INSPECTION

Until about a year and a half ago, when we had serious inspection troubles, the county commissioners always appointed some farmer as inspector. This appointee seldom knew what a set of plans was for except to carry around in his pocket to make it look as if he were doing a good job. Since that time the commissioners have listened to me and have appointed no more farmers, but have turned all inspection over to our office. Either I or my deputy has full charge of inspection and in this way have been able to save the taxpayers quite a sum of money. We kept a close check on eight structures and, in comparison with former inspection methods, we saved a little over $500 for the taxpayers. We do not spend any more time on structures than is necessary. First we stake it out and get the contractor started, then leave orders that as soon as he thinks he has his excavation ready to let us know. We then go out and check the work and if we find the excavation ready for pouring, one of us stays on the job until the concrete is poured. We then go about our other work until he has his forms ready to check when we do the same as before.

IMPORTANT FEATURES OF CONCRETE HIGHWAY SPECIFICATIONS

By Emil Zabel, Jackson County Surveyor

It is generally conceded that the first concrete pavement in the United States was laid in Bellefontaine, Ohio, in the year 1893. Very little headway was made in this type of pavement for rural road purposes until the year 1910. As the number of motor vehicles increased, however, the demand for more pavements increased, and as a result the modern concrete pavement has come into existence. In the evolution of the old concrete slab to the pavement as we know it today, many changes have been made in the specifications. It is well to bear in mind that the making of concrete is still in its infancy and that in the years to come there will be further changes in the specifications governing its production. In the following remarks the Indiana State Highway specifications will be followed closely as a standard. In writing up specifications for a one-course, plain portland cement concrete pavement, there are, of course, several important items to be covered.

SUBGRADE

The important thing to keep continually in mind about the subgrade is that it must support the slab *uniformly*. Concrete roads crossing swamps have surprised observers by the absence of cracks while similar pavements built over old gravel or macadam roads have developed a network of cracks. The soft swampy soil supported the slab uniformly just as water supports a boat, but the hard ridges of macadam or gravel interspersed by softer material used to fill in the depressions supported the slab like the knife edges of a testing machine. As a result, heavy loads caused the pavement to crack over the ridges.

Where hard subgrade is met, as is the case when building a concrete pavement over an old gravel or macadam road, the remedy is to loosen the old material until the full width of the subgrade is uniformly soft and then roll it until it is uniformly compacted. A light roller of 3 or 5 tons is preferable to a heavier one as the principal value of a roller is to smooth out lumps, discover soft places, and consolidate fills as they are being built up. In order to secure the desired thickness of pavement, the specifications should call for a check on the subgrade immediately before the concrete is deposited. This check is made by a subgrade template, or "scratchboard," which rides on the side forms. This template should have nails or prongs set about 8 inches apart with the lower ends pointed and set to subgrade elevation when the template is riding on the side forms. If there is any question whatsoever about the height of the subgrade, the template should be brought back and the subgrade rechecked. Wherever the points scratch, the excess earth should be removed until the scratches disappear.

MATERIALS

Aggregates for concrete pavements should be clean, sound, hard, and tough, and should have low absorption. Cleanness is important because any dirt in the aggregate is likely to work to the surface of the slab during placing and finishing, thus forming a weak, porous, soft layer known as "laitance." Unless this laitance is floated off in the process of finishing, it will later scale off after freezing and leave an unsightly and rough pavement. In order to assure clean aggregates it is usually necessary to wash all sand, gravel screenings, or stone used in pavements.

Soundness is important, especially where the pavement is to be subjected to freezing and thawing. In the spring and fall a pavement may be covered during the daytime with water which becomes frozen solid at night. In order to resist such treatment a slab should be a dense, waterproof concrete. Waterproof concrete is secured with sound aggregates surrounded with an impervious cement paste. Well-graded aggregate from coarse to fine, so that there is a minimum of space between the particles, is important in securing a dense, waterproof concrete. Flat pieces in concrete are objectionable, especially when they lie near the surface, as heavy loads may break them out, leaving shallow cavities in the concrete.

Hardness and toughness are qualities very desirable in aggregate for concrete pavement where there is much steel-tired or tire-chain traffic. Where there is deep snow and traffic travels in ruts and must use tire chains, a hard, tough, wear-resisting aggregate is essential. In warmer climates where no snow or ice is encountered and the traffic is mostly rubber tired, a softer coarse aggregate may be used.

While the maximum size of coarse aggregate may be 2½ inches to comply with Indiana State Highway specifications, the tendency is to specify a maximum of 1½ inches because it makes concrete which is easy to place and finish.

