Example of Pavement Design for a Railroad Intermodal Terminal

John B. Heagler
Department of Civil Engineering, University of Missouri—Rolla
Rolla, Missouri

The design of a pavement for the Birmingham, Alabama, intermodal transfer facility of the Burlington Northern Railway is described. The work was performed in cooperation with the engineering staff of the Springfield region of the Burlington Northern.

The geometry of the layout was established by the Burlington Northern engineering staff. In general it consisted of two parallel roadways 70 ft wide, 3,000± ft long separated by a 60-ft median strip of crushed limestone with drains to remove surface water from the site. The slabs were designed with a 2 percent cross slope to enhance movement of water off the slab to the drains in the median strip. Each slab had one edge at the end of tie at the working track it was to serve.

The physical design parameters associated with the expected maximum loading of the pavement by the operating side loader, the tire pressure, and the wheel configurations are given in the Appendix.

In the initial stages of design a field investigation of the site for the proposed intermodal yard was carried out with the Burlington Northern engineer responsible for the project. The site was an old yard area with years of accumulated miscellaneous fill, cinders, demolition materials, and so forth. In general, the area was considered poorly drained and subject to periodic flooding during periods of extreme rainfall.

Because the material at the site was of such variable nature, test pits were excavated to examine the soil profile and to determine the character of the soil that would constitute the subgrade material. Soil samples from each test pit were obtained and soil tests were ordered on both selected samples and a composite sample of the material. Standard plate bearing tests were not requested due to lack of uniformity of the subgrade and time constraints imposed on the project. The results of the tests indicated that, in general, the subgrade consisted of a silty clay soil of medium to low plasticity. California bearing ratio (CBR) tests resulted in a saturated value of 2 and at optimum moisture a value of 5.

From charts correlating CBR with plate bearing values a k of 100 pci was selected and was believed to be on the safe side. This was especially true because it was planned to overlay the subgrade with 4 in. of select, compacted, dense-graded base material that would increase the value of k. The base course was required to ensure uniformity of support for the pavement and to provide a good, uniform platform for the placement of concrete.

A tentative determination of the thickness requirement for full-depth asphalt pavement was made. This indicated that from 32 to 37 in. of asphalt on a subgrade compacted at least 12 in. below the bottom of the asphalt was required.

A working side loader was in operation on asphalt at a temporary facility in Memphis, Tennessee, where observation indicated that rutting was occurring in the asphalt surface while the unit was transferring load to the rail car. Also, the power steering system on the loader allows the operator to turn the steering unit while the system is at rest, providing high localized rotational shear stresses and tearing of the surface. It was thought that, with the high summer temperatures expected in the Birmingham area, plastic flow, rutting, and surface shearing would likely occur and limit the life of any asphalt pavement placed for this project. With these considerations in mind the decision was made to not use asphalt pavement for the project.

The design of a rigid pavement system was carried out using standard procedures. The magnitude of wheel loads expected to be operating on this project is much like those experienced on airport pavement under heavy wheel loads. With this similarity in mind, use of the Portland Cement Association (PCA) manual, "Design of Concrete Airport Pavement" (1), was extensive, and this work is referenced here in its entirety.

"Influence Charts for Concrete Pavement" (2) developed by Pickett and Ray are available in the aforementioned PCA publication and in "Principles of Pavement Design" (3). These influence charts were used to determine stresses for both interior and edge loading conditions. Values determined by this computation were checked directly with design charts for similar load conditions published in the PCA airport design manual. Stresses determined were then compared with values of ultimate flexural strength of the concrete available in the area to determine factors of safety and an estimation of the allowable repetitions of load.

The Pickett and Ray charts were used for determination of moments and stresses in the interior and at the edge of the pavement under consideration. The 100,000-lb., 90-psi tire imprint configuration was applied to a 15-in. slab. The stress in the concrete at the interior of the slab was determined to be 415 psi and at the edge of the slab 716 psi. The factor of safety for the interior stress is therefore 1.68 for 28-day, 700-psi flexural strength concrete. Increasing the flexural strength by 12 percent to account for long-term strength increase gives a factor of safety of 1.88. The edge stress of 716 psi is obviously not an acceptable stress even for the occasional load at this location. The PCA design manual recommends a 20 percent increase in thickness at the edges to handle high edge stresses. Based on this, a trial analysis was made with 18-in. edge thickness. The computed edge stress for this thickness was 520 psi, which gives a 28-day flexural strength of 1.35 and a long-term strength value of 1.51.

