notice that the workmen held their fingers under the string. The alley has recently been repaired by the contractor after litigation of two years duration.

INSPECTION AND CONSTRUCTION PRACTICES ON INDIANA CONCRETE ROADS

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Our aim is to get the best possible results using the plans and specifications under which the contract is awarded. On state and federal work the plans and specifications are standardized, resulting in standardized methods of construction and inspection. I desire to spend most of my time discussing these methods.

During the fiscal year of 1927 our department had supervision and inspection on 129 contracts. Of these 58 were state and federal projects on which the specifications were very nearly the same. The remaining 71 were county projects on which state inspection had been asked. They were in a number of different counties and the specifications varied considerably. The only general rule which can be followed in inspecting county work where the specifications vary is to get the best possible results under the existing specifications. This work, therefore, requires considerably more time devoted to supervision than where the methods can be standardized.

Building The Grade

The first operation in building a concrete road and in fact any road is the building of small drainage structures and the making of cuts and fills. I will not dwell on the construction of the drainage structures as they would naturally fall under another heading. I will only mention a few of the most important methods we follow in grade preparation which hold equally as good for other types of roads as for concrete. The project engineer sets substantial stakes on or near the right of way line at each 100-foot station and on each side of the road. These stakes are usually 2 inches square and 18 inches long, dressed on two sides to facilitate the marking of station numbers and distances out from the center line. Elevations are taken on each stake and a grade sheet computed giving the distance of the finished grade above or below each stake. The grade foreman is furnished with copies of the grade sheets with which he can level off and determine the cut or fill at

each stake before any bushes, trees, stumps or earth are removed from the roadway. If a grade exists which is too narrow, it is torn down and spread out to full width of the base of the new fill, leveled off and thoroughly rolled with a 10-ton, 3-wheel roller. Then the fill is built up and rolled in layers approximately 1 foot in thickness. The back-filling adjacent to culverts and bridges is placed in 6 inch layers and each layer thoroughly tamped by hand. Occasionally when a pump and plenty of water is available the back fills are puddled. The reason for all of this precaution in building the grade is to build a uniformly compacted grade and minimize the later, unequal settlement which as you all know is very serious for any kind of pavement, but its effect is much more noticeable on a concrete pavement than on a flexible type.

Fine Grading and Form Setting

The next step after construction of the grade is the preparation of the subgrade, commonly called fine grading. Smoothing up to get the grade within one or two tenths of the correct elevation is done with a blade grader and fresno. Fresnos are better than scrapers or wheelers because they can pick up and deposit material in very thin layers. Then form stakes are set to both line and grade one or two feet outside of the form line on each side of the road. These stakes are set at 25-foot intervals. We have found that a much truer surface is obtained, both as to line and grade, if these stakes are set not farther apart than 25 feet. The foundation for the form is then prepared to exact elevation. If a slight fill is necessary the hand tamp is used to compact it. The usual method used in preparing this foundation for the forms is by hand, but some of the more progressive contractors have a form grading machine which is a great labor saver.

As soon as the foundation for the forms is prepared the forms are set true to line and grade and firmly staked. Then the subgrade is completed between the forms to receive the concrete. This is sometimes done by hand but usually with a subgrader pulled on the forms with the blades set to the required depth and cross section. A small roller of about three tons in weight is very useful in compacting and smoothing up a subgrade. On truck units where the concrete materials are hauled to the mixer by truck, it is sometimes a great advantage to do a large part of the fine grading early in the morning or at night when the trucking does not interfere. Where trucks are used the subgrade is continually being worked out of shape. This requires constant attention to assure a correct grade just ahead of the mixer. Here again the small roller with a bulldozer blade is a very useful tool.

With the industrial hauling outfit, when the subgrade is once prepared it stays that way unless the treads of the mixer

push it out of shape. All subgrade crews work to a template riding on the forms and just before concrete is deposited the elevation and section of the subgrade is checked with the template and any irregularities corrected. After the subgrade is completed the uniformity of the grade of the forms is checked with a ten-foot straight edge so any irregularities can be found and removed before the concrete is deposited against them. In order to obtain a smooth surface on the pavement it is very essential that the forms be accurately set with a full bearing on a firm foundation. Any line of forms which does not have an even bearing and firm foundation should be taken up, the foundation corrected and the forms reset. These methods of checking the forms and subgrade cause the workmen to check their own work, greatly aiding the inspection.

Placing of Center Joint and Reinforcing Steel

After the subgrade has been prepared and the forms set, the center joint and reinforcing steel (if any is used) should be placed. The center joint should be placed accurately by means of a template riding on the forms and firmly staked to line and grade. If the center joint is not to correct line it looks bad on completed work and if not to correct grade it weakens the load-transferring effect from one slab to the other. In the latter case the concrete is more liable to spall and start disintegration. All reinforcing steel or continuous dowels should be held in place by metal chairs left in place. We have had some sad experiences by using sleds to support reinforcing steel. When the sled is pulled out it tears a hole in the concrete, the concrete arches over and leaves honeycombed places which later result in cracks. You have probably noticed, on some of our pavements about three or four years old, longitudinal cracks at the center and quarter points. In every case they were caused by the use of the sled to support reinforcing steel. Care is used to see that all dowel bars are either painted or oiled to prevent bond between the concrete and the steel.

