CONSTRUCTION OF CONCRETE ROADS.

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Our specifications for 1923 and 1924 will not permit piling material on the sub-grade. This leaves it up to the contractor to use a central proportioning plant at the railroad switch, which is the ideal method, or to stock pile at convenient locations and use proper measuring devices to insure the correct amount of aggregates for each batch. From the engineer's standpoint, the use of charging bins with a measuring hopper at the bottom and the transporting of the aggregates in light trucks to the mixer on the sub-grade and placing the cement from stock pile directly into the mixer skip, is the best method. It gives the inspector an opportunity to check his cement factor and watch the mixing, placing and finishing without leaving the mixer. With a uniform aggregate, the measuring hoppers will need very slight attention and adjustment.

When a central mixing plant is used, it should be so designed with measuring boxes or hoppers to insure the correct amount of aggregate and cement for each batch and will require an inspector to watch it. It is not desirable to have a lapse of time of more than 30 minutes between mixing and placing. The mixed concrete is generally hauled in Ford trucks equipped with 30 cubic feet dump beds and requires two to four men to unload the concrete from the truck. This method has been used on one of our jobs, but requires a water line for curing unless the calcium-chloride method is used.

Steel forms should be used exclusively and should be of a height equal to the thickness of the pavement. They should have a bearing surface on the sub-grade of not less than 48 square inches per lineal foot of form and weigh not less than 8 or 9 pounds per lineal foot. The forms should be well staked at intervals not exceeding 5 feet and should be set in an absolutely straight line. It is necessary for the contractor to provide sufficient forms for a day and a half's run in order that no form will be removed for at least twelve hours after placing. Forms should be set at all times at least 300 feet ahead of the mixer so the sub-grade can receive its final preparation without delaying the mixer.

The Mix.

On one course roads both the State Highway Commission and Marion County are using 1-2-3 mix. The State specifies a cement factor of 1.7 barrels of cement per cubic yard of concrete, whereas Marion County specifies 1.75 barrels for a stone
aggregate, and 1.67 barrels for gravel aggregate. For the purpose of checking the amount of cement used, it is customary to reduce this cement factor from barrels per cubic yard to sacks per square yard or per lineal foot of pavement. It is also necessary for the inspector to check the cement at intervals not exceeding a half a day's run and when starting a job to check the cement every 10 to 15 feet until the measuring boxes are adjusted to give the proper proportions as required by specifications.

It is necessary to use measuring hoppers or boxes that can be adjusted to secure the correct amount of aggregate necessary to meet the specifications. A measuring device attached to the bottom of overhead bins is the ideal method. Where Ford trucks are used, the method of nailing strips or painting lines on the truck body to insure the correct amount of aggregate, will give good results but requires the striking off of each truck load first for the gravel and then for the sand. There is always a tendency to neglect the striking off of the truck loads on account of the time and labor involved especially when the contractor is pushing the job. Unless each truck is struck off, there will be a lack of uniformity in each successive batch, some containing a little more aggregate, which is generally the case, and some a little less. While the cement may check at the end of a day's run, some spots will have more cement than others. The road is no better than the weakest spot. Uniformity of each batch of concrete is absolutely essential to secure a good, lasting pavement, and too much care can not be exercised by engineer, inspector and contractor to secure these results.

Concrete should be mixed in a batch mixer for a period of not less than sixty seconds after all materials are in the drum, the mixer being operated at the number of revolutions per minute recommended by its manufacturer. The mixer should be equipped with a water measuring device to insure a uniform consistency in every batch and the amount of water used should be the least amount that will produce a workable consistency as every pint of water beyond this amount reduces the strength of the concrete. The mixer should be equipped with a batch meter to register the number of batches poured. For a mixer operating on the sub-grade, the discharging device should be of the boom and bucket type. The consistency should be such as to show a settlement of not over two inches in the slump test.

The concrete should be placed only on a moist sub-grade and should be spread the full depth and width of the pavement by shoveling. The use of rakes should not be permitted. Any manhole tops, railway tracks or other structures should be brought to finished grade before the concrete is placed around them. Concrete should not be placed on a frozen sub-grade.
Finishing Concrete Surface.

