Specifications and Construction Controls to Obtain Smooth-Riding Bridge Decks

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Construction procedures and specification provisions that will produce smooth riding bridge decks are presented.

It is pointed out that the basic principles that produce smooth-riding concrete surfaces are the same for pavements placed on grade and bridge decks. The need for uniform and accurate subgrades is analagous to the need for determining elevations that reflect correct use of actual camber measurements and calculated deflections due to dead loads applied during bridge deck construction.

For bridge decks to ride as smoothly as adjacent pavements, the screed guides or rails that support paving equipment on bridge decks must be set with the same accuracy and precision employed in setting side forms for concrete pavements on grade.

The criteria for proper placing and finishing of concrete placed on grade should be followed in placing and finishing bridge decks. The important difference in the two procedures is the technique of working in the limited space on a bridge deck. Careful planning is required to include all the necessary steps in finishing.

To insure adequate planning and procedures essential to produce smooth-riding bridge decks, the specifications should include requirements regarding: (a) the placing and finishing equipment; (b) the supports for screed guides or rails, and determination of elevations for guides or rails; (c) the properties of the concrete mix; (d) minimum methods for placing, consolidating, and finishing bridge deck concrete; (e) curing methods; and (f) preconstruction conference of engineer and contractor leading to preparation of detailed plan for bridge deck placing and finishing.

● HIGHWAYS and highway bridges are built to accommodate the needs of the motoring public. These needs are (a) uninterrupted traffic flow, (b) safety at high speed, and (c) driving comfort as affected by the riding quality of the pavement. The principal part of a highway observed by the user is the driving surface of the pavement. If the pavement is rough riding, the driver is prone to condemn the entire structure — highway or bridge.

The highway users' opinion of rideability makes no allowance for the manner in which the pavement is supported. The riding quality requirements for a bridge deck are therefore the same as for a pavement on grade. The requirements for a smooth-riding pavement are (a) a smooth, true grade line without long waves and dips, (b) a uniform surface and uniform cross profile, and (c) a smooth surface as indicated by testing with a straightedge.

The grade line of the pavement and initial surfacing control are determined by the forms when the pavement is on grade, and by the screed guides when the pavement is a bridge deck. Both forms and screed guides must be adequately supported to maintain a true position with respect to the subgrade. In setting screed guides on a bridge there

is, of course, the additional consideration of subgrade deflection when the concrete is placed.

Uniformity of surface, cross profile and surface tolerance on a bridge deck are affected by the same factors that affect these characteristics of a pavement on grade. Space limitations on a bridge deck require somewhat different techniques for handling, placing and finishing concrete than are usually employed for a pavement on grade. However, the basic considerations are the same in both cases.

Smooth-riding concrete bridge decks can be constructed. The fundamental principles which apply to construct a smooth-riding pavement on grade apply to construct a smooth-riding pavement on structure. These fundamentals, briefly stated, are: (a) accurately set forms, or screed guides, securely supported; (b) a uniform concrete mix, properly proportioned for the job; (c) proper concrete handling and placing methods; (d) uniform strike-off, screeding and consolidation; (e) longitudinal floating; (f) straightedging by experienced pavement finishers; (g) uniform texturing; and (h) adequate curing.

Understanding and cooperation on the part of design engineer, construction engineer, and contractor are essential to a satisfactory job. The starting point is an accurate structural design and adequate specifications with respect to materials, concrete mix, and methods for handling, placing, and finishing the concrete. Considerable emphasis should be placed on the necessity for sufficient and adquate construction equipment and finishers experienced in use of the long handled 10-ft scraping straightedge.

Prior to the start of construction, a conference between construction engineer and contractor should determine: (a) type and adjustment of screed supports or guides; (b) equipment to be used; (c) material supply; (d) procedure for placing, finishing and curing concrete; and (e) number and qualification of men required.