The cement should be some standard brand of portland cement which has given satisfactory results. It should comply with the standard specifications, and tests for portland cement of the American Society for Testing Materials. Before unloading any cement from a car, the resident engineer or inspector should have a report from the inspector at the plant from which the cement came that the cement in question is satisfactory.

If the cement is put in storage, the contractor should provide suitable means to protect the cement from dampness. Any cement that has become partially set or caked should not be used. If different brands are used, they should be stored in separate piles and should not be mixed.

The cement should be kept in the sacks until ready to be mixed. If the cement comes in contact with wet aggregate, the entire batch of materials should be placed in the mixer and mixed within five hours.

The water used in concrete pavement construction should be reasonably clean and free from oil and organic matter. It should not be brackish, or have an acid or alkaline reaction.

When the coarse aggregate is stockpiled, the piles should be built up in layers not to exceed three feet in height and each layer should be completed before beginning the next. This is to prevent the segregation of the larger from the smaller particles of the coarse aggregate. If the stockpile is built by coning or depositing in one place and the material is allowed to run down the sides, the result will be that the larger particles will roll to the bottom on the outside and the finer particles will be left in the center. For the same reason, in taking material from a stockpile, the process should be reversed and the material removed in layers. All cars of material, whether coarse or fine aggregate, should be tested before being shipped to see that they are satisfactory, and the resident engineer should be notified as to the result.

PROPORTIONING

Another important item in the making of good concrete is the matter of proportioning. In order to secure concrete of maximum strength, the ratio of the aggregates should be carefully checked. In this state where the composition of the batches is determined by *weight*, the specifications call for a cement ratio of not less than 1.70 nor more than 1.72 bbl. of cement per cubic yard of concrete. The fine aggregate or sand should in no case be less than 35 per cent nor more than 40 per cent of the total weight of the aggregates used. The aggregates should be so proportioned as to use the maximum amount of coarse aggregate which will give a workable mix. In computing the cement ratio a sack of cement should be considered as containing 1 cubic foot and weighing 94 pounds.

When the batch is determined by weight, the weight of the sand or stone required for a batch is determined from the weight per cubic foot of the aggregate. The moisture in the sand is determined and allowed for in figuring the batch weight. In weighing the aggregate, the material is run into hoppers hung on the levers of either a dial or a beam scale. It is easy for the operator to turn out materials as rapidly as with the volume measurement and still come within 5 pounds of the exact weight.

In determining the cement content or ratio, a section of pavement, usually about a hundred feet long, is accurately measured as to length and thickness. The thickness of the slab can be determined by taking readings with a level both on the subgrade immediately before the concrete is deposited and upon the surface after the concrete has hardened sufficiently to walk on it. The readings should be taken at intervals of 5 feet in length and every foot transversely. From these readings it is easy to compute the volume and cement ratio since the exact length of the test section has been measured and the quantity of cement used known. These cement content sections should be taken at intervals of about one mile.

CONSISTENCY

The amount of water used in each batch should be such that the consistency will remain uniform. A consistency in which there is any tendency towards segregation of the aggregates should not be permitted. Under a visual examination, the consistency should be such that the batch of concrete when deposited upon the subgrade will tend to settle slowly. The concrete at the edges of the batch should tend to roll rather than run. As the batch settles the individual pieces of aggregate, which should be thoroughly coated with mortar, should crack or break away from adjoining pieces of aggregate. The slump should not exceed 2 inches.

MIXING

In mixing concrete, *time* is the most important factor. Concrete mixed for 2 minutes is from 20 to 35 per cent stronger than concrete mixed only 15 seconds. Longer mixing increases the workability of the concrete and also makes possible a decrease in the quantity of mixing water. Thorough mixing also increases the uniformity of the mix. The speed of rotation has little to do with thorough mixing as long as the R.P.M. is within the limits of 12 to 20. The mixing time is set at one minute in most states.

No materials for a batch of concrete should be placed in the drum of a mixer until all of the previous batch has been discharged from the drum. Water for mixing concrete should be added at the same time the material is entering the drum from the skip. Many specifications require that all the mixing water be in the drum ahead of the materials. This has been found not to be of good practice as it tends to make a concrete of uneven consistency and one that is not so well mixed as when water and materials are added together.

No concrete should be mixed while the temperature is at or below 35 deg. fahr. and no materials containing frost should be used. Concrete that has developed its initial set or has been mixed 30 minutes should not be used. Concrete should not be deposited on a frozen subgrade.

In placing the concrete, workmen should not track dirt or mud into it nor should the subgrade be sprinkled in such a way that dust is thrown onto the exposed edge of the concrete. In case of a shut-down long enough for the concrete to commence hardening, a square butt joint should be made.

