

Slip-Form Paving—Construction Practices on Iowa's Secondary Roads

L. M. CLAUSON, Chief Engineer, Iowa State Highway Commission

Since 1949 over 1,000 mi of slip-form pavement have been constructed in Iowa. Most of these miles are on secondary roads. Several considerations for this construction are presented. Paving on narrow grades, poor soils, subgrade construction, mixing and placing operations, concrete mixes, and smoothness are also discussed.

•SLIP-FORM PAVING in Iowa started in 1949 with a total of 1.5 mi of pavement placed on two projects. The first pavements were placed in 10-ft lanes, using a machine designed and constructed by the Iowa State Highway Commission. Since that time a total of more than 1,200 mi of slip-form pavement have been placed in the state. This type of pavement has been used successfully for secondary, primary, and interstate construction. Variations include use of doweled contraction joints, mesh reinforcing, and various types of subbase. About 75 percent of the slip-form pavement has been placed on secondary roads.

Secondary roads are vital to the agricultural portions of Iowa's economy. There are more than 90,000 mi of secondary roads in Iowa. More than 90 percent of these have some type of all-weather surface. About 34,000 mi are on the farm-to-market system which is essentially the Federal-aid secondary system. Traffic on secondary roads varies considerably, but most paved roads have present traffic varying from 125 to 600 veh/day with about 5 to 15 percent large trucks or similar vehicles. Maintaining granular surfacing on these roads for all-weather traffic is both costly and impractical. Usable aggregate sources are being depleted at a rapid rate, causing longer hauls and higher prices for granular surfacing. The secondary roads with heavy traffic must have a higher type of surface to reduce the annual cost of maintenance.

Road construction on Iowa's secondary roads is done according to standard specifications, using the same degree of inspection and quality control as primary construction. The county engineer is in charge of the work, and he acts in the capacity of a resident engineer for the state on projects involving state or Federal funds.

The paved roads have graded widths from 28 to 34 ft, depending on the age of the existing road, the terrain, and the existence of rock in the cuts. For snow storage, the side ditches are deep and narrow, and the foreslopes and backslopes are steep. The foreslopes vary, but the common foreslope is 2 to 1.

CONSTRUCTION

Subgrade

The roadbed soils are usually used as they are. Soils prevalent in Iowa are A-7-6 and A-6, usually with high index numbers. To obtain embankment soil for a high grade from a narrow right-of-way, the side ditches are usually deep, making soil from lower horizons available for the tops of grades. There seems to be a significant benefit from this.

The pavement may be placed on a roadbed constructed during previous years with little scientific soil selection. When soils are particularly poor, the condition is usually corrected by the county before paving operations begin. This process may include excavation of the roadbed and replacement with suitable material.

Roadbeds usually have some loose granular material on and near the surface. Subgrade preparation work uses this material to the best advantage. The subgrade first receives a general shaping with a motor patrol. This includes scarification of granular material and soil to a depth of several inches. Some movement of this scarified material is required, both along the centerline and transversely. The material is placed and compacted in general conformance with the required final subgrade elevation. The desired grade line is modified, as necessary, to keep movement of material to a minimum. This is possible in rural areas. Changes usually are not greater than 0.1 ft in 100 ft. The loose material is well compacted. The compacted thickness varies considerably, but the thickness in any cross-section is fairly uniform and the change in thickness longitudinally is gradual. Because of the variation, a compaction density is not specified. The resulting subgrade is a soil-aggregate mixture. In some locations the existing roadbed has a particularly high or irregular crown. Several inches of granular material are first salvaged by windrowing. Lower soil is shaved by motor patrol to the desired elevation and wasted on the shoulder or foreslope. This initial subgrade work results in a more uniform subgrade which minimizes any tendency for longitudinal cracking or unevenness from settlement.

