350,443.02. Kansas also has the high-expenditure single project of $852,032.50 for 27½ miles of brick construction in Barton County.

Twenty-eight projects involving 125.1 miles were approved for Wisconsin. The State estimates that this will cost $969,847.10, toward which the Federal Government agrees to contribute $323,282.57. Minnesota, in 11 projects undertakes to approve 283.9 miles at a cost of $775,424.22 with Federal aid of $325,865.40. North Dakota had 19 projects approved. These 7,265.61 miles for which it is estimated $364,085.44 will be expended, with $184,042.69 Federal aid.

Though Indiana had but two projects with a total of 16.05 miles, the proposed construction is brick or concrete and will cost $533,030 with Federal aid of $200,500.

The largest single item of Federal aid allowed was $157,216.89 for 48.45 miles of earth to be built in Oregon at a cost of $400,433.79.

The following tables give a complete detailed record of all Federal aid action upon projects during the months of March and April.

ACTION ON FEDERAL AID PROJECTS DURING THE MONTHS OF MARCH AND APRIL, 1918.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Project agreement executed.	Estimated cost.	Federal aid allowed.
Alabama	10	Butler	8.07	Sand-clay, or top soil		Mar. 16	$27,071.65	$13,535.82
	23	Coffee	9.305	Sand-clay		Mar. 13	23,304.35	11,652.18
	26	Cleburne	3.48	Gravel		Apr. 30	23,296.46	11,648.23
	27	Lauderdale	4.00	Chert		Apr. 13	24,000.00	12,000.00
	29	Tuscaloosa	6.03	Gravel		Apr. 25	19,885.25	9,942.62
Arizona	2	Maricopa	3.78	Concrete	Apr. 17		77,077.00	37,800.00
	4	Yuma	50.68	Earth	Apr. 18		128,700.00	64,350.00
Arkansas	13	St. Francis	4.94	Gravel	Mar. 14		26,180.00	5,467.10
	14	Jefferson	5.17	do	Mar. 19		21,400.50	10,000.00
	15	Prairie	4.50	Bituminous gravel	Mar. 25		25,197.83	10,000.00
California	10	Modoc	10.85	Earth	Apr. 13		69,188.35	34,594.17

ACTION ON FEDERAL AID PROJECTS DURING THE MONTHS OF MARCH AND APRIL, 1918—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Project agreement executed.	Estimated cost.	Federal aid allowed.
Colorado	2	Huerfano and Las Animas	77.00	1 mile brick or concrete, balance gravel or macadam.	Mar. 19		$260,191.91	$130,095.95
Delaware	1	New Castle	6.20	Brick	Apr. 13		493,009.00	31,000.00
Florida	1	Okaloosa	10.45	Sand-clay		Apr. 25	34,083.28	17,041.64
	2	Osceola	4.12	Brick		do	69,678.53	20,000.00
Idaho	3	Custer	20.00	Earth	Apr. 18		69,425.00	23,000.00
	4	do	1.33	do	do		8,052.00	2,000.00
	5	Lemhi	38.00	do	Apr. 13		299,787.40	135,000.00
	7	Custer	18.00	do	Apr. 18		76,034.00	25,000.00
Indiana	3	Johnson	3.75	Brick or concrete	Mar. 6		99,435.00	37,500.00
	4	Putnam and Hendricks	7.25	do	Mar. 22		189,000.00	72,500.00
	5	Wayne	1.50	do	Mar. 6		47,300.00	15,000.00
	6	Clay and Vigo	4.25	do	do		107,520.00	42,500.00
	8	Hamilton	3.30	do	Mar. 8		89,775.00	33,000.00
Iowa	10	Calhoun	18.40	Gravel	Mar. 30		80,608.00	22,297.55
	14	Harrison	18.20	Earth	do		69,740.00	27,803.60
	16	Montgomery	16.00	do	do		57,266.00	16,557.20
	18	Clinton	18.30	Gravel	do		89,991.00	27,686.45
Kansas	2	Labette	44.50	Gravel or macadam	Mar. 26		510,099.39	76,514.91
	3	Barton	27.50	Brick	do		852,032.50	127,804.87
	4	Shawnee	10.00	Concrete	do		273,400.60	41,010.09
	6	Bourbon	6.39	Macadam	Apr. 29		50,175.75	7,526.36
	7	Douglas	18.34	Concrete	do		444,510.00	66,676.50
	11	Sedgwick	7.375	do	do		206,068.61	30,910.29
Massachusetts	7	Hampshire	4.61	Macadam	Mar. 5		123,890.80	46,100.00
	8	Worcester	6.896	Bituminous macadam	do		163,374.00	68,960.00
Michigan	11	Alpena	5.52	Gravel	Apr. 6		43,356.50	21,678.25
	12	Iosco	9.718	do	Mar. 4		66,000.00	33,000.00
	13	Livingston	6.382	do	Mar. 13		91,533.20	40,136.50
	14	Barry	4.399	do	Mar. 4		47,512.57	23,756.28
	19	St. Joseph	3.97	do	do		42,978.65	21,489.32
	20	Van Buren and Kalamazoo	5.585	Concrete	Mar. 22		137,960.24	55,850.00
	21	Kalamazoo	6.00	do	Mar. 19		110,724.40	55,362.20
Minnesota	1	Pine	50.00	Gravel		Mar. 26	172,150.13	80,000.00
	9	Sherburne	8.00	do		Apr. 25	34,334.06	15,000.00
	14	Carver	26.5	do	Apr. 9		49,280.00	20,000.00
	16	Anoka	17.1	Macadam	Apr. 13		91,731.20	45,865.40
	19	Goodhue	4.6	Gravel	Apr. 9		20,000.00	10,000.00
	24	Morrison	52.6	do	Apr. 29		127,600.00	50,000.00
	27	Douglas	37.5	do	Apr. 24		76,194.80	25,000.00
	28	Grant	5.00	do	Apr. 17		22,000.00	10,000.00
	30	Wright	27.2	do	Apr. 13		83,600.00	30,000.00
	31	Kandiyohi	24.0	Earth	Apr. 29		37,070.00	15,000.00
	32	Lyon	31.4	Gravel	Apr. 13		61,464.03	25,000.00
Mississippi	14	George	13.8	Sand-clay	Mar. 30		20,955.00	10,000.00
	16	Simpson	8.4	Gravel	Mar. 5		20,313.09	10,000.00
	20	Walthall	16.8	do	Apr. 29		60,857.50	20,000.00
	23	Pontotoc	2.5	Macadam or gravel	do		16,707.73	6,500.00
	24	Marshall	6.76	Slag or gravel	do		21,332.47	10,000.00
Missouri	4	Boone	3.00	Bituminous macadam	Mar. 18		21,458.36	10,729.18
Montana	2	Wibaux	17.00	Gravel	Apr. 18		22,440.00	11,220.00
	3	Carbon	3.00	Gravel	Apr. 22		16,412.00	8,206.00
	4	do	3.50	do	Apr. 29		15,600.20	7,800.10
Nebraska	1	Lancaster	5.44	Brick		Mar. 25	205,844.87	35,695.00
	3	Hall	32.10	Earth	Mar. 5		39,531.58	19,765.79
	4	Cedar and Wayne	61.25	Sand-clay	Apr. 25		59,525.51	25,698.75
	5	Madison and Platte	52.25	Earth and sand-clay	Mar. 7		53,166.52	26,583.26
	7	Kearney, Adams, Clay, and Nuckolls.	84.50	Sand-clay	Mar. 5		86,773.52	43,386.76
	10	Lincoln	19.00	Earth	Apr. 13		45,100.00	22,550.00
	12	Logan and McPherson	17.5	do	Apr. 9		20,878.00	10,439.00
	16	Kimball and Bonner	26.5	do	Apr. 6		25,575.00	12,787.50
New Hampshire	[1] 10	Grafton and Merrimack	1.55	Gravel	Mar. 6		16,007.31	8,003.65
	[1] 11	Merrimack	1.52	do	Mar. 5		9,937.84	4,968.92
	12	Rockingham	1.75	do	Mar. 6		11,989.89	5,994.94
	14	Coos	.95	Bituminous macadam	Apr. 6		15,150.82	7,575.41
	15	Merrimack	1.73	Gravel	Apr. 25		11,979.44	5,989.72
New York	6	Rockland	5.57	Concrete or macadam	Mar. 14		110,000.00	55,000.00
	7	St. Lawrence	3.5	Bituminous macadam	do		55,000.00	27,500.00
	8	Wayne	3.21	Bituminous macadam or concrete.	do		63,900.00	31,950.00
	9	Fulton	1.06	Macadam	Apr. 6		20,950.00	10,475.00
North Carolina	19	Rockingham	8.22	Top-soil	Mar. 2		24,218.96	10,000.00
	20	Yadkin	7.00	do	do		16,544.44	5,000.00
	21	Person	7.55	Sand-clay or top-soil	Mar. 14		17,934.29	5,000.00
North Dakota	3	Williams	30.5	Earth	Mar. 15		39,658.04	19,829.02
	4	Richland	20.00	do	Mar. 14		13,407.43	6,703.71
	6	Eddy	5.5	1.4 miles gravel, 4.1 miles earth.	do		6,653.53	3,326.76
	7	Stutsman	9.2	Earth	do		12,972.96	6,486.48
	8	Eddy	9.5	Gravel	Mar. 19		23,949.24	11,974.62
	9	Grand Forks	3.6	do	do		11,456.50	5,728.25
	10	Pierce	5.00	1 mile gravel, 4 miles sand-clay.	Mar. 16		7,999.64	3,999.82
	11	Cavalier	7.8	Earth	Mar. 19		7,190.92	3,595.46
	12	Barnes	29.6	4.4 miles gravel, 25.2 miles earth.	Mar. 18		47,775.09	23,887.54
	13	Stutsman	7.9	Earth	Mar. 14		15,080.19	7,540.09
	14	Stark	18.9	do	Mar. 8		18,944.26	9,472.13
	16	Grand Forks	6.9	Gravel	Mar. 19		17,295.12	8,647.56
	17	Griggs	17.5	Earth	Apr. 4		21,707.40	10,853.70
	18	Ramsey	4.51	do	Mar. 18		3,729.17	1,864.58
	19	do	17.1	do	Mar. 26		12,032.90	6,016.45
	20	Wells	18.00	do	do		19,992.50	9,996.25
	21	Bowman	17.7	do	do		15,999.50	7,999.75
	23	La Moure	10.00	do	Mar. 22		11,491.41	5,745.70
	24	Stutsman	26.4	do	Apr. 1		56,749.64	28,374.82
Ohio	8	Knox	4.00	Brick or concrete	Mar. 5		163,893.40	40,000.00
	9	do	2.01	do	do		65,289.13	10,000.00
	10	Wayne	5.00	Bituminous macadam or brick.	do		140,662.50	50,000.00
	11	Ashtabula	11.92	Brick or concrete	Mar. 6		431,790.00	119,000.00
	12	Wayne	6.71	Brick	Mar. 5		170,541.95	50,000.00
	13	Williams	2.05	Macadam or concrete	Apr. 2		49,690.56	14,698.50
	14	do	2.69	Concrete	Mar. 26		66,209.60	19,287.30
Oklahoma	3	Oklahoma	2.04	Brick, concrete, or asphalt	Apr. 6		46,472.80	20,400.00
	4	Comanche	2.68	Concrete	Apr. 24		53,600.00	26,800.00
Oregon	6	Grant and Wheeler	48.45	Earth	Mar. 25		400,433.79	157,216.89

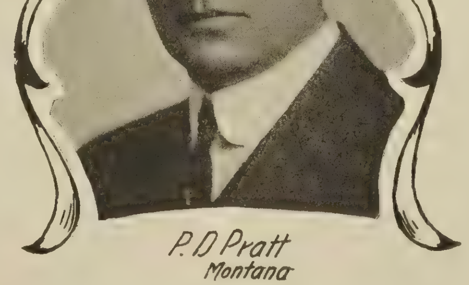
[1] Withdrawn by Highway Department.