The concrete next to the forms should be thoroughly spaded with a straightened hoe or straight spade in order to draw the mortar to the edge and assure a face free from honeycombing.

FINISHING

So far as the public is concerned, the most important feature of a pavement is its smooth-riding finish. The average motorist knows nothing of the hours spent in testing materials, in design, or in securing the proper quality or quantity of slab. All he is interested in is, "How does it ride?" A smooth-riding surface is to be desired because it is one of the factors that tends to increase its useful life. A pavement that is rough is subject to impact and if called upon to carry heavy truck loads will in time break up and disintegrate.

On all country road pavements finishing machines should be used. The only exceptions are mountainous country where the curves and attendant widened sections make finishing machines impracticable. Even on widened curves a finishing machine may be used. In this case a false form is laid to serve as a track for the finishing machine to run on. This form is removed as soon as the surface has been brought to the proper finish and the finishing machine moved forward far enough to take up the form. This form should be removed as soon as possible and the widened space filled with concrete and finished by hand. Care should be taken to see that the edge formed by the false form is shoveled and sliced so as to prevent a longitudinal crack or line of cleavage.

The finishing machine now in general use is the screed machine. This machine usually consists of two screeds, the front screed acting as a strike-off and the other to apply pressure to the surface. Immediately back of the finishing the surface of the pavement should be floated down with floats to remove all high places, fill in depressions, and remove laitance. It is very important to remove all laitance, for if it is left, the surface will scale and become unsightly.

One of the best types of float is that known as the "longitudinal float." This float is usually about 16 feet long and is operated with its long axis parallel to the center line of the pavement. It is made of a plank about 3 inches thick and 10 inches wide, stiffened by a plank set on edge along the top and provided with handles at each end. This float is operated by two men, one at each end, who stand on bridges spanning the pavement. It is worked from one side to the other with a wiping motion, leveling transverse ridges and high spots and filling depressions. Another long handled float consists of a one-inch board about 5 feet long and 6 inches wide to which is attached a long handle. This float is used by one man working from the side. Where this float is used, one should be provided for each side.

Immediately after the surface has been floated down and the laitance removed, it should be checked by means of a 10-foot straight-edge. The straight-edge should be lowered gently to the pavement near the center line and parallel to it. After checking the pavement at the center the straight-edge should be raised and lowered at a point about halfway between the center of the slab and the form or edge. After checking the pavement near the edge, the straight-edge should be moved up about 5 feet, or half a lap, and the process repeated. It is well to use the straight-edge on the forms also to get a check on high or low joints.

When straight-edges are used as floats to remove laitance and to remove high and low spots, the straight-edges should be checked frequently to see that they are true and not worn.

The final operation in finishing is belting, which should be done after the water has disappeared from the surface. The belt usually consists of a rubber fabric about 10 inches wide and about 2 feet longer than the width of the pavement.

The belting should involve short, rapid, transverse strokes having a sweeping longitudinal motion. The object of belting is the even distribution of a granular, gritty, non-skid surface which will diffuse light rays at night, making a surface that is readily visible and not shiny.

A final finish is sometimes given by dragging a strip of burlap about 3 feet wide over the surface, producing an even, gritty surface.

In some localities an ordinary street broom is used to give the final finish. The broom is dragged lightly from center to the sides, causing small ridges which make the pavement more visible at night. All edges and joints should be edged.

CURING

It is very important to keep the pavement wet down for the first few hours after finishing because strength lost by lack of moisture during this period can not be regained by subsequent curing.

When concrete is mixed, it contains sufficient moisture to hydrate the cement. As soon as it is deposited on the subgrade, it begins to lose moisture by evaporation and absorption. In hot, dry, and windy weather, the comparatively thin slabs used in paving dry very rapidly with the result that the moisture in the concrete is insufficient to hydrate the cement. As it dries, the concrete shrinks and tensile stresses are set up while the concrete is too weak to withstand them, resulting in cracks.

It is important, therefore, to cover the pavement with wet burlap as soon as possible without marring the surface.

Ponding can be used only on flat grades. This method of curing should not be resorted to if the subgrade is a soil that swells much when it absorbs moisture, as this swelling while the concrete is still green will cause the pavement to crack and warp.

Sawdust should not be used as a curing agent because it may produce tannic acid which harms hardening concrete.

Two inches of earth or six inches of hay or straw are usually specified, and, in either case, the covering should be kept wet down by frequent sprinkling for a period of several days.