After placing, the concrete should be struck off, tamped and finished by a finishing machine, so designed as to move either backward or forward and at such speed as to thoroughly compact the concrete and eliminate all voids. The machine should go over the concrete a sufficient number of times and at such intervals as will give the desired results. The strike board should cut the concrete at least \( \frac{3}{8} \) inch high to allow for tamping and must conform to the required cross-section of the pavement. Forms and wheels of the finishing machine should be kept clean and free from dirt at all times.

On curves, widened portions of the pavement or in such other cases as the engineer may direct, hand tamping and finishing should be substituted for the mechanical.

The concrete should be struck off by means of an approved template and should be thoroughly compacted with a hand tamper, meeting the approval of the engineer. Immediately after the concrete has been tamped, it should be rolled with an approved metal hand roller, having a smooth even surface approximately 6 feet in length, 12 inches in diameter and weighing not more than 1 pound per inch of length. The roller should be used just as soon as possible without displacing the concrete. In warm weather, especially with rock aggregate, if the concrete has not been mixed too wet, the roller may be used immediately. In cool weather, it may be necessary to delay the first use of the roller for 30 or 40 minutes. If the pavement is not over 20 feet wide, the roller may be operated from one side of the road to the other, by a long handle. If the pavement is much wider than 20 feet, it will be found more convenient to attach a rope to the roller and pull it from one side of the pavement to the other, discarding the handle entirely. In this way, it is possible to roll with greatest facility any width of pavement. The roller should always be moved transversely across the road at a small angle so that it will move lengthwise of the road about 2 feet each trip across. After the first rolling, the same area should be gone over again in about 15 or 20 minutes. The concrete should receive successive rollings at intervals of 15 or 20 minutes until little or no free water is squeezed out. This usually requires not less than 3 rollings, depending upon the amount of water with which the concrete has been mixed, and also on the temperature. The less the amount of water and the warmer the weather, the fewer the number of rollings required.

After the rolling has been completed, the pavement should be finished by two applications of a belt made of canvas or rubber belting not less than 6 inches wide and not less than 2 feet
longer than the width of the pavement. The belt should be ap­plied with a combined crosswise and longitudinal motion. For the first application, vigorous strokes at least 12 inches long, should be used and the longitudinal movement of the belt along the pavement should be very slight. The second application of the belt should be immediately after the water glaze or sheen disappears, and the stroke of the belt should be not more than 4 inches and the longitudinal movement should be much greater than for the first belting.

The edges of the concrete pavement should be rounded with an approved edging tool, having a radius of not more than one inch. The edges at expansion joints should be rounded with a tool having a radius of not more than \( \frac{3}{8} \) of an inch.

The finished surface of the pavement should be true and even. The contractor should be required to test the surface with a 10 foot straight-edge placed on the wet concrete parallel with the center line of the pavement. This straight edge should be applied to the center line and quarter points, and must touch the concrete at all points. Any high places should be cut down and any low places filled up until the finished pavement has a true and uniform surface. In finishing the pavement, this straight-edge should be so placed as to lap the finished surface at least 3 feet. Special care should be used at each expansion joint to insure a smooth surface on both sides of the joint. The straight-edge should be centered on such joints.

Too much emphasis cannot be placed upon the importance of the use of a straight-edge, because this method insures a trueness and evenness of surface of pavement not otherwise ob­tainable.

**Curing of Concrete Surfaces.**

After the concrete surface has been finished, as described above, it should be protected by applying burlap very carefully. The burlap should be placed as soon as possible after finishing, without marring the surface. This does not mean that the concrete would have to be anywhere near the final set. After the burlap has been placed, it should be kept wet by sprinkling with a fine spray of water until the concrete is sufficiently hardened to remove the burlap and place on the other curing material. The burlap should weigh at least 12 ounces per square yard and be in strips 40 inches wide and 2 feet longer than the width of the concrete to be covered. At the ends of the strips should be fastened either iron bars or wooden strips so as to prevent raveling and aid in handling them.