ACTION ON FEDERAL AID PROJECTS DURING THE MONTHS OF MARCH AND APRIL, 1918—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Project agreement executed.	Estimated cost.	Federal aid allowed.
Pennsylvania	5	Somerset	7.45	Brick or concrete		Mar. 29	257,217.07	74,500.00
	6	Blair	3.01	Concrete		Apr. 19	91,319.08	30,100.00
	7	Lawrence	4.98	do		Apr. 1	180,746.50	49,800.00
	[1] 8	Erie	5.454	do		Apr. 2	154,962.25	54,540.00
	12	Northampton	5.9	do	Apr. 6		194,700.00	59,000.00
	15	Beaver	11.1	do	do		427,350.00	111,000.00
	16	Butler	3.3	do	Mar. 7		127,050.00	33,000.00
South Carolina	3	Greenville	4.9	1 mile concrete, 3.9 miles topsoil.		Mar. 13	35,540.37	16,502.31
South Dakota	1	Codington	11.24	Gravel	Apr. 6		47,972.10	19,415.84
	3	Grant	11.8	do	Apr. 13		34,127.78	17,063.89
	4	Brookings	6.5	do	Apr. 6		19,946.30	9,973.15
Tennessee	3	Franklin	10.89	Macadam	Apr. 29		83,784.72	40,000.00
	4	Moore and Bedford	12.27	1.37 miles macadam, 10.9 miles gravel.	Apr. 27		78,657.65	39,328.82
Texas	10	Williamson	21.5	Bituminous gravel	Apr. 29		106,375.50	50,000.00
	11	McLennan	1.25	Asphaltic gravel surface	Mar. 16		10,003.07	5,000.00
	12	do	3.5	Bituminous gravel	Mar. 13		25,003.00	12,500.00
	14	Wise	42.3	Gravel	Mar. 30		170,000.00	80,000.00
	17	Mason	24.0	Sand-clay, and gravel	Mar. 18		22,533.50	11,266.75
	18	Franklin	12.15	Gravel	Mar. 14		49,500.00	24,750.00
	19	Eastland	28.3	do	do		117,983.80	35,000.00
	21	Gregg	24.6	Bituminous macadam	do		57,995.72	19,000.00
	22	Dallas	3.00	Surface-treated macadam	Mar. 5		20,401.48	10,200.00
	23	do	3.00		Mar. 22		14,000.00	7,000.00
	24	do	1.00	Concrete	Mar. 5		20,000.20	10,000.00
	25	do	3.00	Surface-treated macadam	do		19,999.98	10,000.00
	26	Titus	8.00	Bituminous gravel	do		56,039.69	28,019.84
	27	do	11.25	do	do		19,800.00	9,900.00
	28	Morris	10.88	Sand-clay	Mar. 16		65,200.54	32,600.00
	29	Val Verde	3.64	Gravel	Mar. 18		25,687.90	12,843.95
	30	Jasper	13.6	do	Mar. 6		71,696.90	30,000.00
	31	Bexar	18.18	Bituminous gravel	Mar. 22		110,080.76	55,040.38
	32	Harris	3.183	Bituminous concrete	Mar. 16		113,221.22	34,602.19
	33	do	4.592	Bituminous gravel	Mar. 19		48,592.50	15,397.81
	34	Dickens	6.5	Gravel	Mar. 16		32,439.00	15,345.00
	35	Guadalupe	15.7	Bituminous gravel	Mar. 18		69,789.50	34,894.75
	36	Caldwell	15.8	Gravel	Mar. 14		77,061.82	35,000.00
	37	Fayette	11.00	Bituminous gravel	Mar. 18		73,546.00	36,773.00
	40	Bell	36.93	do	Apr. 26		99,963.00	49,981.80
	41	Tarrant	10.00	do	Mar. 16		68,740.65	34,370.32
	42	do	6.2	do	Mar. 18		28,619.25	14,309.62
	44	Robertson	5.5	Gravel	Apr. 13		27,890.50	13,945.25
	45	Hemphill	17.00	Sand-clay	Apr. 25		19,646.00	9,823.00
	46	Gillespie	18.6	Gravel	Mar. 22		41,899.00	20,000.00
	47	Collingsworth	10.5		Apr. 24		10,010.00	5,000.00
	49	Nolan	13.7	Gravel	Mar. 19		43,709.60	21,854.80
	52	Callahan	12.1	do	Apr. 9		50,453.70	25,226.85
	55	Camp	8.00	Gravel or macadam	Apr. 6		69,816.00	17,454.00
	59	Victoria	10.00	Bituminous shell	Apr. 10		33,594.00	15,804.00
	61	Wichita	5.12	Bituminous gravel	Apr. 24		46,158.75	12,500.00
	63	Fannin	7.7	Gravel	do		52,714.15	26,357.03
	66	Comal	19.6	Bituminous gravel or macadam.	Apr. 29		41,250.00	17,500.00
	67	Wheeler	34.82	Sand-clay and gravel	Apr. 24		69,330.05	34,665.02
	68	Gonzales	29.5	Bituminous gravel	Apr. 27		119,116.30	59,583.15
	69	Aransas	10.0	do	Apr. 25		55,331.10	13,841.88
Utah	2	Weber	9.6	Macadam	Mar. 7		32,818.75	16,409.37
	4	Emery and Carbon	63.00	Earth	Mar. 5		109,923.00	54,961.50
Washington	7	Lincoln	8.29	Gravel or macadam	Apr. 19		59,827.02	28,768.56
West Virginia	2	Taylor	2.00	Brick	Mar. 30		57,420.00	8,000.00
	4	Marion	2.4	Concrete	do		43,461.00	13,000.00
	5	Monongalia	2.6	do	do		60,247.00	18,000.00
	6	Mineral	0.78	do	do		12,762.25	6,381.00
	7	Wetzel	1.30	do	do		30,319.30	8,645.00
	8	Wayne	2.00	do	do		60,930.00	8,930.00
	9	Jackson	1.00	do	do		19,958.45	9,979.23
	10	Mason	5.89	do	Apr. 6		133,000.00	16,530.00
	14	Mingo	8.00	Earth	Apr. 17		74,525.00	8,075.00
	16	Barbour	3.2	Bituminous macadam	Mar. 30		33,334.40	8,075.00
	17	Brooke	1.00	Brick and macadam	do		30,872.16	6,080.00
Wisconsin	1	Racine	3.2	Concrete		Mar. 5	53,316.94	17,772.32
	2	Manitowoc	0.61	do	Mar. 25		22,161.92	7,387.30
	3	Kenosha	1.5	do	Apr. 18		28,429.50	9,476.50
	4	Shawano	7.33	Gravel	Mar. 22		36,102.00	12,034.00
	5	Oconto and Marinette	6.58	do	Apr. 13		32,232.84	10,744.28
	6	Oconto	3.01	do	Apr. 24		11,706.75	3,902.25
	7	Waukesha	3.66	Macadam	Mar. 19		29,975.00	9,991.66
	8	Dane	3.4	Concrete	Mar. 22		75,622.27	25,207.42
	9	Kewaunee	1.496	Gravel-macadam	Mar. 16		9,152.00	3,050.66
	10	Walworth	1.82	Concrete	Mar. 25		34,518.00	11,506.00
	11	Milwaukee	2.23	do	Mar. 22		51,678.00	17,226.00
	12	Dane	2.73	Macadam	do		29,645.00	9,881.66
	14	Dunn	4.95	Earth	do		12,342.00	4,114.00
	16	Pepin	2.34	Gravel	Mar. 29		13,612.50	4,537.50
	17	Eau Claire and Chippewa	8.83	Concrete or brick	Apr. 26		169,488.55	56,496.18
	18	Oneida	2.00		Mar. 26		7,424.78	2,474.92
	19	Price	6.9	Earth	Mar. 22		20,790.00	6,930.00
	20	Langlade	6.21	Gravel	Apr. 29		38,995.02	12,998.34
	21	Brown	3.807	Concrete	Apr. 24		80,977.87	26,992.62
	22	Polk	15.3	Earth	Mar. 26		35,138.40	11,712.80
	23	Lincoln	4.15	Gravel	Apr. 24		29,699.78	9,899.92
	25	Marquette	4.16	Topsoil	Apr. 29		17,518.60	5,839.53
	27	Forest and Florence	6.29	Earth	Apr. 9		22,499.99	7,499.99
	30	Kenosha	1.43	Concrete	Mar. 25		27,933.67	9,311.22
	31	Taylor	7.05	Earth	Apr. 6		17,594.50	5,864.83
	37	Portage	5.98	Gravel	Apr. 29		23,900.80	7,966.93
	38	Marathon	8.00	do	do		44,908.60	14,969.53
	39	Racine	0.93	Concrete	Apr. 27		21,752.50	7,250.83
	40	Sheboygan	2.41	Bituminous macadam	Apr. 24		24,047.10	8,015.70
Wyoming	6	Converse	7.5	Earth	Apr. 18		7,689.00	3,844.50
	8	Park		Four bridges	Apr. 6		8,564.52	4,282.26
	19	Natrona	42.72	Concrete, sand-clay, and earth.	do		219,735.59	109,867.79
Total	212		2,530.13				15,651,112.72	5,332,336.34

[1] Sections A and B.

SOME HIGHWAY BUILDERS.



HERE ARE SOME OF THE MEN WHO HELP TO BUILD THE HIGHWAYS OF THE UNITED STATES. FROM TIME TO TIME PUBLIC ROADS WILL PRESENT PHOTOS AND SKETCHES OF OTHER STATE OFFICIALS ACTIVE IN ROAD CONSTRUCTION.

Austin Bradstreet Fletcher, highway engineer of the State department of engineering of California and executive officer of the California Highway Commission, is a graduate of Harvard and of Lawrence Scientific School, from which he received the degree of B. S. in C. E. in 1893. Immediately thereafter he became secretary and chief executive officer of the Massachusetts Highway Commission, which office he retained until January 1, 1910, when he became the secretary-engineer of the San Diego County Highway Commission. He has held his present position since September, 1911, with the exception of a short period on leave of absence in which he was chief engineer of the Office of Public Roads and rural engineer, August and September, 1916. In addition to his other duties he has those of chairman of the State Reclamation Board and member of the executive committee of the State Council of Defense. Mr. Fletcher is a member of the American Society of Civil Engineers, American Society of Testing Materials, American Society for the Advancement of Science, American Society for the Promotion of Engineering Education, American Concrete Institute, Boston Society of Civil Engineers, American Association of State Highway Officials, American Roadbuilders Association, Boston Engineers Club, Harvard Club of San Francisco, and other organizations.

Alexander W. Graham has been State highway engineer of his native State, Missouri, somewhat more than a year. After receiving his degree of B. S. in C. E. from the University of Missouri, he entered the employ of the United States War Department on the low water survey of the Mississippi River. Later, for about five years, he was associated with a firm of consulting engineers in his own State, acting as field engineer on preliminary surveys, borings, investigations, and constructions of bridges, pavements, and street railways. He was resident engineer on some of the largest construction work in the Middle West, among which are the bridges over the Mississippi near Keithsburg, Ill., the Armour-Swift-Burlington bridge at Kansas City, and the Yellowstone River bridge in Montana.

A. R. Hirst, State highway engineer of Wisconsin, was born in New York in 1881. Immediately after graduation from Maryland State College in 1902, he worked six months with the construction corps, Pennsylvania Railroad. Then he entered the employ of the highway division, Maryland Geological Survey, where he remained until 1907 when he went to the Illinois Highway Commission as engineer in charge of construction. A year later found him highway engineer, highway division, Wisconsin Geological Survey, where he remained until the creation of the Wisconsin Highway Commission in 1911, when he became chief engineer of the commission with the title of State highway engineer.

W. S. Keller, B. C. E., University of Alabama, State highway engineer of his native State, began his career in private practice immediately after graduation. After seven years he became assistant engineer of Shiloh National Military Park, where he remained five years, later going as chief engineer to the Madison County, Tenn., Good Roads Commission. Three years later found him superintendent of road construction in the United States Office of Public Roads, then again chief engineer of the Madison County Good Roads Commission. He was county engineer of Dallas County, Ala., for a year and received his appointment as State highway engineer in April, 1911.

Paul D. Pratt, engineer of the State highway department of Montana, has lived in that State for 21 years, and is a graduate, with the degree of Engineer of Mines, from the State School of Mines. He followed mining engineering in Butte until 1907 and then for 10 years was engaged in the practice of general mining and civil engineering in Lincoln County. With the organization of the present State highway commission he received his present appointment.

Clifford Older, chief highway engineer of Illinois, was born in Wisconsin, and graduated from the University of that State 18 years ago. For six years following his graduation he was in the employ of various railways and then became bridge engineer with the Illinois Highway Department, remaining in the service of this department from that time. He was made chief engineer in November of last year.

PENETRATION NEEDLES.

The Journal of Agriculture Research for March 13, 1916, published an article by Charles S. Reeve and F. P. Pritchard of this office in which a new needle for making the penetration test on bituminous materials was proposed. This needle was later adopted as standard by the American Society for Testing Materials. This needle overcame the objection of the commonly used No. 2 sewing needle in that it could be more accurately described and so prepared that all needles would be exactly alike. It was designed to yield substantially the same values as No. 2 needles which had been accepted as standard.

Owing to war conditions and the fact that tool and instrument makers have been overburdened with war work it appears practically impossible at this time to have the manufacture of these needles undertaken commercially and testing engineers and chemists who are desirous of following the recommendations of the American Society for Testing Materials have been unable to locate a supply. The Office of Public Roads and Rural Engineering has, therefore, in an effort to relieve the situation, prepared a number of the needles in its own shops for use in connection with public-service work. These needles will be loaned upon request, but in order that they may be distributed as widely as possible at the start the supply will be limited to one to each laboratory, which may be retained as a standard for the selection of sewing needles which yield the same values.

ADEQUATE RIGHTS OF WAY.

By J. T. BULLEN, District Engineer.

In one of the parishes of Louisiana, the police jury (which is a body having the authority usually invested in county commissioners in other States), about six years ago determined to put an end to the uncertainty of road boundaries or rights of way. Accordingly, they passed an ordinance declaring all roads, then in use by the public, as public roads, and the Louisiana law is so framed that any such roads 10 years after said declaration become public property, unless closed to the public before the expiration of 10 years.

A resolution was also passed that no public road would be granted on any petition unless said petition was accompanied by actual deeds to not less than 40 feet of right of way. It was further required that the parish engineer inspect each proposed new road and report on the adequacy of right of way and feasibility of location for a road.

In the event any property holder along the route of proposed road refused to donate right of way, the police jury required that the other parties interested in opening the new road pay for right of way over objecting property owner or guarantee in writing to pay any costs of condemnation.

This had a tendency to shut off the opening of many useless roads, secured a recorded deed for the new road when opened, and the recorded survey definitely located boundary for all time.

Where heavy fills were necessary, greater widths of right of way were required, and usually not less than 50 feet was secured.

In the South, where the settlement along roads is comparatively thin, now is the accepted time to make economic locations and to obtain rights of way sufficient for future development. With the wide right of way the earth for embankments can be borrowed from the side of road and the borrow pits serve as very useful drainage ditches and to some extent as underdrains and take care of the heavy rainfalls usual to this climate.

County officials everywhere should realize that economic location of highways is of prime importance before the settlement of the country makes the cost of rights of way for correct locations prohibitive. One county in the South spends millions on its highway system and the rights of way are so narrow and crooked that a very large part of the bond issue now being agitated for adequately surfacing the roads must be spent in paying for wider rights of way along better locations.

County authorities frequently lose sight of the fact that the right of way is one of the few things about a highway which, when secured along a proper location, needs no renewal, but is in reality permanent.