Calcium chloride curing is a more convenient method of curing than earth or straw because when once applied, the job is finished. It has been found from tests that water-cured pavements develop at least 10 per cent more strength than those cured with a surface application of calcium chloride. In dry, arid climates, the deficiency of calcium-cured pavements is even more marked because there is not enough moisture in the air properly to dissolve the chloride.

When chloride is used for curing, the amount applied should not exceed 3 pounds per square yard of pavement. More than this amount will cause the pavement to blister and may be a contributing factor towards scaling. The chloride should be applied uniformly and should be free from lumps.

JOINTS

Where slabs accommodate two lanes of traffic, a longitudinal joint down the center is advisable. The purpose of this joint is to prevent longitudinal cracking. It consists of a deformed metal plate whose upper edge comes within a half inch of the surface. The two slabs thus formed should be tied together across the joint with deformed bars. For 18 foot roads, ½ inch round bars, 4 feet long and spaced 5 feet apart are the common practice.

Concrete, like most other materials, expands and contracts with temperature changes and changes in moisture content. As a result of these changes, the pavement cracks. On rural roads it is a question whether transverse joints should be installed, thus dividing the pavement into separate slabs with a space between for expansion, or the pavement be allowed to crack of its own accord and the cracks thus formed filled with some bituminous expansion material. The distance that may be expected between cracks is about 30 feet. The cracks should be filled soon after they appear in order to prevent spalling.

THICKNESS DESIGN

Since the results of the Bates Experimental Road in Illinois have become known most states have adopted the thickened edge pavement, although some still use a uniform thickness slab. Tests and actual experience have shown that the edge of a pavement should be thicker than the center. In the center a wheel load is supported by a full circle of concrete while at the edge it is supported by only a half circle. It is further apparent that where a joint or crack meet the edge the support will only be a quarter of a circle and that, therefore, this part of the slab should be thicker than at the center. It was also found that at night the upper surface of the pavement, cooling more rapidly than the lower, would curl up at the edges and leave that part of the slab unsupported. The most common design used by the various states is what is known as the 9-6-9 design with the 9-7-9 running next. Some states use rods usually ¾ inch to 1 inch in diameter set 4 to 6 inches from the edge about midway between the surface and the subgrade. Usually these rods are smooth and painted or oiled to prevent bond with the concrete.

The crown of a pavement should be sufficient to drain water. A slope of ⅛ inch per foot of width is considered sufficient for rural roads.

INSPECTION

The last factor to be considered in the securing of a good concrete pavement is inspection. In most cases the quality of the finished job depends to a large extent on the type of inspection the job received during the process of construction. This is especially true in case the contractor has taken the job at too low a figure and is inclined to rush the work through without adhering closely to the specifications. When this condition prevails, the inspector should be someone who has had considerable experience. To take a young graduate just out of college and put him in a position of this kind and expect him to be prepared to handle properly all situations that may confront him is absurd. The inspector, before being put in this position, should have worked under an older and more exerienced man where he has had ample opportunity to gain experience, confidence, and complete knowledge of the specifications under which the work is being done. No set of specifications can be made to cover all the details that may come up in the course of construction, and for this reason the inspector is sometimes called upon to make decisions without having the opportunity of consulting his superiors.

Usually the young inspector, out on his first job and anxious to make good, will be inclined to interpret the specifications too literally and in this way may work a hardship on the contractor without gaining any advantage for his employer. Most contractors welcome a competent inspector who has had previous experience and who possesses good sound judgment, for they know then what to expect and can proceed with the work with confidence. There are some contractors, however, who have little faith in the engineering profession, and who are inclined to ridicule certain clauses in the specifications which they consider as stumbling blocks. It is in handling such cases that a good practical inspector is necessary to procure a first class job. The inspector is called upon to use sound judgment backed by a thorough knowledge of the specifications and he must have the courage to make the contractor meet the requirements of the contract.

USES AND ABUSES OF THE THREE-MILE ROAD LAW

By O. M. Darling, Allen County Surveyor

The general public confuses the Three-Mile Road Law with the County Unit Road Law. I have found this to be true in a number of cases when talking to people who are considered to be well informed persons in my community. In Allen County we have used the County Unit Road Law quite extensively and I hear numerous people condemning the Three-Mile Road Law for causes and effects which are due to the former entirely. Let us, as county engineers, endeavor to explain to the people in our counties that the Three-Mile Road Law is a law used to build roads for which only the township or townships in which the roads are situated pay the costs. Recently I heard one supposedly well informed gentleman in our county say that the Three-Mile Road Law should be repealed. He did not see why the city of Fort Wayne should pay for building a road out at Monroeville. Repealing the Three-Mile Road Law would not repeal the law under which the road he had in mind was built. This road was built under the County Unit