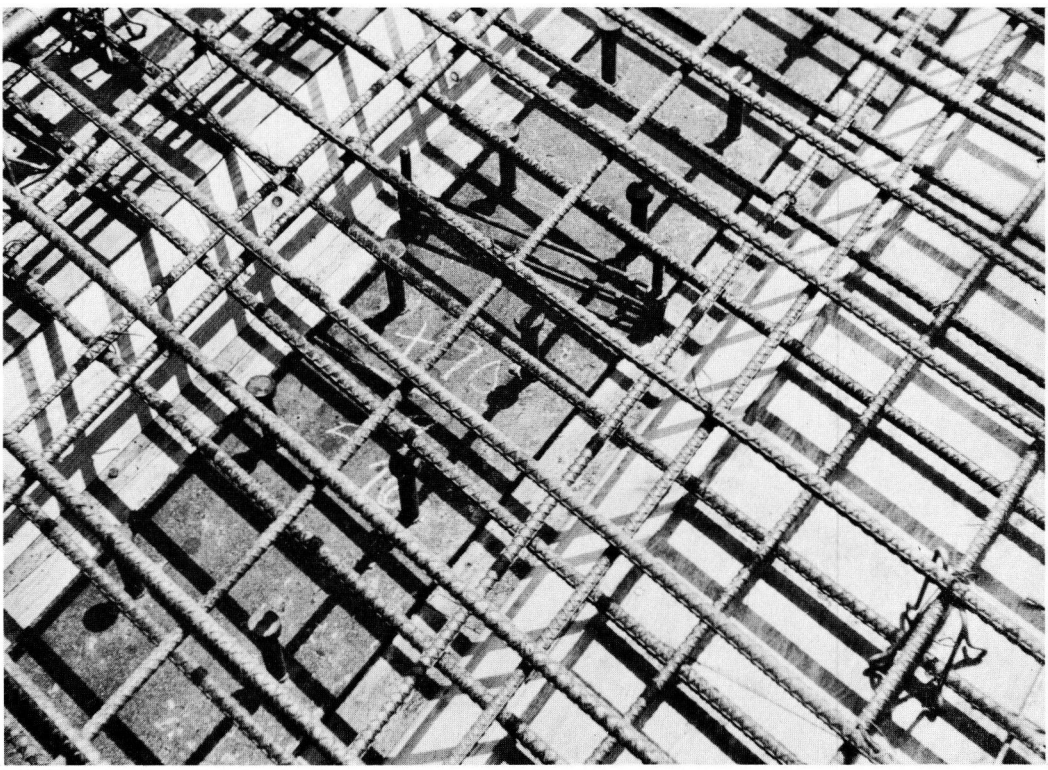

Figure 1. Depth of haunch from top of beam to underside of slab should be variable to permit adjustment for actual camber.

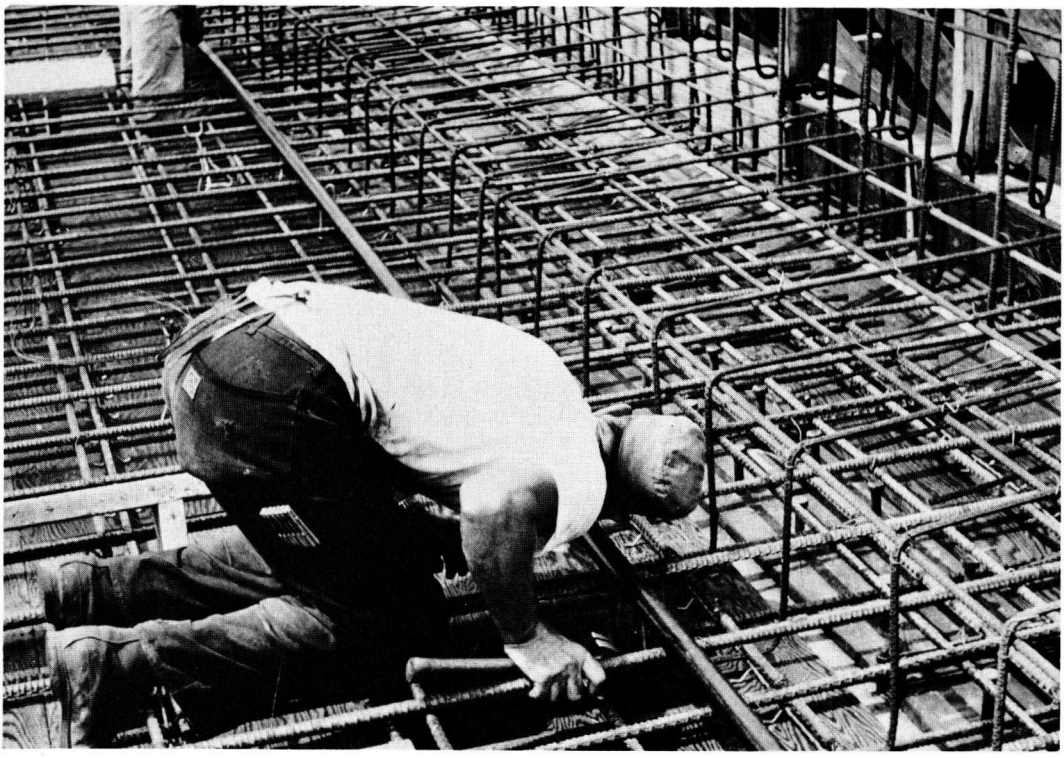

Figure 2. Screed guides and rails should be "sighted-in" after being set to calculated elevations.

Bridge structures vary widely in details of design and erection problems. Frequently considerable ingenuity is required to finally produce the desired structure. This discussion is concerned with the fundamental principles previously stated and which must be applied to each structure to produce a smooth-riding bridge deck.

Two principal causes for rough-riding bridge decks can be observed:

1. Long waves and abrupt dips in the longitudinal profile caused by failure to properly adjust the elevation of screed guides and end dams to compensate for the combined effect of actual camber in main structural members and deflections due to dead loads; and
2. Rough or uneven surfaces caused by inadequate concrete placing and finishing methods.

DESIGN CONSIDERATIONS

Often the designer can incorporate features which facilitate paving construction and thus contribute to a better riding surface.

When possible a stringer, or main beam, should be located under screed guides or rails. When built-in metal curbs, gutters or grade angles may be used as screed guides, the detail should include provision for vertical adjustment. End dams should be adjustable to final elevation in the field. Stringer profiles should be checked against the plan elevation of the deck surface to insure full design slab depth. Depth of haunch, or corbel, from top of beam to underside of slab should be a variable dimension (Fig. 1). The plans should show the loading sequence and calculated deflections due to slab dead loads. On multi-lane pavements consideration should be given to longitudinal joints. When used, these joints should be in line with a roadway lane edge.