THE COMMERCIAL SIZES OF BROKEN STONE AGGREGATES

A report of present practice in the New England and Middle Atlantic States.

By

F. H. JACKSON, JR., Assistant Testing Engineer, and C. W. MITMAN, Aid in Minerai Technology.

IN the summer of 1917, the authors visited a number of representative commercial stone-crushing plants located in the New England and Middle Atlantic States for the purpose of collecting data bearing on those features of plant design and operation which affect the actual sizes of the various grades of broken stone used in road construction and in concrete. This survey comprised the first portion of a general investigation of the subject of commercial crushed stone sizes, which has been undertaken by the Office of Public Roads and Rural Engineering with the object of developing standard sizes and uniform nomenclature for crushed stone aggregates.

The first use of mechanically broken stone in road construction appears to have been as early as 1860, when some paving work was done in the city of Hartford, Conn., with stone broken by means of a newly invented jaw crusher. It was not for many years after this, however, that an attempt was made to screen the product of the crusher into different sizes. In fact, the earliest record the authors have found of the use of a revolving screen for this purpose was as recent as 1890, thirty years after the invention of the jaw crusher. The first revolving screens probably were of the single screen type with one size of holes and were designed solely for screening out material over a given size. The simple expedient of combining two or more screens on one shaft for the purpose of separating the crusher product into different sizes naturally was the next step in the evolution of the industry. During the era of road improvement immediately preceding the introduction of the automobile, when waterbound macadam construction was the principal type of broken-stone road, a 3-section screen was all that was necessary, in the way of screening equipment, to produce the required materials. Furthermore, the nature of the work was such that it was not necessary to pay particular attention to the actual sizes produced other than to see that the material for each course came approximately within the limits specified. The introduction and general use of automobiles, however, has been responsible for the rapid development of many types of bituminous and cement concrete roads designed to meet present-day traffic conditions, which types require special sizes of broken stone, often graded within comparatively narrow limits.

The demand for these special sizes of broken stone has led to the establishment at advantageous points throughout the country of stationary crushing plants designed and equipped to turn out six or seven grades of stone from the same crusher product and with daily capacities running as high as six or seven thousand tons. Unfortunately, the great number of methods or modifications of methods which have been advocated and used in the construction, especially of bituminous macadam and bituminous concrete roads, has resulted in the production of a large number of different sizes of stone for essentially the same kind of work. Thus the crushing plant operator must be equipped not only to supply stone for each type of construction, but he must be ready, on short notice, to change his screen equipment in order to meet possibly minor variations in requirements for size of materials.

Experimental road construction has progressed so rapidly along lines developed by numerous engineers working independently of each other that a multiplicity of minor variations in grading are now being specified for comparatively few actually distinct types of roads. The basis of designating sizes of materials also has developed unsystematically so that distinctly different grades of stone frequently are known by the same name in localities often but a short distance apart, and vice versa. This naturally has caused much confusion in placing and filling orders, often resulting in financial loss to one or both parties concerned. Taking all these facts into consideration, it would seem that maximum efficiency in the operation of stone-crushing plants in general has been prevented by the utter lack of system in adopting and specifying stone sizes in vogue at the present time.

It was with the object of collecting information as to the actual conditions obtaining throughout the country along these lines that the survey of stone crushing and screening plants was begun. It was decided to conduct the investigation by stages, covering a relatively small section of the country at first and then studying and reporting the results obtained before continuing. That part of the country included by the New England and Middle Atlantic States was chosen as the starting point, and each producer in this section, as shown by lists furnished by the United States Geological Survey, was requested to cooperate with this office to the extent of allowing representatives to go over his plants and to collect such information relating to his crushing and screening methods as he was willing to give out. From the replies received a little less than one-half the total number of crushing plants in the sections visited were selected for detailed study. With a total of 90 plants thus chosen, it is believed that a fair representation has been obtained of the practices in vogue for both small and large scale operations on the various types of rock. Of this total, 41 plants in the New England States and 49 in the Middle Atlantic States were visited.

PLANTS INSPECTED.

Beginning in Connecticut, nine plants operating in the trap-rock area in the south-central portion of the State were visited. The scale of operation which probably is most easily illustrated by the daily output of stone, ranged from 100 to 5,000 tons, thus representing plants equipped with from one crusher and one screen to those equipped with as many as nine crushers and seven screens.

The survey in Massachusetts was not so simple as that in Connecticut by reason of the fact that a greater number of rock types occur scattered throughout many sections of the State. Stone-crushing plants, for instance, working in granite rock were visited in the extreme southeastern section as well as in the vicinity of Boston and in the northeastern portion. So-called trap-rock areas were studied in and near Boston and also in the west-central portion, while plants working in rhyolite, dacite (grouped under the name felsite), and sandstone, all located within a 15-mile zone of Boston, likewise were visited. The majority of these plants were of small capacity for one of two reasons. First, and this is true of practically all of the plants working granite, the industry is established primarily for the production of dimension or building stone and crushed rock is produced only from spalls or quarry waste which was of little use prior to the era of cement concrete construction and the bituminous treatment of highways. Second, many of the plants are owned and operated either by the smaller municipalities whose requirements do not justify a large-scale equipment, or by individuals who have a restricted market for their stone because of the lack of railroad transportation facilities.

Vermont, New Hampshire, and Maine are represented by visits to three, two, and one plants, respectively, all working in granite. In four cases, crushed-stone production is subordinate to the manufacture of building stone and hence is not a large operation. In the other two cases, one in Vermont and one in New Hampshire, the quarries are operated by municipalities. The three plants in Vermont are scattered along the east flank of the Green Mountains; those in New Hampshire are situated one in the south-central portion and the other midway of the eastern border of the State; while the Maine plant is located in the west-central portion of the State.

One plant in Rhode Island was visited. This was located in the center of the State. The rock is sandstone of the bluestone variety and is worked on a small scale, the plant having a capacity of about 150 tons daily.

Cutting diagonally across the northern half of the State of New Jersey in a northeast-southwest direction and extending both north and south into New York, Connecticut, and Pennsylvania, respectively, there occurs a rather narrow area of rocks composed of diabase, gabbro, and basalt, generally called trap rock. The well-known value of this type of rock as a road-building material has resulted in its development on a large scale, and many stone-crushing plants are to be found from one edge of New Jersey to the other. Out of a total of 25 or more, 10 were visited and studied. These were chosen so that variations might be noted not only in the scale of operation, but also in the type of rock. In addition to the trap-rock plants, two granite quarries were studied. These occur along a line parallel to but northeast of the trap-rock area.

Whenever the topography would permit, railroad facilities for transportation were included in the equipment, resulting in large-scale operations—i. e., a daily output of crushed stone ranging from 500 to 3,000 tons. This is true of 50 per cent of the plants visited. The balance, without railroad facilities, are dependent upon local trade or that within the radius of motor transportation and therefore are of smaller capacity.

Following the extension of the trap rock area into New York, a visit was made to one of the large crushing plants in Haverstraw County along the Hudson River. The capacity of this plant is rated at 8,000 tons daily. It is equipped with 13 crushers, one with an opening of 66 by 86 inches, and 8 screens. In addition, 10 other plants were visited in New York State, all but one of which are crushing limestone. The exception was a hornblende gneiss quarry, in Herkimer County. Two of the limestone crushing plants are located along the Hudson River, while the remainder are at various points along an east-west line extending from Albany to Buffalo. Here, again, the choice of plants to be studied was based upon variations in rock type and size of operation so that included in the group are plants working in pure limestone, argillaceous limestone, dolomite, and cherty limestones, with daily capacities ranging from 250 to 5,000 tons.

Fourteen plants in Pennsylvania were visited, including five in the eastern, central, and western sections of the State working limestone; three in counties flanking the Allegheny Mountains working siliceous limestone (locally called ligonier); five in a narrow belt extending across the southeastern corner of the State working trap rock; and one in the southeastern corner of the State working a granite deposit. With few exceptions these plants are situated along railroads and are worked on a rather large scale. They produce railroad ballast in addition to their other products. Those plants quarrying limestone of a quality suitable for the manufacture of lime or for flux in steel manufacture, crushed and screened only those portions of the rock strata low in lime content, and as this represents the handling of only a portion of the quarry output, the equipment and capacity is small.

The plants visited in Maryland included two quarrying granite and one trap rock, in Baltimore County; two working in limestone, one near Hancock and the other in the extreme western part of the State. All are operated on a small scale, as they have only a local market and transport their product by motor trucks.

PROCEDURE.

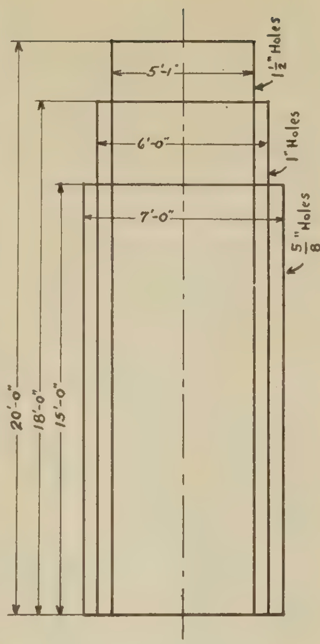
Probably the most important element of the equipment of a crushing plant in so far as quality of grading of output is concerned, is the screen. The present investigation, therefore, centered about this point, but also included other closely related phases of the operation. Thus, the information obtained at each plant included the number, type, and size of primary and secondary crushers; the type, speed, and dimensions of conveyors, and the material each handled, the number of screens in operation, the length over all and diameter of each screen, including jackets, the speed of revolution of revolving screens and their pitch or inclination from the horizontal. In addition, the nominal diameters of the holes (the diameter stipulated when purchasing sections), and the corresponding actual diameter of the holes in each section of the screen at the time of inspection was recorded, together with the total length of each section having the same size of holes. The general arrangements and conditions of chutes for the transfer of stone to bins, and the bins for the storage of stone were noted carefully. A record was made also of each commercial size of stone produced, including the name under which each is sold, the limits of size in which each grade is supposed to lie and, as far as known, the purpose for which each is supplied. Finally, a sample of each commercial size was obtained, ranging in weight from 5 to 25 pounds, depending upon the maximum size of individual pieces. The samples were taken carefully, preferably from an outgoing car, but otherwise directly from the bin, appropriately labeled and forwarded to the laboratory in Washington. As the samples were received, each was analyzed carefully by passing it through a set of screens and recording the weight and the per cent of stone lying between each screen. The screens used were of the standard form, having circular openings of the following diameters: 3 inches, 2½ inches, 2 inches, 1½ inches, 1¼ inches, 1 inch, ¾ inch, ½ inch, ¼ inch. Stone dust and stone screenings were analyzed further by passage through the standard set of sieves used in the analysis of concrete sands. The set includes: 10, 20, 30, 40, 50, 80, 100, and 200 mesh sieves.

DESCRIPTION OF SCREENING METHODS IN USE.

In the course of the field investigations, certain interesting modifications of the elementary revolving screen were noted. These were the result of efforts made by operators to improve the quality of grading of their products. In addition to the ordinary single revolving screen and the single screen carrying a dust jacket over the section with the smallest holes, there were observed complete double and even triple compound revolving screens, as well as various forms of chute and shaking or pulsating screens; the latter introduced usually for the purpose of removing excess dust.

One of the most interesting small operations observed in New England is that of a municipally owned plant in Massachusetts, a few miles north of Boston. This plant works in trap rock and employs a single 26 by 13 inch jaw crusher which feeds to an 18-inch by 60-foot bucket elevator running at a speed of 150 feet per minute. The elevator is set at a very low angle necessitating more buckets for the height attained than usually are employed. It has the advantage, however, of preventing material from falling out of the buckets during elevation, a condition which is observed frequently in cases where the elevator is set at too high an angle. The elevator discharges into a single revolving screen 36 inches in diameter and 12 feet long, containing three standard 4-foot sections with circular perforations of ⅝, 1¼, and 2½ inches in diameter. A dust jacket with ¼-inch round holes and 48 inches in diameter surrounds the ⅝-inch section and the whole revolves at a speed of 13 r. p. m., and is set at an inclination of 1 inch to the foot. This plant, which is typical of a small, single screen outfit, is equipped to turn out four sizes of stone; that between the 2½-inch and 1¼-inch screens; that between the 1¼ and ⅝ inch screens; that between the ⅝ and ¼ inch screens; and that passing the ¼-inch screen. The tailings or that portion retained on the 2½-inch section are returned to the crusher by means of an endless belt and recrushed. To operate the plant requires a 50 h. p. electric motor, and the production is between 100 and 150 tons of stone per working day of eight hours.

The use of double concentric screens may be illustrated by reference to a large and modern trap-rock plant located in the central portion of Connecticut.



This plant is equipped to turn out several thousand tons of stone a day. The initial breaker is a 48 by 72 inch jaw crusher, below which is set a No. 10 gyratory crusher. The product of this gyratory is elevated to a double scalping screen provided with 5-inch holes in the main screen and 2½-inch holes in the jacket. The system thus permits a division of the tailings from this screen into two sizes, those over 5 inches going to one set of crushers and those between 5 and 2½ inches going to another set, while all material under 2½ inches goes direct to the main screen. By this arrangement it will be seen that the tailings can be divided between two sets of crushers set to crush different sizes of stone, thereby considerably increasing the general efficiency of the plant. From the secondary crusher, the stone is again elevated to a second scalper provided with 2½-inch holes, the rejections from which are dropped into a disk crusher. The main screens, which receive all the material passing the 2½-inch openings in both scalping screens as well as the product of the disk, are in two sets, two double screens in each set, placed in parallel. The stone from the crusher house is carried to the first set consisting of two screens having 1¾-inch openings, surrounded by jackets with holes $1\frac{3}{16}$ inches in diameter.

