REPORT

ON

PRESTRESSED CONCRETE HIGHWAY PAVEMENT

1964

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April 7, 1964

Mr. John Swanberg, Chief Engineer
Minnesota Highway Department
Highway Building
St. Paul 1, Minnesota

Re: Prestressed Concrete Highway Pavement
Our File #6467

Dear Sir:

At the request of Mr. Carl Hutchings, Rochester, Minnesota, we have reviewed his patented method of constructing a prestressed concrete highway slab. Enclosed herewith is a brief report covering the pertinent points of this method and an outline of some of the advantages inherent to this type of construction.

We have prepared typical details of a possible test section utilizing this method as shown on Sheets 1 through 3. Certain details and specifications must be prepared to fit the actual test section.

No attempt has been made to provide a complete mathematical analysis of the ultimate strength of the slab. A number of fine articles are available in technical journals covering these aspects. Likewise, a complete and detailed description of the construction operation is not included because many of these details are dependent upon the location, base, grade and alignment of the actual test section.

Review this report. Discuss the advantages and disadvantages of the proposed construction. Additional data and details will be provided to clarify any points when requested. The true evaluation can come only with an actual test. It is respectfully requested that, after careful consideration by your department, a test section is authorized.

Very truly yours,

BONESTROO, ROSENE & ASSOCIATES, INC.

Robert W Rosene

Robert W. Rosene

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I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota.

Reg. No. 3488 Robert W Rosene

Robert W. Rosene

INTRODUCTION

The use of prestressed concrete in the construction industry has received a great deal of attention in the past 20 years. The possibility of applying its advantages to highway and airfield pavements has received increasing interest in the last 10 years. The development of practical applications in the paving field have come much slower than in the building construction industry primarily because of the following:

1. Paving does not lend itself to mass production shop manufactured units.
2. Major design problems have arisen with end anchorage of prestressing tendons, transverse joints, vertical and horizontal curves.

Up to the present time, prestressing methods used with paving slabs have been much more complex than those of conventional pavements. If prestressed concrete paving is to be realized to its full advantage, it is essential that simple and practical construction methods be developed.

Such a system has been developed by Mr. Carl Hutchings, a building contractor from Rochester, Minnesota. The method has evolved over the past 7 years with the first actual test slab poured in July 1960. This was a 12' wide by 3-5/8" thick driveway tensioned with 7/16" cables at 16" on center stressed to 18,900 pounds per cable. Since that time, pertinent points of the system have been patented and refinements made in construction procedure. Engineering for the prestressing and technical assistance for initial testing of the first slab were provided by Morris W. Self, P.E. then on the staff of the Civil Engineering Department of the University of Minnesota and currently with the University of Arizona.

BASIC PRINCIPLES

The design of conventional rigid concrete pavements assumes that the load stresses remain in the elastic range of the concrete with the tensile stresses in the extreme fibers limited to the flexural strength of the concrete. A very inefficient use of the concrete section is made. Also, concrete though strong in compression is weak in tension and is relatively brittle. Allowable deflections within the elastic range are small and once cracked, the concrete section is considered to have failed.

Prestressing provides more effective use of the concrete cross-section and allows the slab to work in both the elastic and plastic ranges. As a wheel load is applied to the slab, bending is created in the form of a dish with both radial and tangential moments. Initial cracking of the bottom of the slab occurs when the limit of the elastic deformation of the concrete is reached. A plastic hinge is formed at that point with no increase in positive moment. The loading can continue with increased radial moment until the negative radial moment equals the magnitude of the positive moment which caused the initial crack. Failure is considered to occur here. Vertical shear occurs with increased loading and the load punches through.

Of great importance is the fact that the initial cracking of the slab does not cause failure. Upon removal of the load, the prestress force closes the crack and the slab regains its rigidity. Of equal importance is the elastic action of the slab under load which allows it to utilize more of the supporting power of the subgrade and to spread the load over a wider area.

Previous test slabs made in Europe and this country have provided much valuable data on optimum values of prestress, subgrade friction, shrinkage, joint spacing and construction techniques. Most of these have utilized post-tensioned prestressing. For highway slabs, pretensioning is considered much more practical. With proper construction methods, it is much less expensive, it protects freshly placed concrete from cracking, minimizes warping at the ends of sections and allows the use of a thinner section with adequate coverage.

Tests have shown that the optimum level of prestress appears to be between 200 to 300 pounds per square inch over the pavement cross-section. Very little increase in load carrying capabilities occurs above 300 psi.

PROPOSED CONSTRUCTION PROCEDURE

The typical details included with this report show the proposed construction. The following brief description of the major components explains the use of each during the construction procedure.

Subgrade & Base: The subgrade and gravel base is to be prepared essentially as for conventional paving. (Ultimately it is expected that a much less rigid base course will be satisfactory for prestressed pavements).

Jackheads: The heart of this system is the patented jackhead wich provides resistance to the prestressing forces. This has been especially designed to withstand the tension in the cables and to be relatively easy to construct. The trench and throat are dug with a small back hoe. The reinforcing, forms and cable conduits are placed and the jackhead is poured.

If horizontal curves are involved, jackheads to resist lateral forces of the cables around the curves are installed. Subgrade slabs are installed beneath each joint located between jackheads.

Side Forms, Sand & Base Covering: Side forms are installed for the paving and a 1" layer of sand is placed and leveled over the base. Two layers of 2 mil thickness polyethylene film is to be spread over the sand with several additional layers over each joint support block. The polyethylene is necessary to minimize subgrade friction to allow sliding which is essential if effective prestress is to be developed in central portions of the slab between joints.

