Certainly before any commercial corporation would consider increasing its investment by as much as one tenth the amount taxpayers are spending in the road building program, the most minute detail would be investigated and would be proved to be absolutely essential. Yet we are not using this deliberate method of analysis and investigation in our road building program. In only a few instances have we developed a complete and comprehensive plan.

In the majority of cases our road building funds are under the control of elected officials, and although these officials may have realized the program most obviously indicated, unless a definite plan has been agreed upon to cover a period of years, much of the expenditure they approve will not be of as great benefit as they themselves intended it to be unless their tenure of office is sufficiently long to permit the completion of their plan. They may be followed by men, or women, equally honest, equally conscientious, and equally public-spirited but with entirely different ideas on the road requirements. Even the most loyal and honest men or women cannot outline the most economical expenditures unless those expenditures are based on study and analysis, and are part of a definite plan.

Four problems face our road building officials: First—On which roads should the money be spent? Second—What types will be most economical? Third—How can the construction be made progressive so that the money spent and the work done will not be lost in the future? Lastly—What should the program be so that the use of the tax moneys will result in the greatest benefit to the community? Adequately to ascertain the answers to these four problems, a definite survey should be instituted, in each county at least, and that survey should take into consideration every part and parcel of the most remote, as well as the most centrally, located township in the county.

Until the road requirements are ascertained by a scientific analysis, and are embodied in a definite plan, with adequate finances arranged for, we will not be in a position to commence to care for the road requirements of the various industries of this nation, economically and without prejudice.

SOME NEW DEVELOPMENTS IN ROAD CONSTRUCTION AND MAINTENANCE

By W. H. Root, Maintenance Engineer, Iowa State Highway Department, Ames, Iowa

We learn by experience. Iowa has financed, constructed, and maintained a large mileage of primary roads in the last few years. The engineers of the Iowa Highway Department in developing this program have encountered many problems, the solution of which has been interesting to us. We trust that a resume of these experiences will be of value to the engineers of other states.

In order for you better to understand our problems let me first paint you a brief picture of our state and its highway system. Iowa has an area of 56,000 square miles, practically none of which is so-called "waste land." As a result of this wide distribution of farm land we have a wide distribution of roads, the total mileage of which is approximately 105,000. Generally speaking, the topography is gently rolling, but we have some notable exceptions in the form of rough clay hills, rough limestone sections, and some very flat gumbo sections. The northwest third of the state was covered by the Wisconsin drift and a large quantity of gravel is, therefore, available in that section. Generally this gravel runs high in fines, with the result that many of our gravel roads border closely on the sand-clay type. Iowa has no large cities. Des Moines, the capital, is the largest, having a population of 143,000. The total population of the state, 2,471,000, is about as evenly divided over the state as are the highways.

Our problem, therefore, is first of all a farm-to-market or a town-to-town problem; however, it is a fact that Iowa lies directly in the path of Chicago, Omaha, and transcontinental east and west traffic, and in the path of Minneapolis, Kansas City, and transcontinental north and south traffic. Iowa has never catered to this so-called tourist traffic, but in taking care of our own town-to-town traffic we have improved a number of through lines which enable us to keep our visitors out of the mud.

On January 1, 1920, Iowa had 25 miles of primary road paving, about .4 of 1% of the total system. By November 30, 1930, this paved mileage had been increased to 3,486 miles, or 48% of the system. Most of this paving has been constructed in the last three years. The program was climaxed in 1930 when 1,027 miles of concrete paving were completed.

Public opinion is difficult to analyze. It can never be safely predicted and it is often hard to account for. In my opinion, the general uprising of the people of Iowa in 1927 demanding an increased paving program can be accounted for as follows:

1. They were most awfully tired of driving in the mud.
2. They were convinced that the gravel road was not a panacea.
3. They were sold on the limited mileage of paving that had already been constructed.
4. Last, but not least, they were convinced that the plan of financing offered was a real bargain.