Here are produced the two largest commercial grades, the first being that part of the product retained on the main screen and the second that part of the product passing the main screen and retained on the jacket. The material passing through the jacket is elevated to the second set of screens, each of which consists of a screen having 1-inch holes and surrounded by a jacket having ⅝-inch holes the first half of its length and ⅜-inch holes the second half. This arrangement divides the stone under $1\frac{3}{16}$ inches in size into four fractions, that passing the ⅜-inch jacket, that between ⅜ and ⅝ inch, and that between ⅝ and 1 inch, and finally that between 1 inch and $1\frac{3}{16}$ inches.

A third variation in screening methods is that in use in one of the larger crushing plants in New York State, working in cherty limestone. The stone from the quarry is delivered first to a large gyratory crusher, which breaks it to a maximum size of 4½ inches. The product is discharged directly into a revolving scalper screen 10 feet long and 61 inches in diameter having circular holes 3½ inches in diameter. The stone passing over these holes is recrushed in a second breaker and is elevated, together with the material passing through the scalper, and discharged into a second screen. The holes in this and all subsequent screens are of such a diameter as to give a grading of stone nominally conforming to the New York State Highway Commission's specifications. This second screen is made up of three concentric screens, as shown in figure 1.

The perforations in the inner screen are 3¾ inches in diameter, those in the middle screen 3¼ inches, and those in the outer screen 2¾ inches. At the time of visiting the plant the stone passing the 3¼-inch holes but retained on the 2¾-inch holes dropped directly into a storage bin beneath, while the material above 3¼ inches in size was recrushed. It will be seen, however, that should there be a demand for it stones ranging in size from 3¾ to 2¾ inches may be supplied easily.

That portion of the crushed stone passing through the 2¾-inch holes is conveyed to a pair of revolving screens, each of which, like the screen just described, is made up of three concentric screens, as shown in figure 2. Here the perforations in the inner, middle, and outer screens are 1½ inches, 1 inch, and ⅝ inch in diameter, respectively. Thus four grades of stone may be produced. The material passing the 1½-inch holes but retained on the 1-inch holes is obtained for a special purpose only, so that usually three grades of stone are produced. These are stone passing the 2¾-inch and retained on the 1½-inch holes, passing the 1½-inch and retained on the ⅝-inch, and that passing the ⅝-inch holes. Each of these sizes is directed to a storage bin under the screens. Should there be a call for stone passing through a ⅝-inch hole, but free from dust, a portion of the stone passing the ⅝-inch holes is removed from the storage bin and charged into a screen 15 feet long and 61 inches in diameter surrounded by a jacket 6 feet long and 72 inches in diameter.

The holes in this screen are ⅝ inch in diameter and those in the jacket ⅜ inch, thus making two additional grades of stone, namely, passing ⅝-inch and not passing a ⅜-inch hole, and all material passing through the ⅜-inch hole.

All five screens are operated at a speed of 14 r. p. m. and have an inclination of 1½ inches per foot of length. To run this whole plant, including three crushers, a pan conveyor, five screens, three conveyors, a balance skip hoist from the quarry, and an air compressor of 1,500 cubic feet capacity, requires a steam plant of 450 boiler horsepower.

The advantage gained by double and triple screens are many, but mention will be made here of only the more obvious. Foremost of these is a large screening area confined within a comparatively short space, thus tending to produce a well-graded stone, and second, the elimination of the congestion and excessive weight of stone, especially at the charging end, and a more even distribution, resulting in a cleaner product and longer life of the individual screen sections.

GENERAL RESULTS OBTAINED.

A comparison of those variations in plant screen design and operation which presumably might influence the grading of the commercial products, and therefore the actual sizes of individual samples as shown by laboratory analyses may be obtained by an inspection of Table I. The plant screen data in each case includes the length, diameter, and size of holes in both the screen section on which the product was retained and that through which it passed. The pitch in inches per foot and the speed in revolutions per minute of each screen also are given. The corresponding laboratory data show the percentage of the weight of the original samples lying between the actual sizes given, based on the use of standard laboratory screens having circular openings. The plants are classified first by States in which they operate, and second, by the type of rock which they handle. They are subdivided further by grouping first all of the plants in the State producing the largest commerical size in general use; second, all the plants producing the next largest size, and so on. The first subdivision in Table I thus shows four plants producing the size stone commonly known as "ballast;" the second, six plants producing stone variously known as 1¼ and 1½ inches, but each sold for use in the same type of construction.

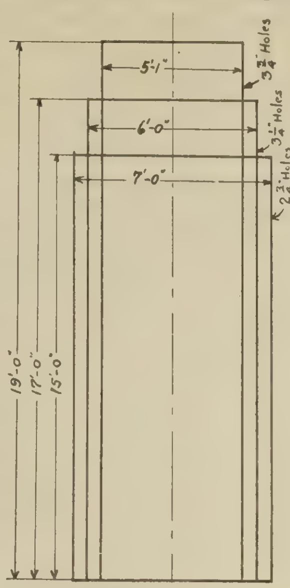


Table 2 shows the total number of tons of all sizes which each plant can produce under average conditions. These capacities were rated by the operators themselves and were not estimated by the observers. It was found practically impossible to obtain any trustworthy data showing the relative amounts of each size produced owing to the fact that changes in screen installation and in the size of crusher opening are being made constantly in order to meet the varying demands of the market. The total horsepower required for efficient operation as given by the operators also is shown. It is recorded, however, only as a matter of additional information and seemingly bears no definite relation to the output of the plant. The discussion of the results obtained may be grouped under four general heads, as follows:

(1) A comparative study of variations in plant screen installation and operation.

(2) A comparison of the nominal sizes for various products as called for by plant screen data with the actual sizes as shown by laboratory analysis.

(3) A comparison of the nomenclature used by the various operators and users of crushed stone in designating the same products.

(4) A comparison of the actual sizes produced with the requirements of State specifications.

VARIATIONS IN PLANT SCREEN INSTALLATION AND OPERATION.

An examination of Table 1 shows, in the first place, that extremely wide variations exist in both the lengths and diameters of the screen sections used. These dimensions are, of course, influenced largely by the scale of operation because the capacity of a revolving screen varies directly with its screening area. Theoretically, also, the length of the screen section should materially influence the grading of the product passing over it, in that the longer the section, the smaller should be the proportion of material retained on it which would pass a laboratory screen with the same size holes. To ascertain whether or not such a relation actually exists the figures in Table 3 were compiled. This table illustrates the comparative efficiency of plant screens of various lengths from 1 to 20 feet. In each case the total number of plants considered is given, together with the per cent of plants which show less than 15 per cent of stone passing a laboratory screen having the same size perforations. It will be noted that in a general way the long screens are more efficient than the short ones so that in almost every case, screens of 10 feet or more in length are 100 per cent efficient, based on a tolerance of 15 per cent, which has been assumed to be a reasonable one.

Screening efficiency, on the other hand, does not appear to be affected by the diameter of the screen used other than that the longer screens, and therefore, as a rule the more efficient ones, usually are the largest in diameter. Other factors shown in Table 1, which theoretically influence the quality of grading, such as speed and pitch of screen, apparently have very little practical effect. This is somewhat surprising, but may be explained by the probable influence of a factor which it was impossible to record, namely, the rate of feeding the stone into the screen. It is well known to all operators that the grading of the several products produced from a revolving screen will be influenced greatly by the rate of charging stone into the screen. Thus when loaded heavily a much larger proportion of fines will be found in the larger sizes than when only a small amount of stone is passing through. It is probable that the predominating influence of this factor has overshadowed the theoretical effect of speed and pitch of screen to such an extent that the small variations, usually found in the latter have no practical effect on the grading of the commercial sizes produced. Reference to table I will show that practically all revolving screens run with a speed of from 12 to 18 r. p. m., and are pitched with an inclination of from 1 to 1½ inches to the foot.

Another interesting point which may be noted in connection with plant design is the wide range in

If You Don't Come Across the Kaiser Will.
W. S. S.

diameter of screen perforations used by different operators in the same State, working the same type of rock and producing nominally the same commercial product. Thus as shown in Table 1, in six plants in New York working in limestone and producing "No. 3" stone, the perforations in the screens retaining this product ranged from 1¼ to 2½ inches, while those in the screen passing the product varied from 2¼ to 3 inches. Again, in Connecticut, as shown in Table 1, eight plants crushing trap rock for so-called 2-inch stone employed retaining screens with openings ranging from 1 to 1⅜ inches and passing screens with openings ranging from 2¼ to 2½ inches. One other illustration will serve to call attention to a condition which apparently exists in all sections of the districts surveyed and for all types of stone. The five trap-rock plants in Massachusetts producing "peastone" as recorded in Table 1 used retaining screens with holes varying from ¼ to ½ inch and passing screens with holes ranging from ⅝ to ¾ inch. Notwithstanding these differences in size of holes, the resultant gradings do not vary as much as might be expected, indicating that slight variations in the diameters of the perforations in revolving screens do not cause corresponding variations in the grading of the products. Yet in the comparatively small field surveyed, screen preforations were found ranging from ⅛ to 3¾ inches, by steps differing by $\frac{1}{16}$ inch. In all, 28 different sizes of screens were noted.

COMPARISON BETWEEN NOMINAL AND ACTUAL SIZES OF PRODUCTS.

For the purpose of determining the efficiency of stone screening operations as they are conducted at present, Table 4 was prepared. It shows the proportion of the total number of plants visited in each State whose products show various percentages passing a laboratory screen with the same perforations as the revolving plant screen on which the products are retained. These percentages are computed for each of the more commonly used grades of broken stone; the total number of plants in each case on which the computation is based also being given. In the several cases where there was no laboratory screen corresponding exactly to the plant retaining screen, the per cent of material passing the next smallest laboratory screen was used as the basis of the calculation. Such errors as are introduced in this way would, of course, tend to show a somewhat more efficient grading than actually existed.

Reference to the table brings out several interesting points. It will be noted that approximately 35 per cent of all the plants studied produce the ordinary commercial stone sizes with less than 5 per cent variation from the nominal sizes as called for by their plant installation. The average by States ranges from 44 per cent to 20 per cent. Likewise, a range of from 0 to 9 per cent of stone passing the respective retaining screens for similar commercial sizes will include about one-half of the plants with the single exception of one State where the percentage is only 30. In order to include products of a large majority of the plants it will be seen, however, that it is necessary to allow a tolerance of at least 15 per cent. Here the same general relations obtain, 75 per cent of the eight plants in one of the States showing less than 15 per cent variation from the nominal, whereas, only 45 per cent of the operations in another State are equally as efficient. The table shows then, in a general way, just what variations may be expected under present actual working conditions in the States visited, between the sizes which a revolving screen is supposed to produce ordinarily and the size it actually does produce.

The general averages throughout the table are reduced materially because of the very poor results obtained in a single State, where, for some reason, wide variations were noted constantly. For instance, for this State the table shows a general average of 62 per cent of all the plants visited having a variation of from 0 to 14 per cent of the stone passing the plant retaining screen, while in other States practically as high a percentage of the plants lie between 0 and 9 per cent variation. Therefore, a more accurate grading of stone may be expected from plants in these States. Bearing in mind the general operation of the smaller type of crushing plant where the whole product of the crusher falls first upon that screen section having the smaller perforations (exclusive of the dust jacket), it might be assumed that the grading of smaller sizes would be poorer than the larger. This appears to be substantiated in Table 4, where the general average for "peastone," for instance, shows only about 50 per cent of all plants with less than 15 per cent variation, whereas a corresponding average for the largest size produced shows about 70 per cent of the plants to be equally as efficient.

Further reference to Table 1 will show in a number of instances samples which contain a certain amount of material larger than the nominal perforations in the plant screen through which the sample was supposed to pass. Such a condition may be due to one of two causes, either to excessive wear in the screens or to poor bin or shute construction, which allows stone of a certain size to drop into the wrong bin. When it is considered, however, that the screening operation is progressive, the passing screen for one size becoming the retaining screen for the next larger size, and that the influence of all the other variables tends to retain a certain amount of stone on each screen which should have gone through, it would seem that the effect of wear may be neglected. From actual observations, moreover, it was found that holes in the ordinary plant screens rarely wear more than ¼ inch oversize, whereas a great many instances of faulty bin or chute construction were noted. The presence of oversize material, therefore, may reasonably be assumed to be due to this latter condition rather than to the fact that the screen perforations are slightly oversize.

COMPARISON OF NOMENCLATURE USED.

The column headed "Product known as," in Table I, contains the name given by operators to each of the 12 products. This information was recorded with the object of showing variations in nomenclature and the resultant confusion that may arise easily in purchasing stone for a special purpose from more than one producer. It brings out very clearly the need of a uniform system of designating commercial sizes of broken stone even if made applicable only within the State. To illustrate, consider the purchase of stone for constructing the bottom course of a water-bound macadam road in one of the New England States. Table 1 shows 17 plants in various parts of Massachusetts equipped to furnish the required stone. Of this total, one designates the size as "2-inch stone," four as "No. 1" stone, two as "No. 3," and two as "egg." Further than this, were a contractor to assume that "No. 3" referred to large stone and ordered accordingly from various plants in the State, it would be possible for him to receive stone chips from several plants. Again, many plants in the State are equipped to furnish stone for cement concrete construction, the stone being a combination of several products. Thus, one plant obtains the required stone by mixing "nut," "chestnut," and "peastone," while another obtains it by mixing "No. 2" and "No. 3."

In another section of Table I, which gives corresponding information with respect to Connecticut, it will be observed that a more uniform designation of stone exists. It is interesting to note, however, that although each of the several operators assigns the same name to stone used for similar purposes, the diameter of the perforations in the passing and retaining sections of the screens varies considerably. Thus, of three plants producing so-called "$1\frac{1}{4}$-inch stone," one obtains it by including all stone passing through $1\frac{3}{4}$-inch holes and retained on $1\frac{3}{16}$-inch holes; the second, by including stone passing through $1\frac{1}{2}$-inch holes and retained on $\frac{7}{8}$-inch holes; and the third, all stone passing $1\frac{1}{2}$-inch holes and retained on 1-inch holes. Again, of two plants producing almost identical stone sizes, the variation being $\frac{1}{16}$ inch in the size of hole of the retaining screen, one sells the product as "$1\frac{1}{4}$-inch stone" and the other as "$1\frac{1}{2}$-inch stone." Inasmuch as all of these products are used widely in the same type of construction and therefore are presumably each giving satisfaction, the question naturally arises, of what use are such slight variations in screen-size openings, especially as has been noted, when correspondingly fine variations in grading are not obtained?