Inspection and Proportioning of Materials

Before any material is used in the pavement the source and the producing plant should be inspected to make sure a uniform and satisfactory quality of material can be furnished. The quantity is often quite important, as continual changing of materials often causes poor results. Uniform material properly handled will produce uniform results so essential in concrete work. To insure satisfactory materials, each car of cement should be tested and each car of sand and coarse aggregate should be visually inspected. If there seems to be any doubt as to any of its qualities further tests should be

made. Grading tests of the aggregates should be run for every five or six cars at least and oftener if necessary to insure the proper grade. Aggregates should be inspected during and after unloading for dirty, coated material. First class concrete can not be made from dirty and coated aggregates. An excess of dust on stone is as objectionable as mud or silt on gravel. In some cases, cars of aggregate inspected from the top appear in first class condition but for some reason the material in the bottom of the car may be unsatisfactory.

The proportioning of materials is usually covered by the specifications. The common method is to proportion by volume assuming that one bag of cement is one cubic foot. The standard specifications have up to this time required an approximate 1:2:3 mix with a definite cement requirement of 1.7 barrels to the cubic yard of mixed concrete. This of course requires adjustment of the proportioning of aggregates to keep the cement content constant. It would require considerable time to go into detail as to how and when to make these adjustments but in general the amount of cement and sand should be left constant and all adjusting made with the coarse aggregate.

At the present time the state is specifying that the aggregates be proportioned by weight. I have had no construction experience with this method. The most accurate and in general the most satisfactory method, both from the construction and inspection standpoint, of proportioning aggregates by volume, is by use of the automatic batcher boxes manufactured by a number of equipment manufacturers. Cement usually comes in bags and even-bag batches are usually arranged for. Split-bag batches are not very satisfactory in that it is next to impossible to get the correct amount of cement in each batch. To make sure the correct number of bags of cement go in each batch the cement for the batch should be piled in a separate pile before any of the bags are emptied into the batch. If the bags are piled up they are very easily counted but if two or three men are emptying cement into a batch it is impossible for an inspector or even the men themselves to be sure just the number of bags used. If a plant inspector is not used, the cement should come to the mixer either in the bags or in separate compartments so the inspector can check the amount of cement used at all times. If separate compartments are used care should be taken to see that they are tight and the cement does not lose out on the road between the plant and the mixer.

Mixing Concrete of Correct Consistency

Concrete should be mixed with a standard paving mixer in good mechanical condition with a water control tank by which the amount of mixing water can be accurately measured.

Leaky water valves should not be permitted. The paving mixer should be equipped with a timing or regulating device by which the discharge chute is locked until the concrete has been mixed for the specified time.

The consistency is controlled by the time of mixing and the amount of water used in the batch. Each concrete inspector is equipped with a slump cone and makes slump tests at least once a day. For a machine finish the slump should be not more than 2 inches or less than ½ inch. If it can not be kept within this range the reason is ascertained and corrected. For good results, both from the standpoint of good concrete and correct finish, the consistency should be as uniform as possible.

Depositing, Striking and Finishing Concrete

After the concrete is mixed it is deposited on the subgrade from the bucket and spread somewhat with shovels. It is then struck off with a mechanical finishing machine of which there are two types, the tamping machine and the screed. Each time over with the machine, concrete should be kept in front of the strike throughout its entire length. If this is not done it will likely result in an uneven surface. On the first passage of the screed machine the concrete should be allowed to pile up 8 or 9 inches high ahead of the screed. This allows the weight of the concrete to compact the concrete in the slab and take the place of tamping. The number of passages necessary with the finishing machine will depend on a number of factors such as percent of grade, consistency, temperature, etc. Usually not less than twice will suffice and not more than three times is necessary. After the finishing machine has completed its work, the surface is checked with a 10-foot straight edge and any noticeable variations removed with a wooden float. Before the final belting a 10-foot float is used transversely. This removes a great number of small ridges and variations in the pavement surface. Then again after the surface of the pavement has hardened sufficiently to walk on, it is checked with a 10-foot straight edge and any variations of ¼ inch or more are removed with a carborundum brick and water.

Construction and Expansion Joints

At the end of each day's run a butt construction joint is made. Round dowel bars ¾ inch in diameter and 4 feet long are placed extending 2 feet into each section of the pavement. At least one end of these dowels is wrapped or oiled to prevent bonding. If these bars are permitted to bond a transverse crack will develop about two or three feet from the construction joint.

Expansion joints are placed adjacent to bridges so as to relieve the bridge of the thrust from the pavement slab. We

have had some serious effects on bridges when these expansion joints were omitted. Dowel bars through expansion joints do very little good but, if placed, the ends of the dowel bars should be capped so as to allow free longitudinal movement of the slab without buckling the bars. Serious trouble may be expected if these bars are not capped.

Curing of Concrete Pavement

Just as soon as the pavement has received its final belting and has hardened sufficiently to prevent marking badly, it is completely covered with strips of burlap. The burlap is sprinkled with a spray nozzle and kept wet until the concrete has hardened sufficiently to walk on without injury. Then the burlap is removed and the concrete covered with straw and sprinkled again or in some instances dykes are built and the pavement flooded with water. Great care should be used to make sure the pavement is kept wet by sprinkling and some moisture retained for at least two weeks. The first three or four days are most important because it is in the early stages that the most damage can be done if curing is improperly handled.

Opening Pavement to Traffic

Our specifications in the past have required that traffic be kept off the pavement for thirty days or longer if considered necessary. However, in the summer months we have considered 21 days sufficient and have opened most pavements within that period. In some urgent cases pavement has been opened to traffic in 14 days. In our recent supplemental specifications the date of opening the pavement is left entirely to the engineer. It is our intention to make test beams at intervals from the concrete as it comes from the mixer and as deposited on the subgrade. These test beams are to be treated and cured the same as the pavement slab. The beams will be broken at various intervals with a portable testing machine and the pavement opened to traffic when the test beams show what we believe to be a sufficient strength, but of course not until the curing period has expired and the pavement cleared ready for traffic. It is believed that during the summer months most of our concrete pavements will be open to traffic within about 18 days.