Let me go into some detail in regard to the plan of financing. It was substantially this. Iowa had a primary road fund at that time of approximately $13,000,000 available annually, made up from auto license fees, gas tax, and federal aid. Any county that wished to hasten the construction of its primary roads was told that it could vote county bonds to finance the work and that the state would guarantee the payment of both principal and interest on the bonds from the primary road fund. Necessarily there were certain restrictions to the voting and issuing of these bonds. The amount that could be issued was limited and the program of road improvement had to be approved by the commission. In fact, the county bond money was turned over to the commission and the work was carried out entirely by commission forces. However, the plan amounted to the county voting bonds and the state paying them. This was so much like a college student getting money from home without asking for it that it was very popular with the counties, and under this plan $99,000,000 of county bonds have been authorized to date.

The most difficult feature was the financing and this has already been explained. There were many other serious problems, such as securing the right-of-way and the preparation of the plans, to say nothing of the actual construction of the pavement. By a quick expansion of the engineering force and a close co-operation between departments, the state was able to put the program over with little delay and in a manner which we believe meets with the requirements of modern engineering.

Another feature which greatly aided in the carrying out of this program was the fact that for many years the commission had been building modern bridges and culverts and constructing modern grades on the important lines. This meant that many miles of grade were ready for immediate improvement with paving.

Construction Details

So much for the general picture of our conditions. Now let us look to a few of the details that have been worked out in this program.

We used the thickened edge pavement developed from the Illinois-Bates tests. Early in the construction of our pavements, especially in those parts of the state where light, washable soils prevail, we found that some means would have to be devised to prevent the washing of the shoulders along the edges of the pavement on side hills. We did not wish to confine the traffic by constructing the conventional curb section, as most of our pavements were only 18 feet in width and none of them more than 20 feet; so we devised what we call "the sloping curb section." This section was first built in 1920 and has since been adopted, with modifications, by many other states. As now constructed in our state, this curb is one foot wide and 3 inches high. It is built monolithically with the slab so that it not only serves as a curb but as an additional thickened edge. The 3-inch rise in the curb is gained in 9 inches horizontal so that there is a 3-inch flat top. This curb, with proper outlets, will confine the flow of water to the pavement and offers no serious resistance to traffic which wishes to turn onto the shoulder.

The development of this curb necessitated the devising of some type of take-off for the water. For several years we experimented with various types of intakes but all that we tried were either inadequate to handle the water or else they

Fig. 1. Sloping curb section used on hills.

restricted the roadway. We then made a study of open flumes. After various starts we decided upon a wide-throated, flat section flume adequate to carry off all the road water and at the same time presenting little danger to traffic forced onto the shoulder.

It was the Missouri loess soil that forced us to work out the curb section. This same soil created another problem which had to be met in a new way. Loess soil is of a blotter-like nature. It will absorb great quantities of water before becoming saturated. We found that pavements laid on loess soils had a much greater tendency to develop hair cracks than pavements laid on other soils. We were convinced that this cracking was due to too rapid loss of water in the early stages of setting. We tried to obviate this cracking by

Fig. 2. Wide throated, flat section flume to direct water from pavement at sags in grade.

Fig. 3. Cars running on shoulder can pass over this flat section flume without damage.

copious wetting of the subgrade, but satisfactory results were not obtained. We then determined to try to cut off this absorption with a layer of tar paper. This scheme worked. In fact, it worked so well on the loess soils that we have adopted it as a standard. It is now specified on all subgrades. We believe that it leads to uniformity of concrete and lessens the possibility of hair checks. It is quite possible that this provision of the specifications will be waived and a slight deduction made from the contract price during the spring of the year, when subgrades are pretty well saturated.

Fig. 4. Layer of tar paper specified on all subgrades for concrete road slabs.