By far the closest approach to a systematic designation of stone sizes is to be found in the products of the crushing plants of New York shown in Table I. Here, with but two exceptions, stone used for similar purposes is sold under the same designation by all operators. This uniformity undoubtedly is the result of the work of the State Highway Commission, which, in its specifications assigns a number to each of the stone sizes used in all work, and although variations appear in the actual diameters of screen perforations in the several plants producing "No. 3 stone" for instance, still the stone produced is intended to conform to the specification requirements.

The condition in one other State will suffice to illustrate the matter. An examination of Table I shows that to supply stone at all conformable to the State requirements, for the construction of the base course of a water-bound macadam road, four plants within Pennsylvania must mix "ballast" and "$1\frac{1}{2}$-inch stone," another "ballast" and "$1\frac{1}{4}$-inch stone," a third "No. 1" and "No. 2" stone, and a fourth "No. 5" and "No. 4" stone. Likewise, of seven plants equipped to furnish the State with stone for the construction of a cement concrete road, three would do so by combining their $1\frac{1}{2}$, 1, $\frac{3}{4}$, and $\frac{1}{2}$ inch stone, one by combining its $1\frac{1}{2}$, 1, and $\frac{3}{4}$ inch stone, one by making a combination of "No. 2," "No. 4," and "No. 5" stone, another by combining "No. 4," "No. 3," and "No. 2" stone, and still another by mixing "No. 3," "No. 2," and "No. 1 clean." In every case, at the time of visiting the plant these combinations were not made directly from the screens but in the cars at the time of loading.. It must be remembered, of course, that the requirements of a local market other than that of the State, necessitated, in the majority of cases, the installation of intermediate screen sections and the assignment of names to the product from these sections for local sales only. Nevertheless, to obtain stone for any future road construction by the State within the market zone of any of the crushed stone operators listed in the tables, it still will be necessary for the engineer in charge to determine the meaning of the names given to the several sizes of stone produced before he can place orders intelligently.

COMPARISON OF ACTUAL SIZES PRODUCED WITH SPECIFICATION REQUIREMENTS.

Having discussed the problems and discrepancies encountered in the production of broken stone aggregates, it is proposed here to call attention to the the products themselves, the actual sizes produced, as compared to the requirements of the corresponding State specifications. Tables 5, 6, and 7 contain the several requirements, in the section visited, for broken stone for use in water-bound macadam, bituminous macadam, and cement concrete construction, respectively, while Table 1 contains mechanical analyses of the products sold in these States. The methods used in specifying sizes vary considerably in the different States. In a number of cases, the specification is confined to a mere statement of the sizes required, without any reference to the basis for determining the size—thus, "the stone shall be from 1½ to 3 inches in size, largest dimensions." In other cases, requirements appear, such as, "shall consist of stones that will pass through a ring 2½ inches in diameter, but not through a ring 1¼ inches in diameter." In one case, the maximum and minimum diameters of holes are given with a proviso that as much as 15 per cent of stone, by laboratory test, may be smaller than the minimum diameter. In still another instance, the State specifies the diameter of the plant screens through which the product passes and on which it is retained, presumably accepting anything produced under these conditions. In Tables 5, 6, and 7 the several requirements may be assumed to be on the basis of the actual size of the stone, as determined by the laboratory test, unless otherwise noted in the tables.

A comparison of these specification requirements with the analyses of the various commercial products turned out in the corresponding States brings out some interesting facts. For instance, one of the New England States requires, as shown in line 1 of Table 5, a product which will pass a 1¼-inch screen and be retained on a ½-inch screen, with the further proviso that the stone be uniformly graded between these limits. Reference to Table 1 shows that not a single one of the 19 Massachusetts plants nominally turning out this product can meet the specifications literally, even if, as several have done, they use plant screens with perforations larger than the specified sizes. If, however, an upper and lower tolerance is inserted in this specification of, say, 5 per cent and 15 per cent to cover relatively unimportant variations from the specifications, 10 of the plants will be able to meet the requirement, the failure of the others being due to the use of screens with 1½-inch instead of 1¼-inch holes.

The same State, as shown in line 1, Table 6, requires for chip stone material passing a ½-inch but retained on a ¼-inch screen. Reference to Table 1 shows that not one of the 17 Massachusetts plants producing this stone can meet the requirement literally. The insertion of the tolerances mentioned above would admit 11 plants with respect to the lower limit, but still would exclude all 17 on the upper limit, principally on account of the general use of screens with ¾-inch or ⅝-inch holes, instead of ½-inch holes.

For the construction of the bottom course of a water-bound macadam road Connecticut specifies stone which shall range "from ¾ inch to 2 inches, longest diameter, mixed in the screens (not in the bins), the smaller sizes to predominate." An examination of Table 1 shows that none of the crushing plants visited in that State meet this requirement. They may approximate it by making a proportional mixture of the two larger products, but even then a large proportion of the stone will exceed 2 inches in size. Likewise, only three out of the eight plants tabulated show gradings at all conformable to the requirement of stone for the top course of a water-bound macadam road. In the case of a bituminous macadam road this State calls for cubical stone as nearly 1½ inches in diameter as possible for use in the penetration course, to be followed by "¾-inch stone," "½-inch stone," and "screenings free from dust." Reference to the table will show what the eight plants visited furnished for this purpose.

In Tables 5 and 6, line 7, are the requirements of New York for water-bound and bituminous concrete aggregates, while in Table 1 are the analyses of the products of a number of plants in that State turning out stone for use in building roads of these types. This specification provides that as much as 15 per cent of material in any of these products may be smaller than the lower limits specified. Reference to Table 1 shows that very few of the plants in the State meet the requirements, even on the basis of a 15 per cent tolerance. Almost all of these concerns appear to be turning out stone much smaller than required by the State. This is especially true of the larger sizes.

A study of the specification requirements of Pennsylvania will suffice to call attention to the obvious conclusion that, whatever the reason, but little coordination exists between the actual sizes of screened stone products and the requirements of the States in which they are to be used. Here an entirely different method of specifying stone sizes is employed, in that the diameters of the holes in the revolving screens on which and through which the product must pass is stated, with the additional requirement that it be graded uniformly between these limits. In other words, the actual equipment of a crushing plant determines whether or not an operator can furnish stone for State highway work. As a typical illustration, for the bottom course of a water-bound macadam road the highway department requires stone that will pass through a revolving screen having circular openings not less than 3 nor more than 3½ inches in diameter, and pass over a revolving screen having circular openings not less than 1¼ nor more than 1½ inches in diameter, and must be graded uniformly. Table 1 shows that six out of eight plants in Pennsylvania are equipped to furnish this stone, but only by combining the two largest commercial products. Of the six plants which can meet the letter of the specification, however, under this condition, the amount of material under 1¼ inches actually in the products themselves varies from 0 to 65 per cent, indicating quite a large possible range in grading under this method of specifying. Another requirement of this State specifies that "$\frac{3}{4}$-inch stone" shall be "of such size as will pass over a revolving screen having circular openings not less than $\frac{5}{8}$ inch or more than $\frac{3}{4}$ inch in diameter, and through a revolving screen having circular openings not larger than $1\frac{1}{4}$ inches in diameter." Table 1 shows five plants which meet the letter of the specification. Laboratory analyses of the products from these same five plants show materials ranging from 0 up to 85 per cent retained on a 1-inch laboratory screen, and from 0 to 58 per cent passing a $\frac{3}{4}$-inch laboratory screen. Such a condition well illustrates the uncertainty of attempting to control the grading of crushed stone products by simply specifying the plant screens over which and through which they shall pass.

GENERAL CONCLUSIONS.

Briefly summarized, the following points brought out by this discussion may be noted:

1. The length of a revolving screen influences the grading of the screen product to a marked degree.
2. Within the relatively narrow limits usually found in plant installation, pitch and speed of screen have no practical influence on grading, probably on account of other predominating factors, such as rate of feed of stone to the screen, which it is impossible, practically, to control.
3. The effect of oversize holes due to wear of the screen is practically negligible in view of the relatively large amount of stone usually held on a revolving screen which theoretically should have passed through it.
4. Small amounts of oversize stone, sometimes found in products screened through holes of certain nominal diameter, usually are due to faulty bin or chute construction, lack of repair, or other deficiencies in storing or handling the material.
5. The grading of the screened product can not be controlled with any degree of certainty by simply specifying the size of openings in the revolving screens over which and through which it shall pass.
6. It is neither practical nor necessary to specify that all material retained on and passing revolving screens of certain sizes shall lie between laboratory screens of the same size.
7. By the insertion of a reasonable tolerance, that is, one wide enough to cover the recognized inefficiency of the revolving screen, and yet close enough to insure sufficiently well graded materials, the laboratory screen may be used logically to control the grading of the plant product.
8. Inspection of the results so far obtained indicate that as much as 5 per cent material should be allowed larger than the size of revolving screen through which the product is supposed to pass, and as much as 15 per cent generally should be allowed smaller than the size of revolving screen upon which it is supposed to be retained. A consideration of the engineering features involved likewise indicates that these tolerances may be allowed ordinarily and still insure material graded sufficiently accurately for all practical purposes.

APPLICATION OF RESULTS OBTAINED.

As stated, this survey was made primarily with the object of furnishing data which might be used as a basis for standardizing crushed stone sizes. It would, of course, be unfair to recommend specifically standard sizes for broken stone for use in the whole country on the basis of the data collected in the comparatively small district surveyed. It is believed, however, that enough information has been obtained to justify tentative recommendations which may be used as suggestions to both producers and users of crushed stone to indicate the possibilities along this line and so stimulate further discussion and criticism.

Any discussion of a system of crushed stone sizes will, of necessity, involve a consideration of the following points:

(1) The system must include each fundamental size which is in general use in recognized types of construction.

(2) The actual limits for each size chosen must be so adjusted as to conform to the best engineering practice for the type of construction involved.

(3) The sizes chosen must be so adjusted with respect to each other as to utilize, as far as possible, the entire product of a crushing plant, with the smallest percentage of tailings.

(4) The sizes chosen must be so adjusted with respect to each other that various combinations of them will conform to the best engineering practice in construction requiring mixed aggregates.

(5) The nature of the material to be crushed (i. e., its physical properties, hardness, toughness, etc.) should be considered in connection with the limits of size chosen.

(6) For convenience each size should be designated by an appropriate name.

(7) A method of specifying each size should be provided which will insure proper material being continually furnished and yet will be practical from the standpoint of economical plant operation.

(8) In addition to the above, another point applying especially to the adaptability of the system to portable, one-job, outfits is that the sizes must be so adjusted as to use as far as possible the entire product of the crusher on the work in hand.

Mention has been made that the unsystematic development of the broken stone road has resulted in the introduction of a great variety of stone sizes for comparatively few distinct types of construction, the variation often being of academic rather than practical significance. For instance, including only the States visited during this survey, a comparison of the current state specifications shows as many as 30 different sizes of stone specified for use in the construction of water-bound and bituminous macadam roads. Bearing in mind that these are all State specifications, and that in all probability many additional differences occur among the requirements of the various counties and municipalities, some idea may be obtained of the number of different sizes in use for these two types of road in this country at the present time. This does not include, of course, the several additional size requirements which have been drawn up from time to time to care for the construction of the various types of bituminous concrete pavements now used so widely. After making due allowances for justifiable variations in sizes due to local conditions, such as peculiarities in type of material, the fact remains that the multiplicity of sizes which exists is not only unnecessary and confusing, but also works a positive hardship upon the producer.

In consideration of the factors given above, there is suggested the general adoption of a series of sizes for broken stone aggregates, which it is believed will meet all essential requirements for the ordinary types of construction in use at the present time. Whole-number sizes have been chosen as far as possible, both on account of simplicity and ease of specifying an exact intermediate requirement when deemed advisable to do so. The permissible variations from the actual size limits here given have been inserted, so as to care for the unavoidable inefficiency of plant screening, as well as different degrees of inefficiency between several plants arising from one or more of the causes which have been noted. Thus it should be possible for an operator to use in his plant revolving screens with the same size circular openings as are used in the laboratory when the material is tested, and thereby produce material which, under ordinary circumstances, will comply with the specifications. In a number of cases there has also been inserted an intermediate size requirement with limits which it is felt are wide enough to permit of economical production and yet rigid enough to insure a product satisfactory for the type of construction in which it is to be used.

The sizes suggested, together with the proposed designation for each, the permissible variations allowed, and the form of specifying, are given below:[1]

No. 00. That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements: Passing a ½-inch screen, 100 per cent; retained on a ¼-inch screen, not less than 20 per cent.

No. 0. That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements: Passing a 1-inch screen, not less than 95 per cent; total passing a ¼-inch screen, 40 to 80 per cent.

No. ½. That portion of the product of the crusher, which, when tested by means of laboratory screens, will meet the following requirements: Passing a ½-inch screen, not less than 95 per cent; retained on a ½-inch screen, not less than 85 per cent.

No. 1. That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements: Passing a 1-inch screen, not less than 95 per cent; total passing a ¾-inch screen, 25 to 75 per cent; retained on a ¼-inch screen, not less than 85 per cent.

No. 2. That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements: Passing a 2-inch screen, not less than 95 per cent; total passing a 1½-inch screen, 25 to 75 per cent; retained on a 1-inch screen, not less than 85 per cent.

