Discussion of a report by Subcommittee VI, ACI Committee 325:

Prestressed Pavement—A World View of Its Status*

By THOMAS CHOLNOKY, L. COFF,
JOHN J. MURRAY and JOHN E. HEINZERLING, and H. KENT PRESTON

By THOMAS CHOLNOKY†

The development of prestressed concrete pavements during the last two decades has lead to some generally accepted conclusions. Design practices rather than design theories have been adopted and various construction techniques have been tried. The ground work has been completed. There is need at this time to review the past and to consider the future possibilities.

The report on prestressed pavements by Subcommittee VI, ACI Committee 325, is of great value in the first respect.

In discussing the future possibilities of prestressed concrete pavements, one should differentiate between airfield and highway pavements. The conditions of design, the possible savings in construction cost, and practical difficulties are quite different for these two applications.

It is not without reason that the largest number of major experimental prestressed pavements and also some full scale installations were built in view of or for airfield use. The reasons are obvious. The loading conditions in airfield pavements seem to suit the characteristics of prestressed concrete better. The magnitude of loads and their position in the interior of the pavement slab seem to utilize the advantages offered by prestressing more advantageously than loads applied on highway pavements. Furthermore, prestressing leads to considerable reduction of airfield pavement thicknesses whereas comparable reduction in highway pavements are not possible since they are already relatively thin. Construction problems and complicated details are less in airfield pavements where grades are generally small and without horizontal curves, and where there are few intersections or widenings.

The superior load bearing capacity of prestressed concrete has been proved repeatedly, unfortunately without sufficient conclusions as far as ultimate loads and safety is concerned. There is need to determine the minimum concrete thickness and amount of prestressing for given loads and variable base conditions. It is generally accepted that prestressed concrete pavements carry loads safely and with greater deflections than conventional

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†Member American Concrete Institute, Vice-President, Sinjon, Inc., Greenwich, Conn.

pavements. The problem of allowable deflections in the base should therefore be re-examined to utilize the greater flexibility of prestressed concrete pavements.

Overlay pavements call for special consideration and may offer a good possibility of the application of prestressed concrete.

The two-way prestressing for airfield pavements seems to be necessary to secure uniform characteristics in the concrete sections. Highway pavements, however, do not seem to need prestressing in the transverse direction primarily because of the stresses created by the governing edge loading conditions.

The necessary amount of prestressing will be governed primarily by economy. The minimum amount to overcome friction plus 100 psi should give a sufficient strength to the pavement section to utilize the advantages of prestressing. The means of prestressing, the timing of its application, the location of the prestressing elements or tendons, if used, and the efficiency by which prestressing is developed in the pavement sections should be further studied and developed.

The full advantage of prestressed concrete sections cannot be utilized unless they are able to develop plastic hinges. Under extreme conditions such plastic hinges cannot develop when prestressing is applied by external means such as jacks. Therefore, the use of internal elements such as strands and wires seem to offer added advantages.

The application and distribution of prestressing forces is affected by the constant volumetric changes which take place in the concrete slab. It is also influenced greatly by the governing friction condition under the slab. Theories and methods should be found whereby prestressing can be developed under the most favorable conditions and with minimum losses.

The future of prestressed concrete pavements depends not only on the findings of further research and development of applicable theories—its good qualities have been already proved—but also on its cost. "Prestressed pavement is not yet competitive from a cost stand point with conventional pavements . . . " It will become so if contractors are given the chance to gain experience and perfect their techniques in conjunction with the development of improved designs and construction methods.

By L. COFF*

The report of the subcommittee would not be complete without mentioning the Chicago pavement slab of the John A. Roebling's Sons Corp., which is one of the largest experimental slabs built in this country. The slab is 144 ft long and 90 ft wide, and was built about 11 years ago.

It is correct that this is neither a road nor a runway slab, and that the load and foundation conditions are unusual because the concentration by the wooden rims of the cable reels exceeds 1000 psi as against 100 psi, a well

*Member American Concrete Institute, Consulting Engineer, New York, N. Y.

known figure for rubber tires. Also, the foundation is on foundry sand of varying depth which is not quite in line with conditions of normal roads and runways. However, the principles of this slab, built in cooperation with and tested by the late C. C. Sunderland, chief bridge engineer of John A. Roebling's Sons Corp., were filed to patent in 1947 and granted to the writer in 1952. The design contains certain features for reducing subgrade friction on a jointless area of 14,000 sq ft, i.e., much larger than any of the domestic tests mentioned in the report.

The appended bibliography is so complete and in detail that a further description should not be required.