Proportioning of pavement aggregates by weight is now an old story; however, this procedure was first tried out in Iowa on two projects in 1923, and in 1924 was made standard practice on all paving jobs. Many other states are also using this method of proportioning. In connection with this weighing of aggregates it is our practice to determine the moisture content of both the fine and the coarse aggregate several times each day so that proportions can be varied to meet exact conditions. One problem encountered in connection with the proportioning of aggregates by weight was the premature discharge of the water from the supply tank because of entrapped air. This trouble has been obviated by a double tank system consisting of a supply tank with open top mounted over the measuring tank. The water discharges from the supply pipe to the supply tank, from which it runs by gravity to the measuring tank. Riser pipes are carried from the measuring tank to above the water level in the supply tank. These riser pipes carry off all entrapped air.

Maintenance Developments

In the maintenance field, too, certain developments have been made which we believe are worth recording. The maintenance of the primary roads in Iowa is paid for directly by the state. The work is supervised by thirty-three maintenance superintendents, each of whom has an average of 230 miles of road. Each superintendent has some earth, some gravel, and some paving in his division.

In the administration of maintenance matters we have discarded maintenance manuals and instruction books and have substituted loose-leaf systems entirely. We believe that it is imperative that the maintenance superintendents have a complete and up-to-date set of instructions available at all times. New men have no way of familiarizing themselves with the customs and policies except through printed instructions, and old men must frequently brush up on these matters. However, conditions change so rapidly and new policies are adopted so often that nothing short of a loose-leaf continuous set of instructions is good for any length of time. We have three sets of loose-leaf letters which govern the maintenance superintendents and their work.

First. A set of maintenance instructions. These are definite instructions which set out completely the commission's current policies.

Second. A set of "tickler letters," which are issued periodically to call the attention of the maintenance superintendents to maintenance instructions which are already in effect but which may have been lost sight of, yet are important at that particular time. For example, we have a maintenance instruction on the destruction of weeds. A tickler letter is issued on this subject in June so that all superintendents will look over their basic instructions and take care of the weeds as contemplated.

Third. We also have a set of loose-leaf letters called "kink letters." These letters explain and illustrate ingenious devices which have been worked out by some one in the maintenance personnel. In other words, if one employee works out a good idea, we believe in passing this information on to the other men in the department.

Next in importance to an efficient personnel is adequate equipment. We have been extremely careful in the selection of our equipment and we are proud of it. In general our equipment is not greatly different from that used by other states. We have, however, I believe, gone further than most states in the matter of housing. We have constructed at various points in the state 98 garages. These buildings are of clay tile construction and range in size from 34 x 40 feet to 34 x 100 feet. One end of each building is used for a shop and the other for storage. These buildings provide safe, warm, economical storage for all maintenance equipment. In every case we try to secure about an acre of ground for a building site. This tract is fenced neatly and used for storage of materials that do not need to be housed. We have invested in all these sites and buildings $650,000. These garages are all equipped with a large supply tank and a pump for gasoline which enables us to buy our gasoline at 4½c a gallon below the station price, less tax.

Fig. 5. Maintenance garage and office building.

An economical scheme has been worked out for the storage of lubricating oil in these garages. Oil barrels are held in a rack near the ceiling. The oil is elevated to these barrels by air pressure and is drained off by gravity. This plan gives more room on the floor and in the winter keeps the oil at a higher temperature.

Our pavement cracks are maintained with bitumen which is applied hot by means of cone-shaped pouring pots. Considerable difficulty has been experienced because of the hardening of the bitumen in the nozzle of the pot. A special paving-pot heater has been designed which attaches to the tar kettle and holds the pot when not in use. The heater has eliminated freezing trouble.

In 1929 we experimented with a double centerline mark on a short mileage of pavement. This proved popular with both the public and the commissioners, and in 1930 we adopted the double centerline as standard. We use two 5-inch lines spaced