SCREED GUIDES AND SCREEDS

Initial surfacing control and final longitudinal profile are determined by the screed guides. Screed guides must be accurately set to calculated elevations so that after deflection from all dead loads they conform to a true and smooth grade line. Elevation of screed guides should be checked by instrument and final minor adjustments made by "eyeing in" to a smooth line (Fig. 2).

Calculated elevations for top of deck forms and screed guides must be determined from consideration of (a) elevations on tops of all supporting beams or girders after erection, (b) anticipated deflections from dead loads and (c) cross slope on the finished surface. Because the screed guides are positioned after the deck forms and reinforcing steel are in place, the dead load deflection to be accommodated will be only that due to the weight of the deck concrete.

End dams and intermediate bulkheads must be set accurately to the final grade line as established in the field. Approach pavements on grade should be constructed after the bridge deck is in place, when they can be adjusted to meet the bridge deck profile.

Depending on bridge length and construction economics, the screeding equipment may be a fully powered finishing machine with oscillating screed, a vibrating screed, or a heavy hand-operated screed. Use of the hand-operated screed should be confined to small areas.

Finishing machines will be operated on bridge elements such as curb angles, or on temporary rails. Adequate supports must be provided to carry the heavy machine without deflection of the rails. Supports should be on structural beams at about 5-ft inter-

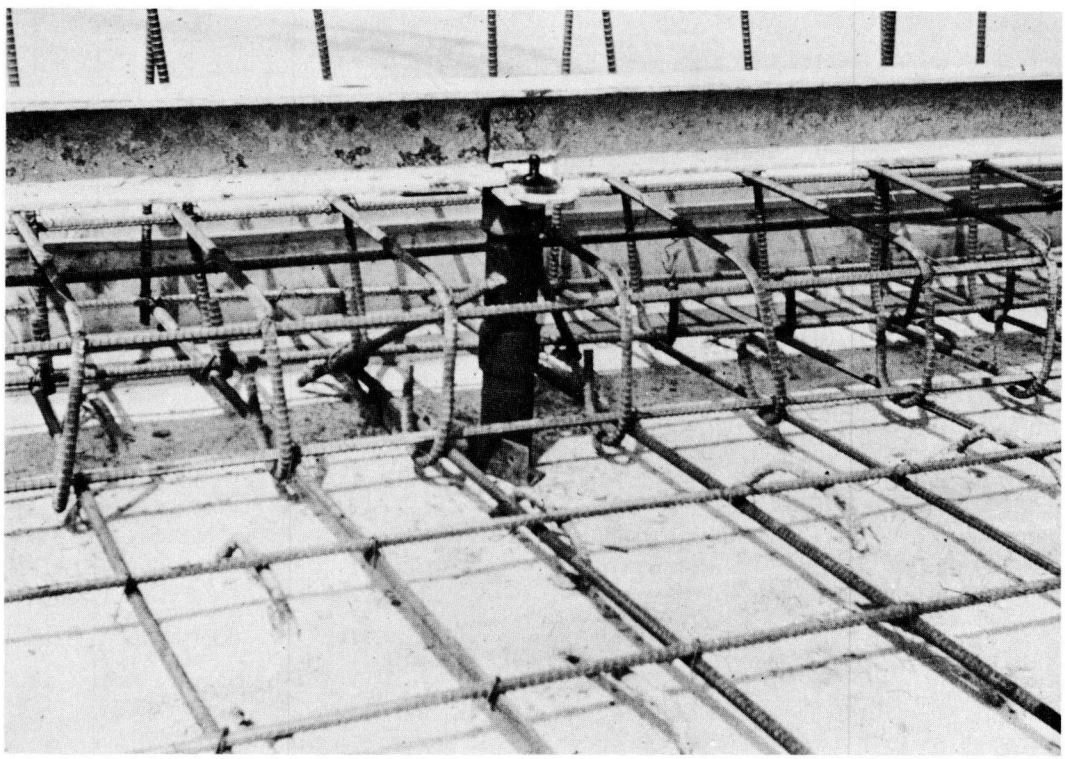

Figure 3. Finishing machine rails should be above the pavement surface. Vertical supports should be fixed on structural members and adjustable to a true elevation.

Figure 4. Concrete should be workable and have a 2- to 4-in. slump. Concrete should be placed against concrete and as near its final position as possible.

vals, with the spacings staggered on opposite sides of the roadway. Finishing machine wheels should be carried above the pavement surface to allow for hand finishing outside the roadway area (Fig. 3). Vertical supports must be fixed, but vertically adjustable to true elevation. Temporary rails and supports must be removable with minimum disturbance of the screeded concrete.

Vibrating screeds may be carried on bridge elements and/or pipe screed guides. Fixed supports must be adjustable and spaced close enough to prevent deflection of the screed guides. Screed guides should be supported on structural members and not on deck forming. Temporary guides must be removable with minimum distrubance to the screeded concrete.

Attention to proper positioning and support of screed guides should eliminate that part of rough riding due to an irregular grade line made up of a series of curves. This is only part of the story, however. Much rough-riding pavement is due to improper methods of handling, placing and finishing concrete. Improperly performed, these operations can produce a rough, uneven pavement even though it may conform generally to a true grade line.