No. 3. That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements: Passing a 3-inch screen, not less than 95 per cent; total passing a 2½-inch screen, 25 to 75 per cent; retained on a 2-inch screen, not less than 85 per cent.

No. 23. That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements: Passing a 3-inch screen, not less than 95 per cent; total passing a 2-inch screen, 25 to 75 per cent; retained on a 1-inch screen, not less than 85 per cent.

No. 123. That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements: Passing a 3-inch screen, not less than 95 per cent; total passing a 1½-inch screen, 25 to 75 per cent; retained on a ¼-inch screen, not less than 85 per cent.

No. 12. That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements: Passing a 2-inch screen, not less than 95 per cent; total passing a 1-inch screen, 25 to 75 per cent; retained on a ¼-inch screen, not less than 85 per cent.

It will be seen that the only revolving screen equipment necessary for turning out any or all of these sizes are screen sections with circular openings 3, 2, 1, ½, and ¼ inches in diameter. Furthermore, in cases where No. 00 or No. ½ sizes are not desired, the ½-inch screen may be omitted, making it possible to manufacture everything by the use of a standard 3-section screen equipped with a ¼-inch dust jacket over the 1-inch section.

The sizes enumerated above may be employed in the construction of the following types of roads:

Type of construction.	Size or sizes.
Broken stone base	No. 3 or No. 23
Water-bound macadam wearing coarse	No. 2 or No. 12
Water-bound macadam screenings	No. 0 or No. 00
Bituminous macadam wearing coarse	No. 2
Bituminous macadam "chips"	No. 1
Bituminous concrete wearing course:	
One-size course aggregate	No. 1
Broken stone for graded course aggregate	No. 1
Broken stone for graded fine aggregate	No. 00
Bituminous concrete "chips"	No. ½
Sheet asphalt, binder course	No. 1
Cement concrete base	No. 123 or No. 12
Cement concrete wearing course	No. 12

It is felt that a careful study of the above will show that, although in some instances minor variations in size might be preferred, practically any of the types of roads here listed may be satisfactorily constructed with the sizes of aggregates proposed. The tables (1 to 7) referred to herein follow.

[1] The form of specification used is that adopted by the First Conference of State Testing Engineer and Chemists and given in United States Department of Agriculture Bulletin No. 555.

TABLE I.

PENNSYLVANIA.

Plant No.	Type of rock.	Product known as—	Plant screens. Pitch (inches per foot).	Speed, r. p. m.	Dimensions. Screen passing product. Length (feet).	Screen passing product. Diameter (inches).	Screen retaining product. Length (feet).	Screen retaining product. Diameter (inches).	Size of holes. Screen passing product (inches).	Screen retaining product (inches).	Mechanical analysis—Per cent between— Over 3 inches.	3–2½ inches.	2½–2 inches.	2–1½ inches.	1½–1¼ inches.	1¼–1 inches.	1–¾ inch.	¾–½ inch.	½–¼ inch.	Under ¼ inch.
1	Trap	Ballast	1½	12	4	72	5	72	3¼	1¾		45	55							
2	do	do	1½	20	9	60	18	60	3	2¼		66	34							
3	do	do	1½	20	15	60	8	60	3	2⅜		51	31	18						
4	do	do	1¼	17	8	60	8	60	3	2		44	43	13						
1	do	1½-inch stone	1½	12	5	72	5	72	1¾	1¼				26	44	27	3			
2	do	do	1½	20	9	60	8	48	2¼	1⅜				66	34					
3	do	1¼-inch stone	1½	20	8	60	8	60	1¾	1⅜					65	31	4			
4	do	1½-inch stone	1¼	17	12	84	12	60	2	1¼				58	33	7				
5	do	do	1¾	12	4	36	4	36	2	1¼				19	37	38	6			
1	do	1-inch stone	1½	12	5	72	5	72	1¼	⅞					11	38	43	8		
2	do	do	1½	20	9	48	9	48	1⅜	1					11	51	36	2		
3	do	do	1½	20	8	60	8	60	1¼	1					1	22	55	22		
5	do	do	1¾	12	4	36	4	36	1¼	1⅛						40	56	4		
1	do	¾-inch stone	1½	12	5	72	4	84	⅞	⅝						7	35	46	12	
2	do	do	1½	20	9	48	6	60	1	½							40	55	5	
3	do	do	1½	20	8	60	8	60	1	¾							68	32		
4	do	do	1¼	17	10	60	10	60	1¼	¾						28	60	12		
5	do	do	1¾	12	4	36	3	48	1⅛	¼						1	33	28	37	1
1	do	⅝-inch stone	1½	12	4	84	(2)		⅝	¼							14	65	21	
2	do	½-inch stone	1½	20	6	60	6	60	½	⅜								43	57	
3	do	do	1½	20	8	60	6	72	¾	⅝							3	37	58	2
4	do	do	1¼	17	10	60	6	72	¾	5/16								25	68	7
6	Limestone	No. 1	1½	15	4	36	4	36	3	2½		10	5	85						
7	do	No. 5	1½	12	4	42	4	42	3	2		15	41	44						
8	do	Ballast	1½	13	6	36	6	36	3	1½		38	50	12						
9	do	do	1½	18	6	48	6	48	2¾	1½		14	25	61						
6	do	No. 2	1½	15	4	36	4	36	2½	1½			15	37	24	21	3			
7	do	1-inch stone	1½	12	4	42	4	42	2	1½				11	25	21	33	10	1	
8	do	1¼-inch stone	1½	12	6	36	4	36	1½	¾				1	6	17	76			
9	do	¾-inch stone	1½	18	6	48	4	60	1½	⅝			24	38	31	9				
10	do	No. 3	1½	12	8	36	8	36	2½	1¾			44	45	10					
11	do	do	1½	15	6	40	4	51	2	1			7	69	19	5				
12	do	do	¾	15	9	36	9	36	1¾	1½				40	30	23	7			
10	do	No. 2	1½	12	8	36	6	36	1¾	⅝				5	21	35	24	14		
11	do	do	1½	15	4	36	4	36	1	¾				9	30	47	15			
12	do	do	¾	15	9	36	4	48	1⅛	⅜						45	40	13	2	
6	do	No. 4	1½	12	4	36	4	36	1¼	¾						13	45	36	6	
11	do	No. 1 (clean)	1½	15	8	36	6	48	1	3/16							8	39	44	9
7	do	No 2	1½	12	6	42	3	51	1	¼							5	46	48	1
8	do	⅝-inch stone	1½	12	6	36	(3)		¾	½							1	26	65	9
9	do	⅝-inch (clean)	1½	18	4	30	4	30	½	¼							55	44	1	

NEW YORK.

Plant No.	Type of rock.	Product known as—	Pitch	Speed	Passing Length	Passing Diameter	Retaining Length	Retaining Diameter	Holes passing	Holes retaining	Over 3	3–2½	2½–2	2–1½	1½–1¼	1¼–1	1–¾	¾–½	½–¼	Under ¼
13	Limestone	2½-inch stone	40°		(1)		(1)		3¼	2¼		31	57	12						
14	do	No. 4	1½	12	4	36	4	36	3¼	2¼	50	23	17	4	4	2				
15	do	do	⅝	18	4	36	6	48	3¾	3	33	39	28							
16	do	do	1½	14	17	72	15	84	3¾	2¾	25	44	30	1						
17	do	do	1⅛	13	6	60	6	60	3¾	2½		13	50	37						
13	do	1½-inch stone	40°		(1)		(1)		2¼	1⅜				14	17	40	28	1		
18	do	do	1	15	8	48	8	48	2⅛	1⅛				75	24	1				
19	do	No. 3	1½	16	4	36	4	36	2¼	1½			11	57	24	6	2			
14	do	do	1½	12	4	36	4	36	2¼	1½				42	41	15	2			
16	do	do	1½	14	15	84	20	61	2¾	1½			16	55	20	9				
20	do	do	1¼	19	10	46	10	46	2¾	1¾		8	40	44	7	1				
15	do	do	⅝	16	6	48	6	48	3	2½		24	36	35	3	2				
13	do	¾-inch stone	40°		(4)		(4)		1⅜	½						2	23	56	19	
18	do	do	1	15	8	48	6	48	1⅛	⅜						5	23	26	41	5
19	do	No. 2	1½	16	4	36	4	36	1½	1¼				5	54	32	8	1		
14	do	do	1½	12	4	36	4	36	1½	1¼					3	26	50	20	1	
21	do	do	1¾	14	4	60	4	60	1¼	¾				5	14	33	41	7		
16	do	do	1½	14	20	61	15	84	1½	⅝					3	7	36	38	16	
20	do	do	1¼	19	10	46	10	46	1¾	¾				24	19	33	20	4		
15	do	do	⅝	16	6	48	6	48	2½	1¼					23	39	32	6		
17	do	do	1⅛	13	6	60	8	42	1¼	⅝					4	9	48	34	5	
18	do	⅜-inch stone	1	15	4	48	12	48	⅜	¼									78	22
19	do	No. 1	1½	16	4	36	4	36	1¼	7/16					3	15	45	23	11	3
21	do	do	1¾	14	4	60	3	72	¾	3/16							2	32	65	1
16	do	do	1½	14	15	61	12	72	⅝	⅜								5	51	44
20	do	do	1¼	13	8	48	8	48	⅝	¼								12	79	9
15	do	do	⅝	16	6	48	5	60	1½	⅞								22	60	18
17	do	do	1⅛	13	8	42	8	42	⅝	½								22	74	4
19	do	Pea	1½	16	4	36	3	48	7/16	3/16								9	58	33

NEW JERSEY.

Plant No.	Type of rock.	Product known as—	Pitch	Speed	Passing Length	Passing Diameter	Retaining Length	Retaining Diameter	Holes passing	Holes retaining	Over 3	3–2½	2½–2	2–1½	1½–1¼	1¼–1	1–¾	¾–½	½–¼	Under ¼
24	Granite	2½-inch stone	¾	10	4	42	4	42	3	2		13	65	22						
24	do	1½-inch stone	¾	10	4	42	6	42	2	1¼			16	79	5					
25	do	do	1½	12	4	36	4	36	2	1½			9	67	18	6				
25	do	1-inch stone	1½	12	4	36	4	36	1½	1					39	51	10			
24	do	¾-inch stone	¾	10	6	42	4	42	1¼	⅝					6	65	27	2		
25	do	do	1½	12	4	36	4	36	1	¾						10	59	31		

(1) Square mesh.
(2) Pulsating screen, 4′x 10′.
(3) Pulsating screen, 3′x6′.
(4) Gravity screen, 8 feet by 24 inches.

TABLE I—Continued.