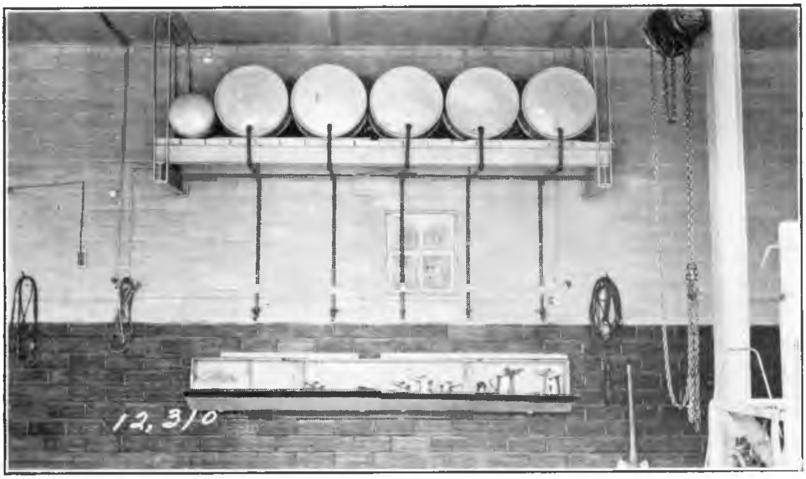

Fig. 6. Arrangement for handling oil in maintenance garage.

Fig. 7. Bituminous pouring pot heater attached to bituminous kettle.

10 inches apart. We believe that the double centerline tends to spread the traffic silghtly and thereby reduces the amount of sideswiping.

Raising Slabs with Hydraulic Pump

Probably the most outstanding recent development in pavement maintenance is the hydraulic pump which has been recently developed for raising pavement settlements. The engineering profession is familiar with the laws of hydraulic pressure and their various applications to engineering problems; however, it remained for John Poulter, a mechanic of the Iowa State Highway Commission, to apply this hydraulic principle to the raising of pavement slabs. For a considerable period of time he experimented with simple homemade devices for producing hydraulic pressure and applying it to slabs. When he had convinced himself that slabs could actually be raised by hydraulic pressure, he developed a machine to produce the pressure and applied for a patent on the process of raising slabs by hydraulic pressure.

The first machine used for raising a slab by this method consisted of a tractor valve and valve guide. The guide was grouted in a hole which had been drilled through the slab; mud was poured into the guide; and the valve stem was in-

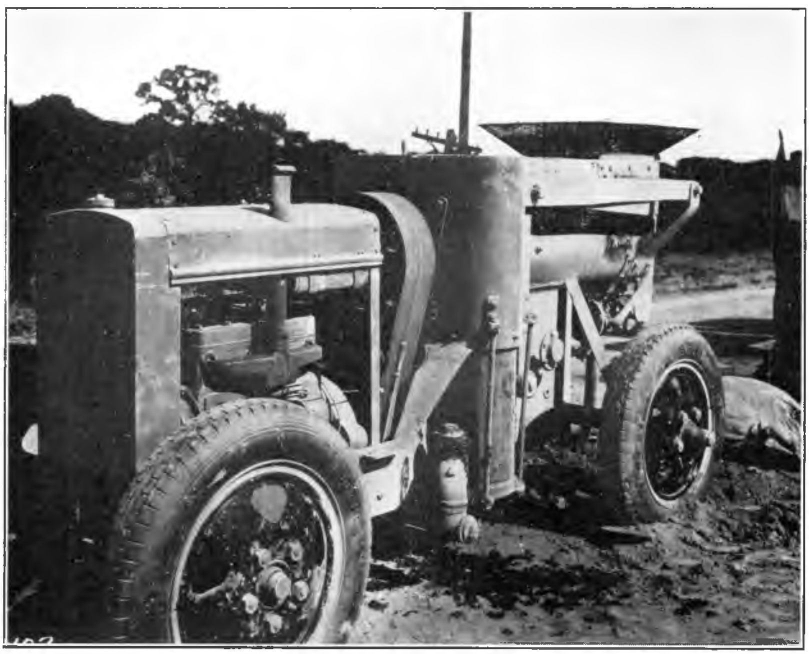

Fig. 8. The Poulter mud pump for raising settled pavement slabs.

serted. Pressure was produced by the weight of a man standing on the valve.