CONCRETE MIX

A prerequisite for construction of a smooth-riding pavement is production of a concrete mix uniform in composition, workability, and consistency. The mix characteristics must be geared to the job. Because considerable reinforcing steel must be incorporated in a bridge deck slab, the maximum size of coarse aggregate will be ¾ in. to 1 in. for the usual slab depths. To be readily workable, concrete with this size of coarse aggregate will require a sand aggregate ratio of 38 to 40 percent or higher.

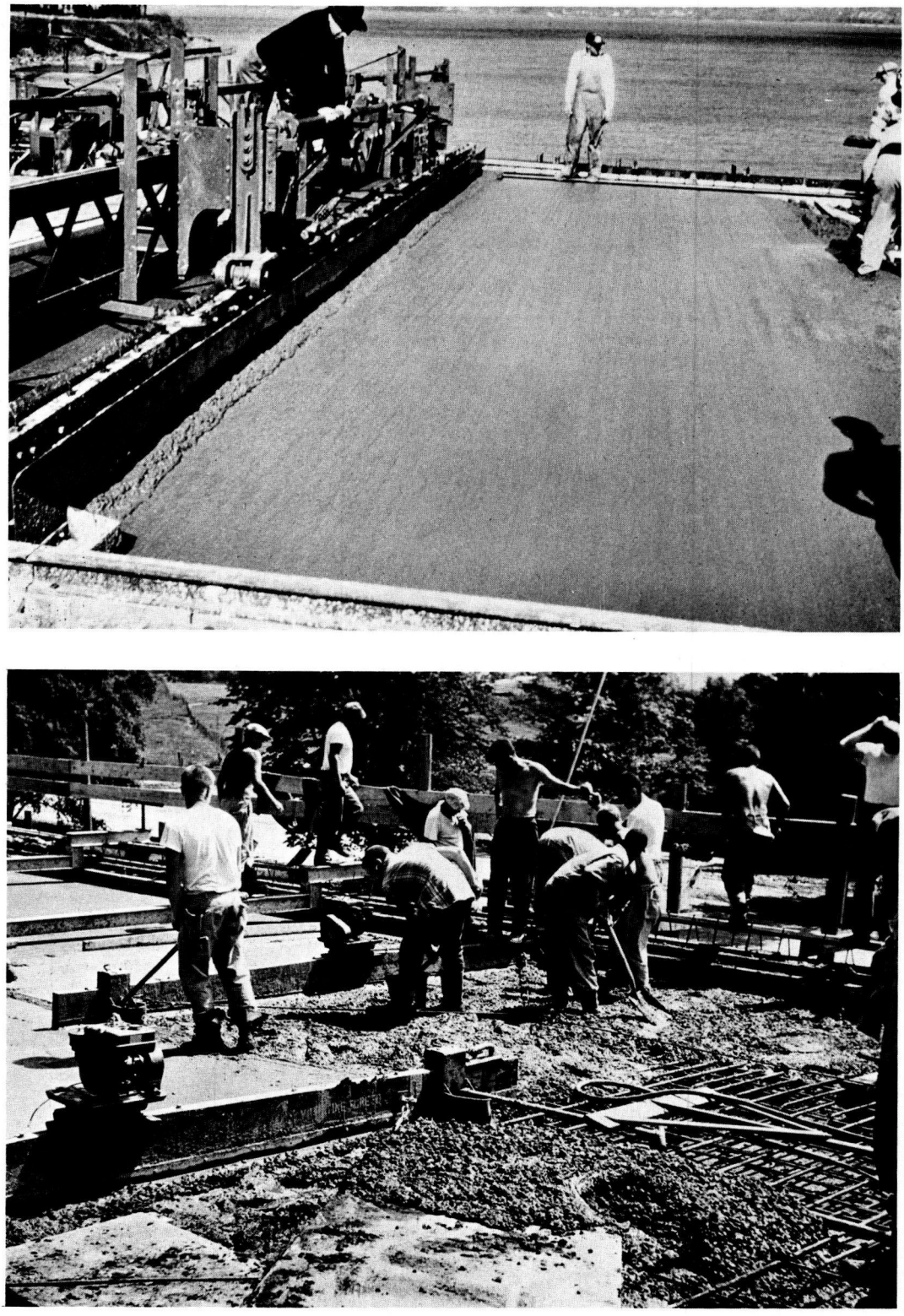

Figure 5. Finishing machines or vibrating screeds should move at a uniform rate and strike off the full paving width in one operation.

When the deck will be subjected to severe exposure conditions, the water-cement ratio should be not more than about 5 ¼ gallons of water per sack of cement. The consistency or slump of the mix should be between 2 and 4 in. With the foregoing factors established, it will be found that the cement factor for air-entrained concrete will be about 6 ½ to 7 sacks per cubic yard. This cement factor is slightly higher than for normal pavement mixes, due to increased slump and smaller maximum size of coarse aggregate.

Air entrainment increases durability and provides resistance to scale produced by de-icing chemicals. For the type of mix being discussed, the air content of the fresh concrete should be 6 percent, plus or minus 1 percent. Regardless of durability requirements, air entrainment is recommended for all pavement concrete because of improvement in workability.