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By JOHN J. MURRAY* and JOHN E. HEINZERLING†

The subcommittee is to be complimented on its excellent and factual reporting of the work which has been done in the field of prestressed concrete pavement. This serves the useful purpose of informing the profession and should further encourage the continuation of the development into more advanced phases.

The subcommittee is also to be complimented on its brief, but pertinent analysis of the advantages of the prestressing method of pavement construction. Prestressed concrete offers to the engineer the tool needed to solve the "joint" problem. It has been recognized that the joint must inevitably be the weak point of any concrete pavement and must be the focus of eventual failure, however long delayed by refinement of treatment. To supplement the report of the subcommittee, we would like to offer the following additional comments.

*Member American Concrete Institute, Development Engineer, Jones & Laughlin Steel Corp., Pittsburgh, Pa.
†Member American Concrete Institute, Project Engineer, Richardson, Gordon and Associates, Consulting Engineers, Pittsburgh, Pa.

The subcommittee has pointed out, in Item 10 of the summary, that the experimental work done so far "will stimulate and benefit other investigations in their search for answers to the remaining unsolved problems." It may be emphasized here that in no other area of civil engineering is research better justified. This is because of the standardization of pavement sections used. Refinements become more essential and mistakes more costly because of repeated use of a developed design.

There is little question that prestressed concrete pavement has been demonstrated to have qualities superior to our present designs. Because of this it appears logical that refinement of design should tend toward prestressed concrete. The development of prestressed concrete pavement has reached the point where the construction should be carried into experimental traffic strips where its action under actual traffic, in various climates and various weather conditions, can be evaluated and compared with conventional pavement.

With reference to the design of a prestressed concrete traffic test pavement, we note that the subcommittee comments under "Design Practices," p. 830, that: "Design methods to date have been somewhat empirical," and further, "slab thicknesses have been selected rather than designed . . . " Although these are incontrovertible statements of fact, they are hardly to be considered departures from current practice in pavement design.

Actually all pavement slabs have been developed by field trials. It is true that analytic methods have been used to explain the action of pavement slabs and much good has come out of this work. However, the lack of a positive method of analysis to evaluate the many independent variables of subgrade condition, climate, season, thermal change rate, moisture gradient, etc., should not discourage the practical trial of prestressed concrete pavement by as wide a group of state highway departments as possible.

We are looking forward to this subcommittee continuing its good work by encouraging the initiation of test programs by highway departments supported by the Bureau of Public Roads.

By H. KENT PRESTON*

The paper gives an excellent coverage of the present status of prestressed concrete pavements.

The first sentence under the heading "Choice of Methods of Prestressing," p. 833, reads: "There are two general methods of inducing the necessary initial compressive stress in the concrete of pavement slabs: post-tensioned steel cables, and jacks reacting against abutments of some description." This statement is correct in a report dealing only with pavements that have already been built. However, such a comprehensive report seems incomplete without some mention of the pretensioned method which has recently received considerable study and offers definite advantages in many cases.

*Engineer, Construction Materials Division, John A. Roebling's Sons Corp., Trenton, N. J.

The tensioning elements for a pretensioned pavement would be seven-wire, uncoated, stress-relieved prestressed concrete strands manufactured in accordance with ASTM A 416-57T. Long straight pavements are best adapted to the use of pretensioned strands. Briefly, the erection procedure is as follows:

1. Build abutments or drive piles at each end of the runway to serve as anchors for the initial tension in the strands until the concrete in the pavement has cured to specified strength. These abutments can easily be 12,000 to 15,000 ft apart if necessary.

2. Place seven-wire strands from anchor to anchor for the width of the first placement. If the pavement is to have transverse prestressing also, the transverse tendons will be post-tensioned. Place metal hose or other devices to make holes for the transverse tendons. Place transverse forms at expansion joints. (These joints will be 500 to 1500 ft apart depending upon friction of slab on base and details of joints being used.) Tension seven-wire strands to full load and place concrete from anchor to anchor.

3. Make second, third, etc. placements in the same manner as the first until the entire width has been placed.

4. When last placement has reached required strength, place and tension transverse tendons.

5. Release longitudinal seven-wire strands from anchorages and cut them at expansion joints.

The pretensioned bonded method has several advantages for those pavements where details permit its use.

A. Since the tendons are fully bonded, any damage is confined to the area in which it occurs.

B. Friction between the tendons and their enclosures is completely eliminated since the tendons are in the open when they are tensioned. This is important, because the distance between joints is usually long, which means large friction losses in post-tensioned tendons.

C. The designer has complete freedom in his choice of location for expansion joints. He simply places forms across the width of the pavement at points where joints are desired. When strands are cut at the anchorages they are also cut at each joint.

D. Use of seven-wire strand for the full length of the pavement reduces field labor for placing and tensioning to a minimum.