From this small beginning has been developed the modern Poulter mud pump for raising pavement slabs. It is a two-cylinder reciprocating pump powered by a 20-horsepower gasoline motor. It is made up of the following principal parts:

(a) A hopper for receiving earth, water, and cement.
(b) A mixing chamber for mixing the materials.
(c) A receiving chamber for holding the mud and delivering it to the cylinders.
(d) The pump itself.
(e) An outlet hose.
(f) The power plant.

The actual raising of the slab is a simple process. First, a 4-inch expansion joint is cut across the pavement at one end of the settlement. This is done to prevent a binding action when the slab is raised. Next, $2\frac{1}{2}$-inch holes are drilled through the slab, some near the edge and some near the center joint. The holes are spaced from 4 inches to 10 inches apart, depending upon the location of the cracks in the slab. This work is done with the ordinary compressed-air jackhammer and pavement breaker.

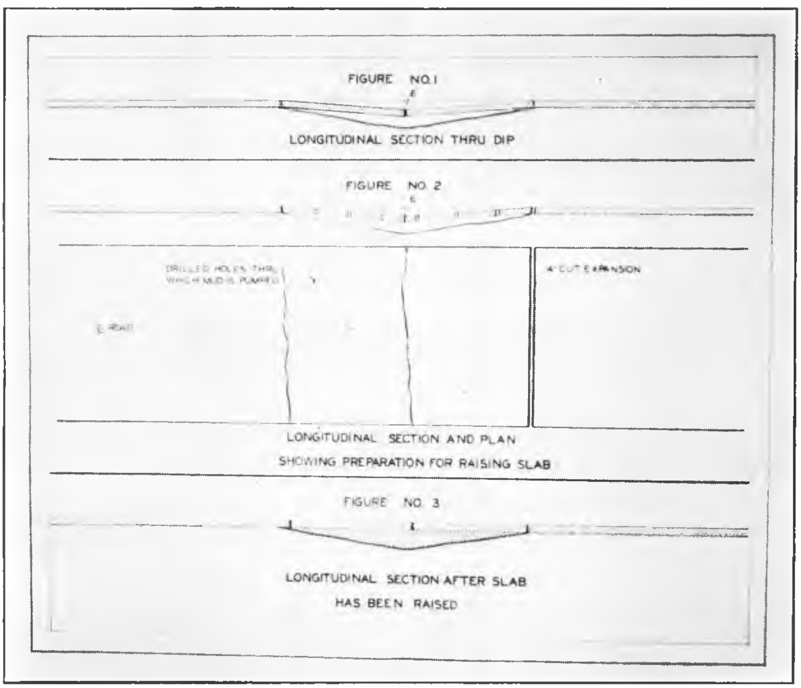

Fig. 9. Plan and elevation views illustrating method of raising pavements.

After the slab has been prepared as outlined above, the mud pump is put into operation. Earth is brought to the pump in trucks; black top soil and loess have proved most satisfactory. Sand wears the cylinders too fast; gravelly soil clogs the valves; and heavy clays do not readily form the creamy grout necessary.

Portland cement is added to the earth in the proportion of 1 to 20. The primary reason for adding cement is to cause the grout to set up quickly after it is pumped. This "setting up" is not a typical cement set but is an action which produces the same effect as a slight drying out of the mixture. It was early found that under certain conditions the mud pumped in one hole would escape from other holes or from under the edge of the slab and that no pressure could be built up. It was found that by waiting for an hour or two the mud would stiffen sufficiently so that pumping could be resumed. The addition of 1 part cement to 20 parts earth has reduced this waiting time from one or two hours to from fifteen to twenty-minutes. Laboratory experiments were carried on, using various proportions of lime, cement, and plaster of Paris; and the 1 to 20 proportion, using Portland cement, was established as the most satisfactory mix. These experiments also showed that the addition of cement greatly reduced the shrinkage. The shrinkage of plain earth and water mixture was found to be 10%, while the shrinkage of the 1 to 20 mixture was found to be only 3½%.

The hose leading from the pump is a high-pressure 2½-inch fire hose. This is reduced at the outlet to a 2-inch steam hose, which has some elasticity. This outlet hose is placed in the hole in the pavement; and when the pump is started, the pressure of the mud passing from the 2½-inch hose to the 2-inch outlet expands it and holds it tightly in the hole.