HANDLING AND PLACING CONCRETE

Usually the mixed concrete will be placed in the forms from bottom dump buckets or concrete buggies. The handling and transporting method must be controlled to avoid segregation. Buggies should work on movable platforms or bridges. Concrete should be dumped against concrete previously placed, and as near its final position as possible (Fig. 4). Deep, widely spaced piles of concrete should be avoided, because the density of the concrete at the bottom of the pile will differ from that of the concrete shoveled into the spaces between piles. Spud vibrators will usually be needed to consolidate the concrete around the reinforcing. Vibrators should not be used to move concrete. The concrete should be spread by shoveling to approximate grade before screeding. Walking in the concrete should be kept to a minimum.

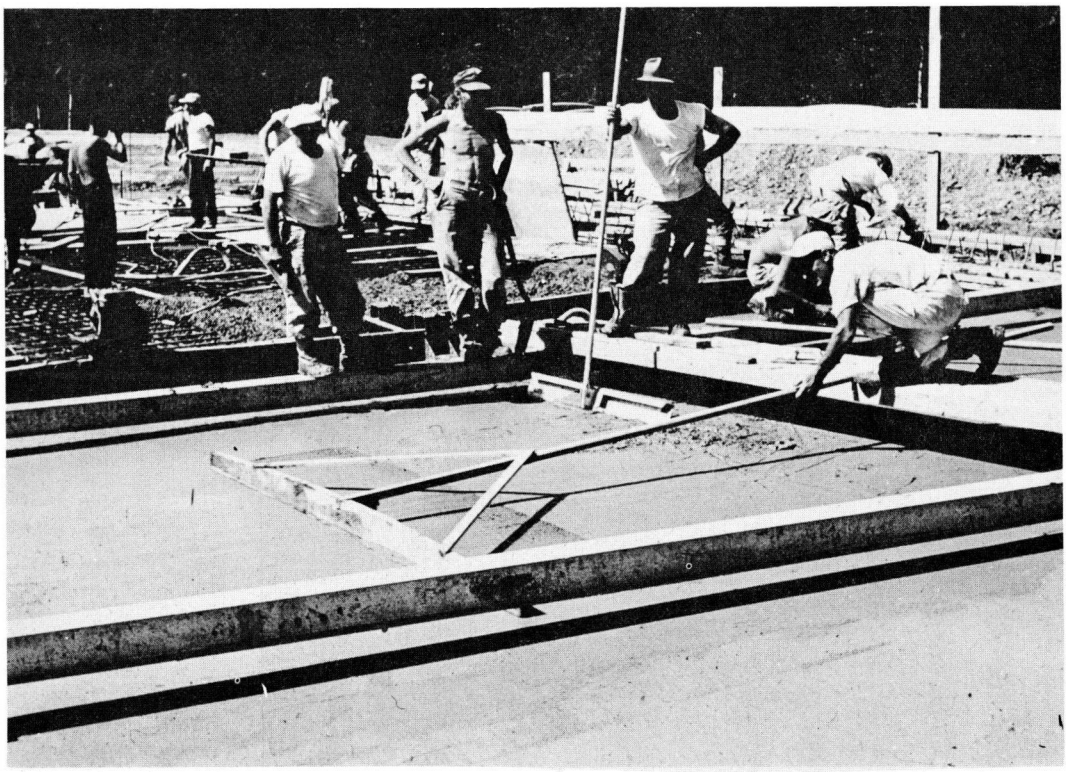

Figure 6. Work bridges may be required to avoid walking in the concrete after screeding.

