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.

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**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.
The first concrete slab built by the Indiana Commission was eighteen feet wide, six inches thick at the edges and eight inches at the center. The concrete was a 1:1½:3 mix. All of this was common practice at that time. The pavement section which is thicker at the center than at the edges is still good for types of road where there is no slab action in supporting the load and where the surface wear is a considerable factor in the destruction of the pavement. Concrete pavement under present day traffic does not wear to any great extent. The load is transmitted to the grade by slab action. Therefore a uniform eight inch slab was adopted and the mix changed to a 1:2:3. While we were not bothered to any great extent by longitudinal cracks, it is very desirable when cracks do occur that the slabs be kept from separating and the cracks opening. In order to do this it is necessary to put transverse steel in the slab.

In a recent design adopted by the Commission, this has been taken care of by one-half inch transverse bars spaced four feet apart. The corner of the slab is a weak point for supporting the load. We have always put ¾ inch dowel bars at transverse construction joints to transmit part of the corner load to the adjacent corner but only recently have we put in a continuous dowel bar at the edge of the slab to help transmit the load across transverse shrinkage joints. By strengthening the weak points in the slab by addition of steel, we believe that a seven inch uniform slab reinforced in this way is as strong or stronger than an eight inch slab not reinforced. The cost figures out slightly less.

The first brick pavements were grout filled but later the bituminous filled pavement was adopted. Recently the continuous dowel has been added to the base of brick and bituminous concrete pavement. The latest specifications provide for a 1:2:3 mix in the base of brick and bituminous concrete pavements instead of 1:3:5 as originally specified.

Construction

The building of the grade on state roads is practically the same standard practice as used everywhere and has not been changed appreciably since the Commission started operations. However, in our most recent specifications, we have provided a slightly different method of widening existing embankments. The specifications call for the old embankment to be torn down, widened to full width and thoroughly rolled before any additional material is placed. We believe this will cause better fills to be constructed.

The first contracts awarded permitted aggregates to be stored upon the subgrade and had no definite restrictions as to the cutting up of the subgrade by hauling over it. We find that
this did not permit the proper preparation of the subgrade, so later contracts provided that all aggregates should be kept off the subgrade, at least five hundred feet in advance of the laying of the pavement, and no hauling allowed over the subgrade when the wheels cut down more than two inches. This provides a more uniform subgrade which is very essential in road construction.

We formerly checked the subgrade to see if it was the proper elevation by the string and rule method, now we use a templet which slides on the forms. This insures a more correctly shaped subgrade than the former method. About the time the Commission started construction, the finishing machines for concrete pavements were in their experimental stage. They were used on some of the first contracts, while on the others the hand finishing was used. The machine finisher produces a denser concrete and a smoother surface. Now finishing machines are used on all jobs.

On the first job a straight-edge was used for checking the surface only at construction joints, but now our inspector and the finisher check and re-check every foot of pavement before the concrete sets. This gives them a chance to correct a rough surface when it can be properly corrected. The result is much smoother pavements.

It has been determined by taking cores out of the pavements laid that the thickness of the slabs were quite variable. In some places the variation was nearly 50% from the required thickness. Since we have used more precaution in checking the surface of the pavement, also in checking the subgrade to see if it is the proper elevation, we find that the variation from the required thickness is usually not more than 10%.

While we do not feel that we have the final answer for slab design, we do feel our design will compare favorably with any other design of the same cost.