The earth and cement are shovelled from the truck directly into the receiving hopper and water is added. The materials pass from the receiving hopper to the mixing chamber, which resembles the old-style continuous concrete mixer. When the material enters the pump, it is a soft grout, the moisture content of which is about 45%.

No figures are available as to the exact amount of pressure built up by the pump. The weight of the slab, of course, is only about ¾ of a pound per square inch, but fairly high pressures are necessary in order to break the slab loose. Once it starts, little pressure is needed to raise it. Some difficulty has been experienced in starting the slabs, but no slabs have been encountered that could not be raised. Some of the older outlet hose has blown out. It is estimated that in some cases a pressure of 50 pounds per square inch has been built up.

Iowa has had five mud pumps operating the past season. Some of the slabs which were raised early in the year settled

Fig. 10. Raising a section of pavement with Poulter mud pump.

slightly again and the mud pump was brought back and the slabs again raised to grade. The holes in the slab will not be filled permanently until no further settlement is probable.

The fact that a considerable quantity of water is introduced into the subgrade is not considered to be a serious matter. While the mud as pumped has a moisture content of about 45% and while the mud which has been under the pavement for two weeks in the fall of the year still contains about 43% moisture, it is not believed that serious harm will result therefrom. The earth as delivered to the pump has a moisture content about the same as the average subgrade on fills, or approximately 25%.

The figures on the Iowa work are interesting. During the season 200 settlements, comprising 9,292 linear feet, have been raised from 3 inches to a maximum of 13 inches. For this work 1,911 cubic yards of earth and 2,299 sacks of cement have been used. Eight hundred ninety-nine cubic yards of black top would have been required to raise the settlements by that method.

The materials have cost $1,580.16, the labor $8,329.08, and the rentals of equipment $8,987.29, making a total cost of $18,896.53. As 18,584 square yards have been raised, the cost has been $1.02 per square yard. Also, as 1,911 cubic yards of earth have been pumped, the cost has been $9.88 per cubic yard of material pumped. Of the 1,911 cubic yards of material used, 899 cubic yards were required to raise the slab to grade. The remaining 1,012 cubic yards (53% of the total) went to fill the voids under the pavement.

While this method is slightly more expensive than the black top method (Iowa costs are about 75c per square yard for raising with black top), it is so much more permanent that we believe the extra cost is justified.

It is anticipated that this method can be extended to prevent settlements. Pavements on fills which are expected to settle can be sounded occasionally; and, if the soundings show voids under the pavement, these voids can be pumped full of mud before the pavement settles. Such procedure would result in greater safety to the traveling public and in greater economy to the state.

LOOKING AHEAD IN ROAD IMPROVEMENT

By Robert Kingery, General Manager, Chicago Regional Planning Association

Beginning the year 1931 with 2,825 miles of state and county highway pavement in the metropolitan region of Chicago, those road officials who are collaborating in constructing their systems of paved roads in accordance with co-ordinated plans, have no thought of a let-up. They plan to continue the construction of new 40-foot-wide pavements, new two-lane pavements, highway grade separations, and railway grade separations until the paved highway system compares with the number of motor vehicles. It is their objective to remove the congestion by widening the present main highways where they are congested, and by building new routes to divide the traffic load more evenly.

Almost 280 miles of the highway system outside of the City of Chicago is four-lane pavement, 40 feet wide or more; and 1931 should see over 140 miles more of broad pavement of this type added to the system. At the same time the construction of 230 miles of new 20-foot pavement is definitely on the program, while 30 bridges, 21 highway grade separations, and 42 railway grade separations are to be planned.

A special feature of this program is the pavement construction under way or to be built this season within the City of Chicago by the County of Cook. When the 1929 gasoline tax law was adopted, the Board of Cook County Commissioners immediately allocated the county's entire share of this tax fund to City of Chicago streets, on recommendation of the County Superintendent of Highways and the Chicago Regional Planning Association. Last year, 1930, saw the beginning of