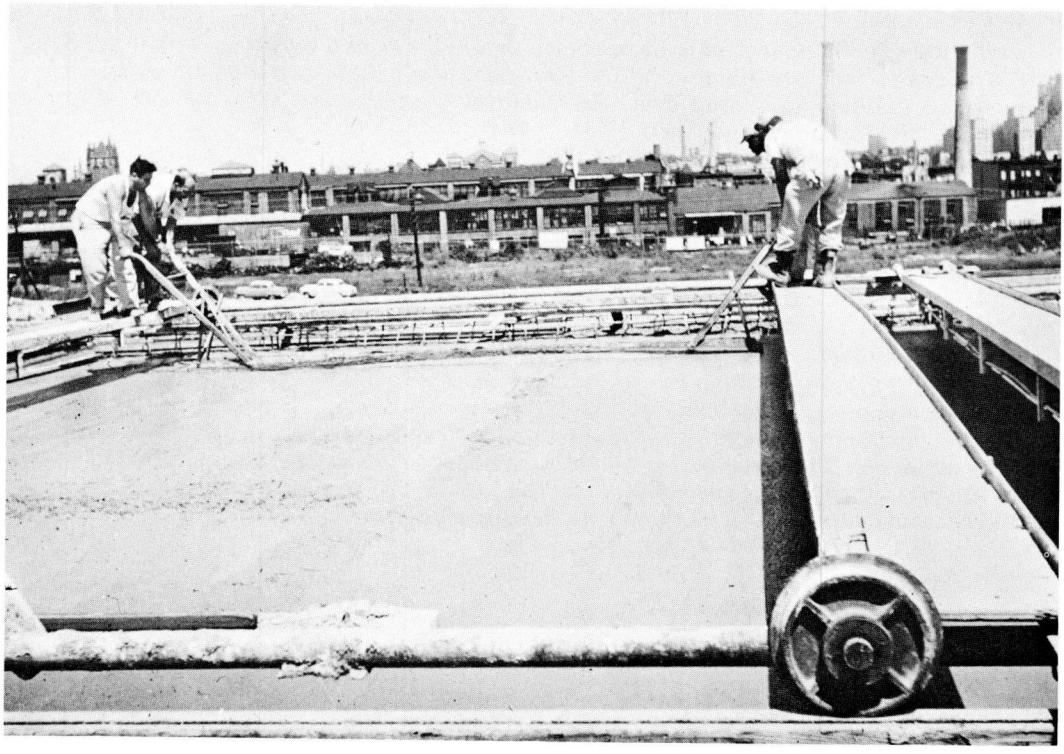

Figure 7. The longitudinal float removes slight waves left by the screed.

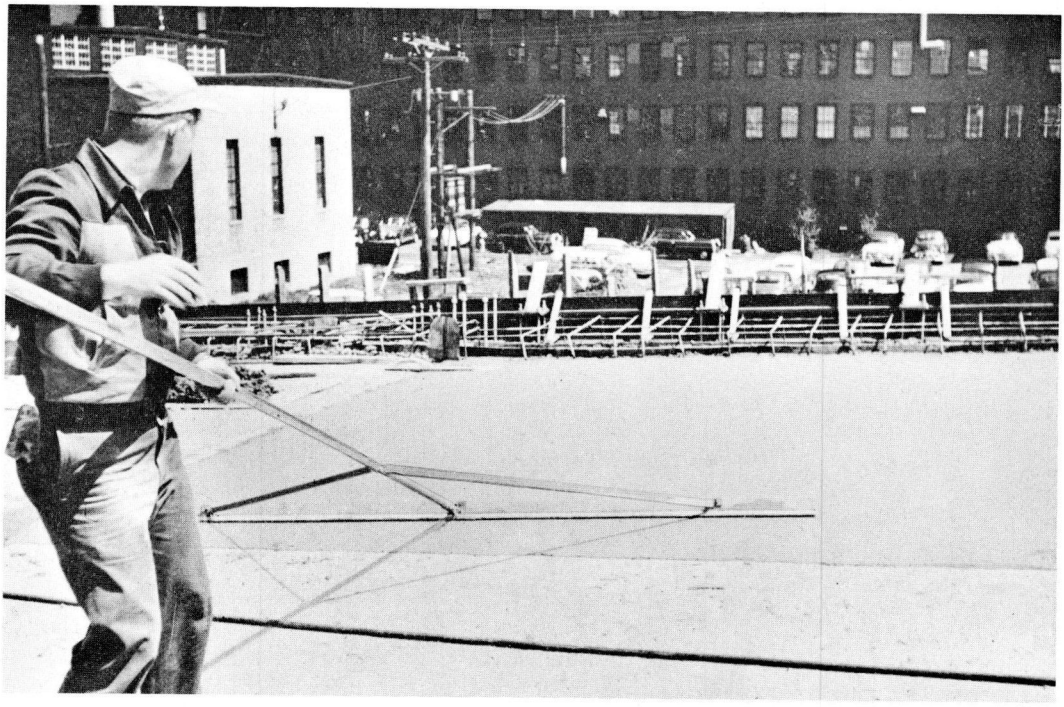

Figure 8. The 10-ft straightedge is required for a smooth-riding surface.

SCREEDING CONCRETE

Finishing machines or vibrating screeds should be moved slowly and at a uniform rate along rails or screed guides which have been accurately set and securely supported (Fig. 5). A uniform amount of concrete should be kept in front of the screed at all times, and for the full width of the screed.

Finishing machines should strike off the full width of pavement in one operation. When vibrating screeds are used, two or more may be operated across the width being placed. The screeds should be moved forward closely together to prevent possibility of a "cold joint."

As mentioned previously, screed guides or rail supports must be arranged to be removable with minimum disturbance to the screeded concrete. Voids left after removal should be filled with concrete — not mortar.

It should be emphasized that walking in the concrete must be prohibited after the screeding operation. Walking in the concrete pushes coarse aggregate aside and leaves a pocket of mortar. This pocket will be of different composition and density than the adjacent concrete and can be expected to subside at a different rate.

Substantial work bridges will frequently be needed for all operations following screeding (Fig. 6). Work bridges should be planned and fabricated well in advance of concreting. Preparations should include means to support and move work bridges.

FINISHING CONCRETE

Final finishing of concrete in a bridge deck is subject to the same basic requirements