Plant No.	Type of rock.	Product known as—	Plant screens: Pitch (inches per foot).	Speed, r. p. m.	Dimensions: Screen passing product: Length (feet).	Diameter (inches).	Screen retaining product: Length (feet).	Diameter (inches).	Size of holes: Screen passing product (inches).	Screen retaining product (inches).	Mechanical analysis—Per cent between—: Over 3 inches.	3–2½ inches.	2½–2 inches.	2–1½ inches.	1½–1¼ inches.	1¼–1 inch.	1–¾ inch.	¾–½ inch.	½–¼ inch.	Under ¼ inch.
		MARYLAND.																		
26	Granite	Ballast	1½	15	20	60	10	60	3	1½		36	53	11						
27	do	2½-inch stone	1½	12	5	48	5	48	2	1¼			5	47	33	10	5			
26	do	1½-inch stone	1½	15	10	60	10	60	1½	1					11	52	35	2		
26	do	1-inch stone	1½	15	10	60	8	72	1	⅜							31	56	13	
27	do	Chips	1½	12	5	48	5	48	1	⅜						6	26	39	27	2
		NEW YORK.																		
22	Trap	2½-inch stone	1	15	20	60	20	60	3⅛	1⅞		44	40	16						
22	do	1½-inch stone	1	15	14	60	10	60	2¼	1⅛				46	20	20	11	3		
22	do	¾-inch stone	1	15	10	60	8	72	1⅛	5/16						9	43	31	16	1
23	Granite	No. 3	1¼	11	10	84	20	84	2¾	1½		5	21	55	12	7				
23	do	No. 2	1¼	11	20	84	10	84	1½	¾					10	22	54	14		
23	do	No. 1	1¼	11	10	84	12	96	¾	5/16							1	11	66	22
		NEW JERSEY.																		
29	Trap	2½-inch stone	1	12	10	42	6	47	2½	1⅞		39	54	7						
30	do	do	1	14	10	48	15	48	3	2¼		70	30							
31	do	Ballast	1½	15	8	51	8	51	3	2	34	55	11							
33	do	1-inch stone	1⅛	12	4	48	4	48	1⅞	1⅛					15	31	42	11	1	
33	do	1½-inch stone	1½	15	8	51	7	51	2¼	1½				49	47	4				
28	do	do	1½	12	4	48	4	48	2⅛	1⅛			5	95						
29	do	do	1	12	4	42	8	48	1⅞	1¼				33	34	26	7			
30	do	do	1	14	6	48	6	48	2¼	1¼			32	65	3					
31	do	do	1½	15	8	51	8	51	2	1¼				76	24					
32	do	do	1½	12	4	48	4	48	1⅞	1⅛				42	35	13	10			
33	do	¾-inch stone	1⅛	15	8	51	8	51	1¼	¾						7	54	34	5	
28	do	do	1½	12	4	48	12	36	1⅛	¾					9	83	8			
30	do	do	1	14	4 6	60 48	4 6	60 48	1¼	¾						11	78	11		
31	do	do	1½	15	6 6	51 51	4 4	60 60	1¼	⅝					10	40	47	3		
33	do	½-inch stone	1⅛	15	6	51	6	51	¾	½								26	64	10
28	do	do	1½	12	4	48	3	60	⅝	¼									66	34
28	do	⅝-inch stone	1½	12	12	36	4	48	¾	½								27	66	7
29	do	½-inch stone	1	12	6	42	4	56	¾	¼							5	29	44	23
		MASSACHUSETTS.																		
34	Trap	Egg	1	13	6	48	6	48	2½	1½			55	38	5	2				
35	do	do	1¼	18	4	40	4	40	2½	1½			39	49	12					
36	do	2-inch stone	1	15	4	48	12	48	2¼	1⅝			25	61	14					
37	do	No. 1	1	18	3	36	1	36	2½	1½			39	40	13	6	2			
38	do	2-inch or No. 3	1	18	4	32	4	32	2½	1½			28	68	4					
34	do	Nut	1	13	6	48	12	48	1½	1					8	53	31	8		
35	do	do	1¼	18	4	40	4	40	1½	1				11	23	53	11	2		
36	do	1¼-inch stone	1	15	12	48	6	70	1⅝	1⅛				15	51	26	8			
34	do	Chestnut	1	13	12	48	4	60	1	¾					4	15	64	17		
35	do	do	1¼	18	4	40	3½	52	1	⅝							62	33	5	
36	do	¾-inch stone	¾–1	22–15	6	70	6	60	1⅛	⅝						4	57	36	3	
37	do	No. 2	1	18	1	36	2	36	1½	¾						9	37	48	6	
38	do	1½ inch or No. 2	1	18	4	32	4	32	1½	⅝					16	49	31	4	3	
34	do	Pea	1	13	4	60	2	60	¾	½								37	59	4
35	do	do	1¼	18	3½	52	3	60	⅝	¼								15	68	17
36	do	do	¾	22	6	60	6	60	⅝	⅜								20	78	2
37	do	do	1	18	2	36	3	36	¾	¼								21	55	17
38	do	do	1	18	4	32	3	40	⅝	⅜								19	75	6
39	Sandstone	2½-inch stone	1¼				2	30		2			49	44	5	2				
39	do	2-inch stone	1¼		2	30	4	30	2	1¼				59	36	5	1			
40	do	do	1	15	3	36	3	36	2½	1¼			5	50	27	15	2	1		
39	do	1-inch stone	1¼		4	30	4	30	1¼	¾						23	56	20	1	
40	do	do	1	15	3	36	3	36	1¼	⅝						9	34	49	8	
39	do	½-inch stone	1¼		4	30	3	42	¾	⅜						1	1	57	39	2
40	do	do	1	15	3	36	4	36	⅝	⅜								18	75	7
41	Granite	2-inch stone	1	11	6	32	3	32	2½	1¼			24	58	14	4				
42	do	No. 1	1½	18	5	30	5	30	2	1			16	36	26	19	3			
43	do	2-inch stone	1½	30	5	24	5	24	2½	1½			5	58	32	4	1			
44	do	No. 1	1½		4	30	4	30	2½	1½			18	50	21	10	1			
45	do	2½-inch stone	1	15			3	30		1½			47	33	15	1	4			
46	do	No. 1	1	12	6	48	6	48	2¼	1½			42	56	2					
47	do	2-inch stone	1¼	11	6	48	6	48	2¾	1¾			45	40	5					
41	do	1-inch stone	1	11	3	32	6	30	1¼	[2] ½						10	46	39	5	
42	do	No. 2	1½	18	5	30	5	30	1	⅝						5	36	49	10	
43	do	1-inch stone	1½	30	5	24	4	36	1½	¼					36	44	17	2	1	
44	do	No. 2	1½		4	30	4	30	1½	¾					19	44	27	8	2	
45	do	1½-inch stone	1	15	3	30	2	42	1½	¼					25	38	19	11	4	3
46	do	No. 2	1	12	6	48	6	48	1½	¾				9	37	28	23	3		
47	do	1½-inch stone	1¼	11	6	48	6	48	1¾	1⅜				49	41	10				
47	do	1-inch stone	1¼	11	6	48	5	60	1⅜	⅝					5	53	31	10	1	
41	do	½-inch stone	1	11	6	30	3	32	½	⅜							2	11	81	9
42	do	Pea	1½	18	5	30	4	42	⅝	[2] ¼								16	80	4
44	do	No. 3	1½		4	30	(2)		¾	¼								6	73	21

[1] Square holes.

[2] Grizzly.

TABLE 1—Continued.

MASSACHUSETTS—continued.

Plant No.	Type of rock.	Product known as—	Plant screens. Pitch (inches per foot).	Plant screens. Speed, r. p. m.	Plant screens. Dimensions. Screen passing product. Length (feet).	Plant screens. Dimensions. Screen passing product. Diameter (inches).	Plant screens. Dimensions. Screen retaining product. Length (feet).	Plant screens. Dimensions. Screen retaining product. Diameter (inches).	Plant screens. Size of holes. Screen passing product (inches).	Plant screens. Size of holes. Screen retaining product (inches).	Mechanical analysis—Per cent betwee Over 3 inches.	3–2½ inches.	2½–2 inches.	2–1½ inches.	1½–1¼ inches.	1¼–1 inch.	1–¾ inch.	¾–½ inch.	½–¼ inch.	Under ¼ inch.
46	Granite	No. 3	1	12	6	48	5	60	¾	½	.....	.....	.....	.....	.....	.....	.....	44	56	.....
47	do	Pea	1¼	11	5	60	4	72	⅝	¼	.....	.....	.....	.....	.....	.....	.....	16	58	26
48	Rhyolite	2-inch stone	1	15	8	36	6	36	2¼	1½	.....	.....	48	49	2	1	.....	.....	.....	.....
49	do	do	1	18	5–5	38–32	5–5	38–32	2½	1½	.....	.....	48	42	6	4	.....	.....	.....	.....
50	do	do	1½	10	6	48	6	48	2½	1½	.....	.....	50	39	7	3	1	.....	.....	.....
51	do	do	1	.....	3	28	3	28	2½	1½	.....	.....	16	61	18	5	.....	.....	.....	.....
52	do	2-inch or No. 3	½	13	4	36	4	36	2¼	1¾	.....	.....	21	70	6	3	.....	.....	.....	.....
48	do	1-inch stone	1	15	6	36	6	36	1½	¾	.....	.....	.....	3	8	19	47	21	2	.....
49	do	do	1	18	5	38–32	5	38–32	1½	¾	.....	.....	.....	2	25	33	33	7	.....	.....
50	do	do	1½	10	6	48	6	48	1½	¾	.....	.....	.....	5	27	39	27	2	.....	.....
51	do	do	1	.....	3	28	4	28	1½	¾	.....	.....	.....	.....	16	40	36	8	.....	.....
52	do	1½-inch stone	½	13	4	36	6	36	1¾	¾	.....	.....	.....	15	44	16	21	4	.....	.....
48	do	½-inch stone	1	15	6	36	5	48	¾	⅜	.....	.....	.....	.....	.....	.....	3	17	56	2
49	do	do	1	18	5	38–32	(1)	.....	¾	¼	.....	.....	.....	.....	.....	.....	.....	40	56	.....
50	do	do	1½	10	6	48	5	60	¾	⅜	.....	.....	.....	.....	.....	2	22	37	37	.....
51	do	Pea	1	.....	4	28	(3)	.....	¾	¼	.....	.....	.....	.....	.....	.....	.....	29	54	1
52	do	do	½	13	6	36	2	48	¾	⅜	.....	.....	.....	.....	.....	.....	.....	62	37	.....

CONNECTICUT.

Plant No.	Type of rock.	Product known as—	Pitch (inches per foot).	Speed, r. p. m.	Screen passing product. Length (feet).	Screen passing product. Diameter (inches).	Screen retaining product. Length (feet).	Screen retaining product. Diameter (inches).	Screen passing product (inches).	Screen retaining product (inches).	Over 3 inches.	3–2½ inches.	2½–2 inches.	2–1½ inches.	1½–1¼ inches.	1¼–1 inch.	1–¾ inch.	¾–½ inch.	½–¼ inch.	Under ¼ inch.
53	Trap	2-inch stone	1½	13	15	60	15	48	2½	1¾	.....	.....	56	44	.....			.....	.....	.....
54	do	do	1	12	8	48	8	48	2¼	1¼	.....	.....	14	53	21	6	3	3	.....	.....
55	do	do	1½	30	32	72	24	48	2½	1½	.....	.....	41	57	1	1	.....	.....	.....	.....
56	do	do	1½	18	5	48	10	48	2½	1½	.....	.....	40	60	.....	.....	.....	.....	.....	.....
57	do	do	1½	.....	10	36	8	48	2¼	1	.....	.....	5	58	13	12	10	2	.....	.....
58	do	do	1½	18	5	38	10	38	2¼	1½	.....	.....	26	51	21	2	.....	.....	.....	.....
59	do	do	1	20	5	48	5	48	2¼	1¾	.....	.....	56	40	4	.....	.....	.....	.....	.....
60	do	do	1¼	15	6	36	6	36	2½	1½	.....	.....	4	69	24	3	.....	.....	.....	.....
53	do	1¼-inch stone	1½	13	15	48	12	60	1¾	1 3/16	.....	.....	.....	57	37	6	.....	.....	.....	.....
54	do	1-inch stone	1	12	8	48	8	60	1¼	⅞	.....	.....	.....	.....	11	51	30	7	1	.....
55	do	1¼-inch stone	1½	30	20	48	16	60	1½	⅞	.....	.....	.....	.....	17	44	32	6	1	.....
56	do	1-inch stone	1½	18	10	48	5	60	1½	1⅛	.....	.....	.....	.....	70	29	1	.....	.....	.....
58	do	1¼-inch stone	1½	19	10	38	8	50	1½	1	.....	.....	.....	.....	18	50	30	2	.....	.....
60	do	1½-inch stone	1	20	5	48	5	48	1¾	1¼	.....	.....	3	52	34	10	1	.....	.....	.....
53	do	¾-inch stone	1½	13	18	48	8	60	1	⅝	.....	.....	.....	.....	.....	.....	12	77	11	.....
54	do	do	1	12	8	60	12	30	⅞	⅝	.....	.....	.....	.....	.....	.....	24	63	13	.....
55	do	do	1½	30	12	60	8	48	⅞	⅝	.....	.....	.....	.....	.....	1	57	36	6	.....
56	do	do	1½	18	5	60	12	48	1⅛	⅝	.....	.....	.....	.....	.....	14	84	1	1	.....
57	do	do	.....	.....	8	48	(2)	.....	1	½	.....	.....	.....	.....	.....	.....	20	56	23	1
58	do	do	1½	18	8	50	12	36	1	⅝	.....	.....	.....	.....	.....	.....	29	63	8	.....
59	do	do	1½	18	6	48	6	48	¾	⅝	.....	.....	.....	.....	.....	.....	19	39	39	3
60	do	do	1¼	15	6	36	6	48	1	⅝	.....	.....	.....	.....	.....	7	49	36	8	.....
53	do	½-inch stone	1½	13	18	48	15	60	⅝	⅜	.....	.....	.....	.....	.....	.....	.....	18	78	4
54	do	do	1	12	12	30	8	42	⅝	¼	.....	.....	.....	.....	.....	.....	.....	9	74	17
55	do	do	1½	30	8	48	7	60	⅝	⅛	.....	.....	.....	.....	.....	.....	.....	43	54	3
56	do	do	1½	18	12	48	8	60	⅝	⅛	.....	.....	.....	.....	.....	.....	1	6	54	39
57	do	do	1½	.....	(2)	.....	(2)	.....	½	⅜	.....	.....	.....	.....	.....	.....	.....	28	71	1
58	do	do	1½	18	12	36	8	50	⅝	¼	.....	.....	.....	.....	.....	.....	2	14	75	9
59	do	do	1	20	6	48	6	48	⅝	⅜	.....	.....	.....	.....	.....	.....	.....	1	47	52
60	do	do	1¼	15	7	48	(2)	.....	⅝	⅛	.....	.....	.....	.....	.....	.....	.....	1	35	64

MAINE, NEW HAMPSHIRE, AND VERMONT.

Plant No.	Type of rock.	Product known as—	Pitch (inches per foot).	Speed, r. p. m.	Screen passing product. Length (feet).	Screen passing product. Diameter (inches).	Screen retaining product. Length (feet).	Screen retaining product. Diameter (inches).	Screen passing product (inches).	Screen retaining product (inches).	Over 3 inches.	3–2½ inches.	2½–2 inches.	2–1½ inches.	1½–1¼ inches.	1¼–1 inch.	1–¾ inch.	¾–½ inch.	½–¼ inch.	Under ¼ inch.
61	Granite	No. 3	1½	24	3	30	3	30	2½	2	.....	10	27	34	20	8	1	.....	.....	.....
62	do	Tailings	1	22	.....	.....	3	32	.....	2	.....	66	30	4	.....	.....	.....	.....	.....	.....
63	do	No. 4	1	14	3	32	4	32	2½	1¼	.....	6	45	36	13	.....	.....	.....	.....	.....
64	do	No. 3	1	16	3	42	8	42	3	2	.....	27	37	36	.....	.....	.....	.....	.....	.....
65	do	No. 1	1½	18	4	36	4	42	2	1½	.....	.....	61	32	7	.....	.....	.....	.....	.....
61	do	No. 2	1½	24	3	30	4	30	2	1	.....	.....	.....	24	51	25	.....	.....	.....	.....
62	do	do	1	22	3	32	3	32	2	1¼	.....	.....	.....	.....	44	33	16	7	.....	.....
63	do	No. 3	1	14	4	32	4	32	1¼	¾	.....	.....	.....	19	18	34	26	3	.....	.....
66	do	do	1	13	4	42	4	42	1½	⅝	.....	.....	.....	5	42	33	18	2	.....	.....
64	do	No. 2	1	16	8	42	4	42	2	1	.....	.....	8	52	17	15	8	.....	.....	.....
65	do	do	1½	18	4	42	4	42	1½	¾	.....	.....	.....	2	19	38	35	6	.....	.....
61	do	No. 1	1½	24	4	30	3	42	1	⅜	.....	.....	.....	.....	.....	5	19	37	37	2
62	do	do	1	22	3	32	3	32	1¼	½	.....	.....	.....	.....	.....	2	49	42	7	.....
67	do	No. 3	1	18	2½	36	2½	36	1	½	.....	.....	.....	.....	.....	.....	43	45	12	.....
61	do	Pea	1½	24	3	42	(3)	.....	⅜	3/16	.....	.....	.....	.....	.....	.....	.....	3	51	46
63	do	No. 2	1	14	4	32	4	32	¾	¼	.....	.....	.....	.....	.....	.....	26	54	19	1
66	do	do	1	14	4	42	4	42	⅝	⅜	.....	.....	.....	.....	.....	.....	.....	14	74	12
67	do	do	1	18	2½	36	2½	36	½	¼	.....	.....	.....	.....	.....	.....	.....	.....	83	17
64	do	No. 1	1	16	4	42	(3)	.....	1	¼	.....	.....	.....	.....	.....	.....	19	31	31	19
65	do	Pea	1½	18	4	42	3	54	¾	¼	.....	.....	.....	.....	.....	.....	7	70	22	1

[1] Gravity screens.