An adequate track path for the slip-form tracks is prepared with a form line grader or cutter. The surface of this path is of utmost importance. It must be true and firm for a smooth riding surface. The mixture of soil and aggregate is spread and compacted 1 ft outside this path to insure proper material in the track area. Paving hubs are placed at intervals of 50 ft on tangents and 25 ft on vertical and horizontal curves and transitions. These are offset 2 to 3 ft, depending on the shoulder width available. The contractor sets steel rods inside the hubs and connects them with a string line at the proper elevation. There is a reference guide on the form line cutter. Recently an electronic control device has been used in conjunction with a steel wire. After the track path is established, all traffic is kept away from the path except equipment which must use it.

The subgrader operates on tracks in the track path at some distance ahead of the concrete placing operations. There is no feasible manner for the batch trucks to detour. A bridge must be provided over this machine to permit trucks to pass. At least 500 ft of finished subgrade is required ahead of paving operations to assure a smooth surface. This minimizes the possibility of small swales which may not be noticeable to the inspector at any other time before the pavement is placed but are objectionable to high-speed traffic.

Immediately ahead of the paver is the tail plane, adjusted to the proper subgrade crown which provides for the desired pavement thickness. It operates on tracks in the track path.

Subgrade constructed in this manner appears to be quite satisfactory. The soil-aggregate mixture provides not only a uniform subgrade of better quality than the native soils, but also an excellent base for the track path.

The contractor has the option of covering the subgrade with paper or polyethylene film or sprinkling it with water. In the past, polyethylene film has been used on the subgrade rather than sprinkling immediately ahead of the paver. Batches must be trucked over the subgrade, which becomes wet enough when sprinkled for tires to pick up enough to leave an irregular subgrade surface and to contaminate the batches in the skip. Also, another water truck would reduce efficiency.

Placing Concrete

Space at the paver is limited. All paving operations must be done at least partly within the limits of the pavement edges. This includes the paving mixer and the haul trucks, since it is impossible to bring service trucks on the shoulder alongside new pavement, and the ditches are often not usable for this traffic.

Concrete is usually mixed on the grade, although ready-mixed and central-mixed concrete have been used successfully. The rate of progress is restricted by rate of delivery and mixing and not by the slip-form paver. For primary work, as many as three mixers have been used on the grade with one paver. For secondary work, the

narrow roadbed limits grade mixing to one mixer. Placement rates of 3,700 ft of 6-in. pavement, 20 ft wide, are possible with an efficient operation.

Present slip-form pavers use either internal vibrators or pan-type vibrators to consolidate the concrete. Both seem to be satisfactory.

Edge slumping has been a major problem on only a few slip-form paving projects. It is experienced occasionally when consistency is not uniform and during days of high humidity. These areas are corrected by the use of wood forms kept in readiness.

Roughness and edge slumping seem to be related to the uniformity of the concrete. Air-entrained concrete seems to be more sensitive to the amount of water in the concrete than the non-air-entrained concrete. It is important to use good dispensing equipment and to keep it in good condition to insure a uniform quantity of admixture. Aggregate is being produced by high-volume plants. The stockpiling time is frequently short, causing large variations in aggregate moisture. It is evident that good control of both materials and moisture is necessary to achieve uniformity of the concrete. County engineers have been given technical assistance in training inspectors in control testing and inspections. Everyone concerned has learned the value of uniform consistency. On those projects where there is still a lack of uniformity, roughness and edge slumping are still problems.

Paving aggregate in Iowa contains some shale and other light aggregates which have a tendency to rise with vibration, causing a small amount to concentrate near the surface, which is objectionable. If this light aggregate accumulates ahead of the paver for some distance and is consolidated on the concrete surface at one location, the resulting pavement surface is very objectionable. This is mentioned because concrete for the thinner pavements used on secondary work is very sensitive to vibration, and equipment should be carefully controlled to provide for the correct vibration.

Curing

White-pigmented curing compound is used for initial and final cure. It is difficult to bring burlap to the new pavement and to keep it wet, since there is no room on the shoulder for either burlap trucks or water trucks. The ditches are often too deep and too narrow for such traffic. Early application of curing water to the pavement encourages edge slumping, and curing should start while the edges are still tender.

Shouldering

Shoulder soil is hauled in trucks, dumped in piles just off the pavement, and leveled by motor patrol. Hauling units having axle loads in excess of 12,000 lb are not permitted on the pavement during shouldering operations. There is no space for hauling equipment of any kind on the shoulder area.