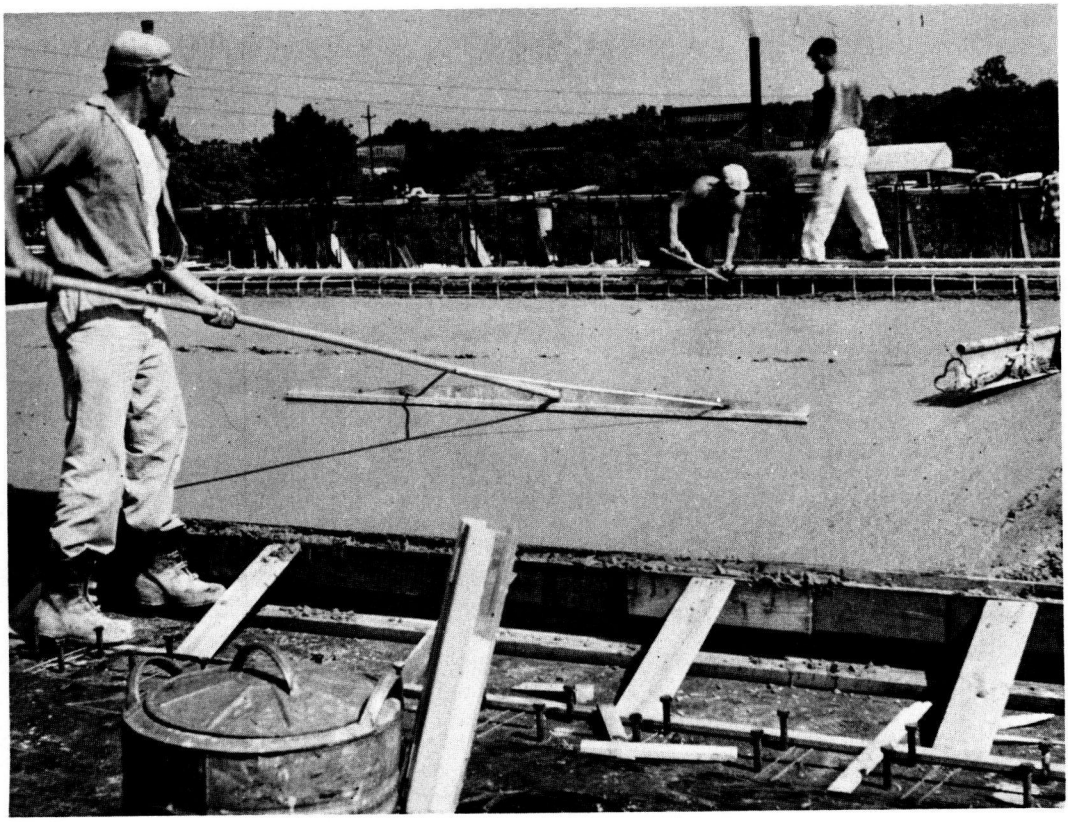

Figure 9. Final surface check is made with a lightweight 10-ft straightedge.

Figure 10. When wet burlap is used for curing it must be kept saturated.

as concrete in a pavement on grade. The only difference is that the work must frequently be done from work bridges above the concrete surface. Finishing operations should be delayed as long as possible so that the concrete will have had time for subsidence. "Finishing concrete" in this discussion includes the operations of using a longitudinal float, a scraping straightedge and application of surface texture.

The first of these operations is the use of a hand-operated longitudinal float, 16 ft in length, equipped with plow handles and worked from a pair of bridges spanning the full width of the roadway (Fig. 7). This is standard equipment, and usually of a metal channel section. The longitudinal float is operated transversely across the surface with a sawing motion, returned in the same path, and then moved ahead one-half length. The operation is then repeated.

Final surfacing is obtained by use of a long-handled 10-ft scraping straightedge (Fig. 8). This piece of equipment must be used by an experienced pavement finisher. It may be of wood or aluminum, and for best results should weigh in the range of 30 to 45 lb. The straightedge should be operated across the full working width in one operation. When necessary, it must be handled from work bridges spanning the pavement.

The straightedge is operated by placing it on the near edge of the pavement, sliding it across the surface with the handle about 10 in. above the pavement, and returning along the same path with the handle at shoulder height. It is then moved ahead one-half length and the operation repeated. The scraping straightedge should be used as late as possible so as to benefit by the final slumping of the concrete.

The pavement surface at all joints should be carefully straightedged while the concrete is being finished. Any necessary transitions to meet such joints should be carried out on long lines with no abrupt change, so that a smooth-riding joint is secured.

A light checking straightedge should be used while the concrete can still be worked (Fig. 9). Any irregularities observed should be corrected and the needed steps taken to prevent a recurrence of such defects.

Smoothing lutes are sometimes used to float down high spots, fill surface voids, or to work up mortar for final texturing. They are about 4 in. wide, and 4 to 6 ft in length. Use of the smoothing lutes usually produces short waves or hollows in the surface. Following use of a smoothing lute, the surface should be carefully checked with a 10-ft straightedge.

The final surface texture will usually be produced with a burlap drag. The burlap should be a seamless strip, longer than the paving width and wide enough to that at least a 24-in. width is in contact with the surface. It should be kept wet and free from hardened concrete. In some cases a light broom finish is used; but the burlap drag finish is considered to produce the most even surface and the smoothest ride.

BULKHEADS

Deck placing will usually start and end at a transverse joint. However, where it is necessary to set an intermediate bulkhead it should be installed with the greatest of care, so that the exact pavement cross-section is maintained along this line. Vertical dimensions should be set and checked from piano wire measurements to eliminate sag. A key-way strip should usually be installed in these construction joints. Tooling of the joint edge is unnecessary and undesirable.

CURING

Curing should be placed as soon as possible without marking the fresh concrete. If a double layer of wet burlap is used, it must be kept saturated (Fig. 10). White pigmented membrane has been used successfully with spray applications.