[2] Pulsating, 6 by 6 feet.

[3] Gravity screens, 3 by 9 feet.

TABLE 2.

POWER REQUIREMENT AND OUTPUT OF CRUSHING PLANTS.

Plant No.	Type of material.	Total horsepower.	Output per day.	Plant No.	Type of material.	Total horsepower.	Output per day.
			Tons.				*Tons.*
1	Trap	175	300	35	Trap	100	500
2	do	700	2,500	36	do	130	600
3	do	400	1,000	37	do	25	150
4	do	420	1,000	38	do	45	90
5	do	80	400	39	Sandstone	25	100
6	Limestone	200	500	40	do	50	100
7	Sandstone	240	300	41	Syenite	40	100
8	do	150	450	42	Granite	40	150
9	Limestone	400	1,000	43	do	70	100
10	do	100	200	44	do	35	90
11	do	90	600	45	do	35	100
12	do	50	100	46	do	175	500
13	do	2,000	5,500	47	Slate	100	250
14	do	50	200	48	Rhyolite	75	200
15	do	350	1,000	49	do	85	250
16	do	400	3,000	50	do	125	400
17	do	310	1,000	51	do	60	150
18	do	250	900	52	do	40	90
19	do	35	85	53	Trap	610	5,000
20	do	550	3,000	54	do	275	900
21	do	175	400	55	do	350	1,000
22	Trap	2,000	8,000	56	do	100	400
23	Gneiss	1,200	3,000	57	do	150	400
24	Trap	50	250	58	do	150	400
25	Granite	100	100	59	do	340	900
26	do	1,000	2,500	60	do	75	200
27	do	125	1,000	61	Granite	30	100
28	Trap	300	500	62	do	40	100
29	do	50	225	63	do	35	150
30	do	450	900	64	do	60	150
31	do	385	1,200	65	Sandstone	75	200
32	do	75	150	66	Granite	85	200
33	do	300	1,500	67	do	75	50
34	do	225	300				

TABLE 3.

EFFECT OF LENGTH OF SECTION ON EFFICIENCY OF PLANT SCREENING.

Length of plant screen retaining product.	Per cent of total plants, samples from which show less than 15 per cent passing a laboratory screen with same size holes as corresponding plant screen.					
	2-inch stone.		¾-inch stone.		Pea stone.	
	Number plants sampled.	Per cent.	Number plants sampled.	Per cent.	Number plants sampled.	Per cent.
Feet.						
1	1	0	....	....	....	....
2	....	....	1	....	1	....
3	5	40	1	100	10	50
4	11	45	13	60	9	55
5	5	80	2	100	3	35
6	10	80	7	70	6	50
8	7	85	8	65	4	100
10	3	70	3	100	....	....
12	1	100	4	100	2	50
15	2	100	....	....	1	100
18	1	100	....	....	....	....
20	3	100	....	....	....	....

TABLE 4.

EFFICIENCY OF PLANT SCREENING.

Grouped by States and sizes.

Number of plants.	Approximate size of product.	Proportion of plants showing the following variations from nominal size.			
		Less than 5 per cent.	Less than 10 per cent.	Less than 15 per cent.	Over 15 per cent.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
18	2½ inches to 1½ inches	22	44	66	34
16	1½ inches to ¾ inch	37	62	75	25
17	¾ inch to ½ inch	35	47	47	53
	Average	29	51	63	37
8	2½ inches to 1½ inches	50	50	75	25
6	1½ inches to 1 inch	33	66	83	17
8	1 inch to ½ inch	13	51	76	24
8	½ inch to ¼ inch	50	63	63	37
	Average	36	56	75	25
8	3 inches to 2 inches	63	63	75	25
10	2 inches to 1½ inches	20	40	50	50
8	1½ inches to ¾ inch	38	50	75	25
8	¾ inch to ¼ inch	63	75	75	25
	Average	44	56	68	32

TABLE 4—Continued.

EFFICIENCY OF PLANT SCREENING—continued.

Grouped by States and sizes—Continued.

Number of plants.	Approximate siz. of product.	Proportion of plants showing the following variations from nominal size.			
		Less than 5 per cent.	Less than 10 per cent.	Less than 15 per cent.	Over 15 per cent.
5	3½ inches to 2½ inches	0	0	40	60
10	2½ inches to 1½ inches	20	30	30	70
9	1½ inches to ¾ inch	11	33	55	45
9	¾ inch to ¼ inch	33	44	55	45
	Average	20	30	45	55
4	3 inches to 2 inches	75	75	75	25
9	2 inches to 1½ inches	44	55	66	34
6	1½ inches to ¾ inch	50	50	67	33
4	¾ inch to ¼ inch	0	0	0	100
	Average	43	59	56	44
	General average	34	49	61	39

TABLE 5.

WATER-BOUND MACADAM.

State requirements for size.

State.	Bottom course.		Top course.		Screenings.	
	From—	To—	From—	To—	From—	To—
Massachusetts	2½	1¼	1¼	½	½	Dust.
Connecticut	2	¾	2	1	½	Dust.
Maine	2¾	1¾	1¾	¾	¾	Dust.
New Hampshire	2½	1¼	1	½	½	Dust.
Vermont	2½	1½	1½	½	½	Dust.
Rhode Island	3	1	1	Dust.	....	
New York	3¾	[1] 2¾ or 1½	2¾	[1] 1½	⅝	Dust.
Pennsylvania	[2] 3½ or 3	[2] 1½ or 1¼	[2] 3	[2] 1½ or 1¼	[2] ¾ or ⅝	Dust.[3]
New Jersey	3½	2¼	2¼	1½	⅝	Dust.
Maryland	3	1	2	1	1	Dust.

[1] As much as 15 per cent by laboratory test allowed smaller than the lower limit in each case.

[2] Materials must pass over and through revolving screens of the sizes indicated.

[3] If screenings of ¾-inch maximum size are used, they shall contain not less than 15 per cent nor more than 12 per cent, by weight, of dust passing No. 100 laboratory sieve, and not less than 12 per cent, by weight, of particles passing No. 20 and retained on No. 100 laboratory sieve. Screenings passing ⅝ inch shall vary between limits proportionately higher than those specified above.

TABLE 6.

BITUMINOUS MACADAM.

State requirements for size.

State.	First course.		Second course.		Seal.	
	From—	To—	From—	To—	From—	To—
Massachusetts	2½	½	½	¼	½	¼
Connecticut	2½	¼	¾	½	....	....
Maine	3¼	2¼	2¼	1	1	¼
New Hampshire	3	1¼	1	½	½	¼
New York	2¾	[1] 1½	1½	[1] ⅝	⅝	[1] ⅜
Pennsylvania	[2] 3	[2] 1½ or 1¼	[2] 1¼	[2] ¾ or ⅝	[2] ¾ or ⅝	[2] ¼
New Jersey	2¼	1¼	1¼	⅝	⅝	¼
Maryland	3	1	1	Dust.	1	½

[1] As much as 15 per cent by laboratory test allowed smaller than the lower limit in each case.

[2] Materials must pass over and through revolving screens of the sizes indicated

TABLE 7.

CEMENT CONCRETE WEARING COURSE.

State requirements for size.

State.	From—	To—
Massachusetts	1½	¼
Connecticut	1¼	½
Vermont	1½	¼
New York	2¾	[1] ⅜
Pennsylvania	2 or 1½	[2] ¼
Maryland	2½	¼

[1] As much as 15 per cent by laboratory test allowed smaller than ⅜ inch.

[2] Materials must pass over and through revolving screens of the sizes indicated. Not more than 5 per cent by laboratory test to pass a ¼-inch round opening.

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105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
136. Highway Bonds.
230. Oil Mixed Portland Cement Concrete.
249. Portland Cement Concrete Pavements for Country Roads.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
*284. Construction and Maintenance of Roads and Bridges, from July 1, 1913, to December 31, 1914. 10c.
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.
373. Brick Roads.
386. Public Road Mileage and Revenues in the Middle Atlantic States.
387. Public Road Mileage and Revenues in the Southern States.
388. Public Road Mileage and Revenues in the New England States.
389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914.
390. Public Road Mileage in the United States. A summary.
393. Economic Surveys of County Highway Improvement.
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.
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.
*555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials. 10c.
583. Report on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.

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OFFICE OF PUBLIC ROADS CIRCULARS.

(In applying for these circulars the name of the office as well as the number of the circular should be given, as "Office of Public Roads Circular No. 89.")

Cir. 89. Progress Report of Experiments with Dust Preventatives, 1907.
*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.
*96. Naphthalenes in Road Tars. 1. The Effect of Naphthalene upon the Consistency of Refined Tars. (1911.) 5c.
*97. Coke-Oven Tars of the United States. (1912.) 5c.
98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. *49. Motor Vehicle Registrations and Revenues, 1914. 5c.
52. State Highway Mileage and Expenditures to January 1, 1915.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
62. Factors of Apportionment to States under Federal Aid Road Act Appropriation for the Fiscal Year 1917.
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.
*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.

FARMERS' BULLETINS.

(The Farmers' Bulletins are a series of popular treatises issued by the Department of Agriculture. The following list includes only numbers contributed by the Office of Public Roads, and should be applied for by numbers, as "Farmers' Bulletin No. 239".)

F. B. *239. The Corrosion of Fence Wire. 5c.
311. Sand-Clay and Burnt-Clay Roads.
338. Macadam Roads.
*403. The Construction of Concrete Fence Posts. 5c.
*461. The Use of Concrete on the Farm. 5c.
505. Benefits of Improved Roads.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

(In applying for these separates the numbers should be given, as "Yearbook Separate No. 638.")

Y. B. Sep. *638. State Management of Public Roads; Its Development and Trend. 5c.
*712. Sewage Disposal on the Farm. 5c.
727. Design of Public Roads.
739. Federal Aid to Highways.

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 Cements.
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.
Vol. 6, No. 6, D–8. Tests of Three Large-sized Reinforced-Concrete Slabs under Concentrated Loading.
*Vol. 10, No. 5, D–12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction. 15c.
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.

*Department supply exhausted.

FARMERS DO UTMOST, BUT CITY MEN MUST HELP.

With favorable weather and with a supplement of man power from the towns and cities to help in farm tasks of particular strain, especially in harvesting, there is every reason to anticipate increased yields of farm products in the United States this year over the record production last year, but the promise for the future does not in the least warrant relaxed efforts both for greater production and for greater conservation. The increases should be reassuring to consumers and a matter of encouragement to farmers that they can again overcome difficulties. There is a continuing need for large supplies of food and feed products, not only for our own population but for the Allies in Europe who will depend more and more on this country.

The farmers last year responded generously to the patriotic appeal of the President, the Department of Agriculture, the State Colleges of Agriculture, and other public agencies, by planting and harvesting the largest acreage in crops on record in this country. Since July of last year the Department of Agriculture, in cooperation with the Agricultural Colleges and other State and local organizations, has labored unceasingly to maintain, and if possible to increase in 1918, the record acreages of 1917, with necessary adjustments especially to provide for larger production of wheat and other bread grains which are most needed.

The results of the Department's efforts are now becoming apparent. The indicated increased acreage in food crops this year over the record crop of 1917 is gratifying. An increase over the record for peace times would have been striking in view of all the difficulties. The vigorous efforts of the farmers evidence their patriotic determination to help win the war. Reports indicate that in order to plant larger acreages with less help than ever before, farmers are working from early dawn until black darkness, utilizing to the fullest capacity all their man power, family power, horse power, and machinery, and setting an example of extraordinary exertion and efficiency which might well be followed in other essential industries. The work of the farmers and of the agricultural agencies is not spectacular and does not catch the public eye, but it is nevertheless unceasing and effective and is as vitally important as any other service rendered in the Nation in this emergency. American farmers are entitled to and should receive the fullest credit, appreciation, and recognition. They and their families are doing and will continue to do their utmost to help win the war for human freedom against the outlaws of the military autocracy of Europe which threatens all that is held most dear and sacred by civilized peoples.

Farmers have done and will continue to do their part. They have planted generously. They will need the assistance in cultivation and harvesting of many additional laborers. The critical factors in crop production after planting will be weather and labor. Weather is beyond human control, but the necessary labor for cultivating and havesting the food crops planted by the farmers of this country must be supplied when and where most needed.

The Departments of Agriculture and Labor are cooperating and are taking every step possible to help the farmers secure labor. It now devolves upon the cities and towns to lend assistance. This duty exists in peace times because the urban communities are vitally dependent upon the back country for their very existence; some owe their very being to the surrounding rural districts. In this emergency they must labor with other agencies to see that the crops are cultivated and harvested. I trust that the thoughtful people of the towns and cities will realize that the farmers can not work miracles, and that upon the cities rests the responsibility of furnishing the necessary supplement of man power.

D. F. HOUSTON,

Secretary of Agriculture.