Bar Chairs: Continuous bar chairs with plates are to be placed as required on the base to support the cable at the proper height.

Cables: Cables are threaded through the conduits of the end jackhead and pulled to and threaded through each succeeding jackhead to the end of the section being constructed.

Tensioning: Cables are tensioned using hydraulic jacks to the exact desired prestress and secured with cable chucks. Cables can then be pulled back to the next jackhead without cutting cables. If necessary to splice cables, splicing chucks are used. For curves, partial tension is provided by the main jackheads and the balance is provided by pulling the cable groups into position laterally using the transverse jackheads at approximately 100' spacing along the curve. Steel mesh reinforcing is installed at joints to minimize the possibility of cracking where some slipping of the cut cables may occur.

Cable Supports: Bar chairs are repositioned and cables tied to each chair for safety and to prevent movement of the chair during concrete placement. In vertical or horizontal curves where cables must be held down to the proper position, hold down anchors are installed.

Concreting: Concrete is poured using conventional equipment and methods. Expansion joint assemblies are placed at the designated locations and the slab finished in the normal manner. Standard curing procedures are to be used.

Joint Sawing: After sufficient curing, the first cut at each joint is to be made to a point just above the cables. When test cylinders indicate the concrete has achieved its required compressive strength, the second cut through the cables is made using two saws working from the outside of the slab to minimize unequal stresses. No longitudinal center joint is contemplated at this time.

Expansion Joints: When the concrete has completed its curing, expansion joint plates are installed and those joints requiring only a poured joint filler are filled.

ADVANTAGES

Some of the basic advantages provided by this proposed system of pretensioned prestressed highway slabs are as follows:

1. More economy of materials in that a 4" slab will have superior load carrying capacity than the conventional 9" slab.

2. Fewer joints with resultant decrease in joint maintenance costs and better riding qualities.

3. Longer life due to capablility to withstand greater loads without cracking or with crack being tightly closed when load is removed.

4. Suitability for use over shifting subgrades or lighter base courses without damage.

5. Suitability for use with conventional equipment and methods with only minor modifications.

COST COMPARISONS

Cost comparisons have been made between the proposed 4" thickness prestressed test section 5200' long and a conventional 9" slab for the same distance. As with any new procedure or experimental section, the cost of the first one installed is understandably greater than is expected of future sections. Inherently, the use of a 4" slab and wide joint spacing provides considerable savings in concrete and joint sawing and filling. This is believed to be more than sufficient to offset the added materials and labor required for the prestressed slab once construction techniques have been refined. Comparative costs are shown in Appendix I.

CONCLUSIONS

The following conclusions have been drawn from the study of the proposed method of prestressed paving construction and from other technical bulletins and articles on this subject.

1. Prestressed concrete highway paving offers much promise for better quality more maintenance free highways provided that practical problems of construction can be solved.

2. The proposed method provides a practical solution to the major problems of:

   A. End anchorage for pretensioning
   B. Expansion joints
   C. Vertical and horizontal curves
   D. Use of conventional equipment and methods

3. Full evaluation of this method and of prestressed paving can only be accomplished by a well planned full scale test section approximately one mile in length.

4. This test section should best be located in the Metropolitan area where it will receive heavy usage and where it can conveniently and constantly be checked by the Highway Department and other interested parties.

5. A detailed set of plans and specifications together with additional design data can be prepared only after an exact location with grade, alignment and other construction information is established. This section should preferably be in a project already under contract.

6. A test program should be outlined utilizing the suggestions contained in the Highway Research Board Special Report 78.

7. The construction work can best be carried out by change order to an existing contract under the construction supervision of the Highway Department with technical assistance of Carl Hutchings and our firm.

APPENDIX I.

COST COMPARISONS

4" Prestressed Concrete Test Paving (5200' Section)

4" Paving	13,900 sq.yd. @ $3.00 - - - - - - - - -	$ 41,700
Mesh Reinf.	400 sq.yd. @ $0.40 - - - - - - - - -	160
Prestressing Cables - Installed	- - - - - - - - - -	8,000
Jackheads	4 Units - - - - - - - - - - - - - - -	5,500
Joint Support Slabs	- - - - - - - - - - - - - - - - - -	1,410
Steel Expansion Joints	- - - - - - - - - - - - - - - -	13,080
Joint Sawing	- -	90
1" Joint Sealing	- - - - - - - - - - - - - - - - - - -	60
1" Sand Bed	- -	700
Polyethylene (2 layers)	- - - - - - - - - - - - - - -	1,750
		72,450
	+ 15% Engineering & Contingencies - - -	1,086
		$ 73,536

Conventional 9" Reinforced Paving (5200' Section)

13,900 Sq.yd.	Paving @$3.90/sy - - - - - - - - - -	$ 54,210
13,900 Sq.yd.	Reinforcing, mesh & Dowel Assemblies @$1.05/sy - - - - - - - - -	14,595
		68,805
	+ 15% Engineering & Contingencies - - -	1,032
		$ 69,837

Normal Paving Comparison of Costs

	9" Concrete Paving	4" Prestressed Paving
Paving - - - - - - - - - - - - - - -	$ 3.90	$2.50 to $2.75
Reinforcing and Joints - - - - - -	1.05	1.50 to 1.75
	$ 4.95/sy.	$4.00 to $4.50/sy.