As soon as the burlap covering is removed, the surface should be covered with straw to a depth of at least 3 inches. The straw should be thoroughly wet and kept moist by sprinkling
with water for a period of at least 20 days, under favorable weather conditions, and longer if the engineer so directs, during which time all traffic should be kept off the concrete by the erection of suitable barricades and maintenance of same.

On level stretches of pavement, the concrete may be cured by building suitable earth dykes to such height as will permit the entire pavement to be covered with water to a depth of not less than 2 inches. The water should be maintained at this minimum depth for a period of at least 20 days. This method is very effective but can be used only on comparatively level grades.

Another method of curing is to use not less than 2 inches of earth covering instead of straw. The same restriction as to sprinkling for 20 days applies to this method.

The use of calcium chloride is comparatively new but its use eliminates the necessity of a water line where a central mixing plant is used. When used, the surface of the concrete, after the removal of the burlap, should be uniformly covered with not less than 3 pounds of granular or flake calcium chloride per square yard of pavement. This treatment should not be applied under 8 hours after finishing and preferably 16 hours. The treated surface should be protected from rain for a period of at least 12 hours, or additional applications should be made following rains, to insure 3 pounds of calcium chloride per square yard of surface for a period of at least 12 hours.

Expansion joints should be provided by placing permanently in position, a preformed, solid body of compressible asphaltic compound reinforced on both sides with a high grade, asphalt saturated wool felt, for the full depth thereof. The joint filler should be a suitable bitumen which will not become soft enough to flow in hot weather or brittle in cold weather.

Our practice in Marion County has been the use of an expansion joint one inch in width placed across the pavement perpendicular to the center line of the road at the end of each day's run. All expansion joints should extend the full depth of the pavement. Edges adjacent to the joint should be rounded to a radius of not more than 1/4 of an inch with a suitable tool.

Dowels of 3/4 inch round rods 4 feet long should be used at each expansion joint. These dowels should be placed on 3 foot 6 inch centers and should extend 2 feet into each slab. The 2 foot length of the dowel placed at the time of quitting work should be wrapped in heavy paper to prevent bonding. The next morning these dowels should be pulled out about 2 inches to allow for expansion. The other half of the dowel should be bonded in the slab. It will be necessary to have holes bored in the night board to facilitate placing the dowels.

It has been the practice in Marion County during the last four years to specify 40 pounds of steel reinforcing per hundred
square feet of pavement. However, beginning with 1923, we adopted the Illinois standard using a $\frac{3}{4}$ inch round bar, not bonded, with a steel contraction joint on the center line of roadway. We are also using $\frac{1}{2}$ inch dowels 4 feet long spaced on 5 foot centers through the contraction joint to tie the two halves of the slab together. These dowels are bonded.

Concrete should not be mixed nor deposited when the temperature is below freezing. If, at any time during the progress of the work, the temperature is at, or in the opinion of the engineer would, within twenty-four hours, drop to 35 degrees Fahrenheit the water and aggregate should be heated and precaution taken to protect the work from freezing for at least 10 days. In no case should concrete be deposited upon a frozen sub-grade.

**CHANGES AND IMPROVEMENTS IN DESIGN AND CONSTRUCTION OF INDIANA STATE ROADS.**

By J. T. Hallett, Road Engineer, Indiana State Highway Commission.

**Design**

During the short existence and activity of the Indiana State Highway Commission, there have been several changes made in the design and construction of its roads, a few of the most important of which I will mention.

When the construction of the Indiana State Roads started in 1919 there was a general feeling among road enthusiasts and engineers that where there was a fairly good road existing, the grade of the old road should be followed so as to have a better base for the new road. The Highway Department with this idea in view laid many grades following very closely the old grade. The result was short, choppy grades connected with short vertical curves.

The first plans put out by the Highway Department showed some vertical curves as short as fifty feet in length. Our experience has shown us that when following the grade of an old gravel or macadam road so closely it is an impossibility to get a uniformly compacted sub-grade so essential to eliminate cracking of the pavement. Our conclusions were that on entirely new construction, the old road bed was more of a liability than an asset, therefore we are now laying our grades with longer tangents and longer vertical curves somewhat disregarding the old road bed. In every respect it makes a better road. We are now using a minimum length of three hundred feet for vertical curves, as compared to fifty feet at the start.