As previously noted, the geometry of the pavement layout places one continuous edge at the end of tie. When the side loader is operating under full load with rail cars occupying the track, it will be virtually impossible for the wheel of the loader to occupy the edge of the pavement. Therefore it was decided that the 18-in. thickened edge was adequate. The final cross section of the 70-ft-wide paved area consisted of three slabs, 24, 22, and 24 ft wide with the outside slabs 18 in. thick to a width of 6 ft tapering to 15 in. thick in the next 4 ft.

Load transfer at both longitudinal and transverse joints is extremely important to prevent such discontinuities in the slab from acting as free edges. Tie bars to hold the slabs together and maintain load transfer through the longitudinal joint were installed. These were 7/8-in. deformed bars, 33 in. long at 24-in. spacing. This provided 0.3 in.^{2} of steel per foot of slab. Dowel bars were used for load transfer at all transverse joints. Dowel bar analysis was performed using a modification of standard procedures to determine load distribution from the wheel loads to the dowel bars. Because of the width of the tire, it was believed that more equivalent dowel bars would be more effective in transferring stress than standard procedures indicated. Also, due to the length of the tire imprint, the wheel would be partly transferring load across the joint by the time the centroid of the load approached the joint. Analysis of the stress in the slab at the joint indicated that 30 percent load transfer through the joints by the dowel bars would be adequate.

The dowel bars selected were 1 1/4 in. in diameter, 25 in. long, smooth bars at 14-in. center-to-center spacing, the first dowel to be placed 7 in. from the edge. Both the tie bar and the dowel bar dimensions and spacing recommended are in close agreement with that which can be selected from appropriate design charts in the PCA manual.

The last element in the design considerations was to evaluate the need for temperature reinforcement in the slab. The slab length selected was 25 ft, which is quite short and implies that the concrete tensile stress due to slab movement relative to the base material will be quite low. However, due to continued concern for the integrity of load transfer across any crack that might form, it was thought that caution dictated the use of at least some mesh to ensure aggregate interlock would be effective in transferring load. A 66-33 welded wire fabric was selected to give 0.093 in.^{2} per foot of reinforcement where analysis indicated that 0.065 in.^{2} per foot would be adequate.

At this point the design of the slabs to carry the imposed loads is essentially completed. Assumptions about the strength of the concrete and subgrade that must be obtained in the field have been made. Careful control of subgrade and base course compaction is essential because the slab support is dependent on these components of the pavement. Concrete strengths that must be obtained through careful supervision have been assumed in the design. Field inspection by competent personnel must be accomplished throughout the entire project.

Because this is the first installation, some slight modifications have been included in other designs, but, as a whole, the procedures used and the results obtained appear to be completely satisfactory.

REFERENCES

1. Design of Concrete Airport Pavement. Portland Cement Association, Skokie, Ill., 1973.
2. G. Pickett and G.K. Ray. Influence Charts for Concrete Pavement. ASCE Transactions, Vol. 116, No. 49, 1951.
3. E.J. Yoder and W.W. Witczak. Principles of Pavement Design, 2nd ed. John Wiley and Sons, New York, 1975.

APPENDIX--DESIGN PARAMETERS AND DEFINITIONS

Vehicle

Single axle load when fully loaded = 200,000 lb maximum
Single front wheel load = 100,000 lb
Wheel spacing (front axle) = 10.0 ft
Tire tread width (front wheels) = 30 in.
Rear (steering unit) wheels maximum axle load = 43,000 lb
Wheel spacing (rear axle) center to center = 30 in.
Tire tread width (rear wheels) = 20 in.
p = tire pressure = 90 psi
A = area of tire contact = 100,000 lb/90 psi = 1,111.1 in.^{2}
L = length of tire imprint = 43.47 in.
W = width of tire imprint = 30 in. (tire width)

Material

k = subgrade modulus = 100 pci
E_c = modulus of elasticity of concrete = 4×10^6 psi
μ = Poisson's ratio = 0.15
f_r = modulus of rupture of concrete = 700 psi at 28 days
f_s = allowable stress dowel bar intermediate grade steel = 27,000 psi
f_s = allowable stress cold drawn wire = 43,000 psi