Shouldering is permitted after the concrete has attained an age of 14 days. The engineer may delay shouldering if cool weather delays curing.

DESIGN

Most secondary designs in Iowa are for a uniform thickness of 6 in. and a width of 20 ft, although there have been some projects with thicknesses of 7 or 8 in. and widths of 21, 22, or 24 ft. The parabolic crown is usually $1\frac{1}{2}$ in. based on 20 ft. The only steel reinforcement is a No. 4 bar across the centerline at 30-in. spacing. Longitudinal and transverse joints are sawed, the latter spaced from 20 to 40 ft. In some cases joints are sawed dry because getting water to the saw becomes a major problem.

For economy, some contracts have not required joint filling. To date, pavements with light traffic seem to perform about the same with or without joint filler.

The concrete used with most secondary pavements has 5.10 sk/cu yd of cement, along with 55 percent of $1\frac{1}{2}$ -in. coarse aggregate and 45 percent of fine aggregate. The specifications permit a wide range of mixes in which the cement is increased as the sand is increased. For economy the contractor has the option of using unseparated aggregate. This permits the use of aggregate from smaller sources which usually have less costly aggregate production equipment. The quality of the aggregate is the same as required for primary work.

This concrete mix is lean when compared to standards used by some other states. The pavements are designed for fairly light traffic, and the resulting concrete seems to be satisfactory for that purpose. Where heavier traffic is anticipated, a mix with more cement is specified.

PAVEMENT CHARACTERISTICS

Slip-form pavement characteristics can be considered from several approaches.

Pavement Strength

Concrete pavement cores showed an average 1963 strength of 3,939 psi for all concrete with the 5.10-sk cement factor. This strength includes an age correction factor for estimating the 28-day strength. A few of the counties spread salt for ice and frost control, though sand is used when necessary. Where salt is used, the spreading rate and frequency of use are usually less than those used for primary work. Some of the older pavements with heavier traffic show minor signs of surface abrasion, but this is not considered serious.

Smoothness

All new pavements are checked with a U. S. Bureau of Public Roads type of roughometer. This is a standard method for determining smoothness of the riding surface. These results, reported in inches of roughness per mile, have been classified only as slip-form and fixed-form pavement, with no classification by primary or secondary system. This roughness agrees numerically with the Bureau's roughometer. For 1963 all new slip-form pavement averaged 73 in./mi for 174 mi checked, and new fixed-form pavement averaged 98 in./mi for 59 mi checked. In 1964 slip-form paving averaged 72 in./mi for 273 mi measured, and new fixed-form paving in 1964 averaged 78 in./mi for 104 mi measured. Urban projects and short pieces of reconstruction are usually somewhat rougher, and they are usually paved with fixed forms.

These results show that the average slip-form pavement is smoother than the average fixed-form pavement. Slip-form pavement shows more variation in smoothness, particularly for new slip-form outfits—both equipment and crews—and for conditions of nonuniformity. Usually the pavement placed following a day's work joint is somewhat rougher. Lack of uniform consistency appears to be a cause for roughness. Frequent interruptions during a day's run usually results in rougher pavement. An improperly constructed track path may cause roughness or swales in the pavement. Although these are all potential sources of roughness which may be relatively more important for slip-form operations, the roughometer results indicate that these can be overcome.

Thickness Variation

Pavement contractors are paid on a square yard basis, adjusted for areas with deficient thickness. An analysis of thicknesses shows that the contractors seem able to control thickness about as effectively with slip-form pavement as with fixed-form pavement. A 1962 study showed that 97.1 percent of the cores from all slip-form pavement placed that year were not more than $\frac{1}{4}$ in. deficient in thickness. This compares with 96.5 percent for fixed-form pavement.

GENERAL COMMENTS

Customary evaluation methods show that slip-form pavement is comparable to other pavements. The special problems related to Iowa's secondary roads result from narrow and high grades and poor soils. High grades are beneficial for several reasons, including availability of better soils. The narrow roadbeds make special construction techniques desirable. Economies can be made in construction costs when fairly low traffic is anticipated.