CONSTRUCTION CONTROL

Construction control that produces satisfactory work is a compound of experience and application of adequate specifications. An adequate specification insures that differences of opinion which may affect the quality of the construction will be resolved on the basis of engineering experience. It also provides a legally binding agreement as a basis for the engineer to establish those construction controls which he knows from experience are necessary to produce a satisfactory structure.

Most highway bridges are built by agencies which have established Standard Highway Specifications. Where more detailed bridge deck specifications are needed, they probably would be incorporated as a supplement to, or a revised section in, the Standard Specifications. In either case, the form and wording should conform to local practice. For this reason, the suggested specification provisions which follow are presented in outline form.

SUGGESTED SPECIFICATION PROVISIONS FOR PLACING AND FINISHING CONCRETE BRIDGE DECKS

General

Conform to Standard Specifications requirements, except as supplemented or modified herein.

Conform to plan dimensions and elevations, except as modifications are approved by the engineer.

Place deck concrete in the sequence shown on the plans.

Construct curbs, sidewalks, and parapets after curing of deck concrete is completed.

Surface smoothness tolerance the same as for pavements on grade, but not more than $\frac{1}{8}$ in. in 10 ft.

Finishing procedure and equipment the same as for pavement on grade, except:

1. Single, suspended screed, power driven finishing machine is permitted for strike-off and screeding; or
2. Vibrating screeds are permitted for strike-off and screeding;
3. Hand finishing methods permitted outside of mechanically screeded areas, and to a bulkhead in case of equipment breakdown;
4. Longitudinal float may be hand operated.

Preconstruction conference of engineer and contractor to review proposed construction procedures and requirements.

Materials

Conform to Standard Specification requirements.

Composition of Concrete

Maximum water cement ratio: not more than 5 ¼ gallons per sack.

Fine aggregate portion of total aggregate: 35 to 45 percent.

Consistency: 2 to 4-in. slump.

Air entrainement: 6 percent plus or minus 1 percent for ¾ - in. and 1-in. maximum size coarse aggregate.

Minimum cement factor: not less than 6 sacks per cubic yard.

(Where severe exposure is not a consideration, the water and cement requirements can be modified to suit local conditions.)

Construction Methods

Finishing machine wheels to be supported above pavement surface on temporary rails or other horizontal structural device.

Vibrating screeds to be supported on temporary pipe guides, grade angles, etc., at surface elevation.

Vertical supports for screed guides or finishing machine rails to be fixed, but vertically adjustable; spaced to limit deflection under the screed or finishing machine to not more than ⅛ in. in 10 ft; erected on structural members, unless permitted otherwise by the engineer; removable to at least 2 in. below the surface, with minimum disturbance of the concrete.

Screed guides, or rails, to be set to elevations determined from the profile grade line, and adjusted for calculated deflections and surface cross slopes (the relative difference in elevation between the top flanges of structural beams as erected and the surface grade must be determined to insure required slab thickness and cover over reinforcement).

Screed guides, or rails, to be surfaced before placing concrete; final surfacing, after elevations have been checked by instrument, by minor vertical adjustments to the supports while "eyeing in" to obtain a smooth surface.

Concrete to be delivered at uniform, adequate rate by buggy or bucket ahead of finishing machine or screeds.

Concrete to be placed without segregation, spread to approximate grade, and consolidated around reinforcing before screeding.

Finishing machine to be power driven for oscillating screed and machine movement.

Vibrating screed to be power vibrated and moved with positive means, such as by cranking or by winch and cables; pulling by hand lines may be approved by the engineer when he has determined that the method will produce satisfactory results.

Screeds adequate to cover not less than the projected width of approach pavement, and preferably the full width of deck being placed.

Screeding to progress forward at a slow and uniform rate.

All operations following screeding to be performed without walking in the concrete; from work bridges if necessary.

Voids left after removal of screed guides and supports to be filled with concrete — not mortar.

Sixteen-foot longitudinal float worked parellel to pavement centerline with a sawing motion across the width of surface and back, before moving ahead one-half length.

Ten-foot long-handled finishing straightedge to be used by experienced pavement finisher; straightedging to be delayed as long as possible to allow for subsidence.

Ten-foot testing straightedge to be used while concrete is still workable and irregularities can be corrected.

Surface texture to be the same as on approach pavement.

Curing by continuously saturated burlap, paper or white pigmented curing compound, to be applied as soon as possible without marking the fresh concrete.

At least 15 days before starting concrete placement, the contractor to submit for the

engineer's approval a plan for concrete placing and finishing operations, material supply, equipment and men to be used.

CONCLUSION

The essential requirements discussed herein have been found for many years to be good practice in securing smooth-riding surfaces on bridges and highway pavements. The suspended nature of a bridge and the limited working space usually create conditions requiring careful planning and some ingenuity if basic requirements are to be met. Where pavements have not been satisfactory from a smooth-riding standpoint, it has been observed that one or more of the requirements discussed herein has been omitted. Surprising as it may seem, much important bridge deck paving has been observed where many of the procedures mentioned here were omitted, and only the barest screeding tools were used. Simply screeding off the fresh concrete and applying a surface texture is not adequate to finish a pavement expected to have a smooth-riding surface. It is important that adequate design and specifications be provided, and that the engineer and contractor review the matter of essential equipment and procedure for paving.