Research Studies in Connection With Design Features of the Florida Turnpike

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• THE 110-MILE, 4-lane, limited-access Florida Turnpike from Miami to Fort Pierce was opened to traffic January 25, 1957. In the design of this facility a number of problems arose which were solved only after extensive studies and investigation.

The purpose of this paper is to outline a number of the major problems involved, describe their peculiarity and to record studies, experimentation, and analysis on which recommendations were based for policy determination of the Florida Turnpike Authority.

LIMEROCK IN CONSTRUCTION OF THE TURNPIKE

The existence of a thick layer of oolitic limerock at shallow depths beneath the ground surface in the general vicinity of the south 35 miles of the Florida Turnpike contributed greatly to the low cost of building the south 60 miles of this highway.

This limerock is referred to in south Florida as Miami limerock and has long been extensively used as an aggregate for concrete in structure and pavement mixes, both asphaltic and concrete, as well as for flexible pavement base construction. It produces an excellent pavement base with several qualities peculiar to itself.

Its most outstanding quality is the great ease with which it can be processed into a base of uniform density and accurate surface contour. In natural state and shallow depths averaging 4 to 6 ft below surface, a systematic stripping operation is practical. The limerock varies considerably in its stratification and is normally removed only to economic depths by dragline after suitable fragmentation. The top surface is sometimes irregular and requires care in clean production to avoid mixing with the overlying sand, which is quite similar in color and general appearance to the finer fragments of the rock. As the water table is quite high in the area, much of the rock is removed from below water and is left in windrows to drain before further processing.

The specifications used for pavement base course on the Florida Turnpike required that, "The material shall be crushed or broken up to such size, before being placed on the road, that not less than 97 percent will pass a 3½-in. sieve and it shall be graded uniformly down to dust. All fine material shall consist entirely of dust of fracture." This meant the windrowed limerock must pass through some type of primary crusher, after which it is loaded and hauled by truck to the subgrade.

Florida Turnpike base was 8 in. deep and laid in two 4-in. layers. The standard procedure was to spread the material as it came from the quarries with a Jersey type spreader, although some dozer spreading was also done, to an initial 4-in. depth. The incoming loads were brought in over the previously placed rock to give greater compaction to the bottom 4-in. layer which was then bladed to approximate true cross-section and graded and tested to see that 95 percent of modified Proctor density had been obtained. Additional compaction was required prior to placing the top 4-in. layer if the density was deficient.

The specifications required that the top layer be placed not more than one day after placing the bottom layer. The top layer was spread in the same manner as the bottom, after which it was scarified to a depth slightly penetrating the first layer but only deep enough to develop a bond between the two layers. The next step was blading to obtain uniformity of moisture and gradation. Usually it was necessary to use water to bring the rock up to its optimum moisture content of around 12 percent, although following heavy rains a drying process was required. This particular material breaks up to an unusual degree under scarification and blading, and it develops a heavy top layer of fines which, when wet, roll up into an ideal surface mortar of natural limerock fines. This mortar roll then can be spread uniformly over the cross-section by skilled blade operators to create a surface of unusual uniformity of texture and accuracy of section contour. Grades, elevation-wise, cannot possibly be achieved to the same degree of accuracy where the bladework is necessary, as is possible where forms are set to exact grade as in concrete pavement. However, the Miami limerock can be placed to a remarkable degree of accuracy and, in surface appearance, is so similar to concrete that close examination is needed to detect a difference.

After the top surface has finally been completed and 95 percent density developed, the final step is surface priming with asphalt prior to spreading the 2½-in. thickness of plant-mixed asphaltic-concrete binder and wearing-surface courses. The exact time for application of this primer is mainly dependent on weather conditions.

The base requires a certain period to harden, similar to the setting of concrete. In dry weather, this period is shorter than in wet periods and averages around three days. Before priming and the curing period, it is sometimes desirable to "hard-plane" the surface. This consists of a light surface scraping operation performed with the blade set at a heavy back slope to remove a surface glaze which develops in the material and, unless removed, acts as a barrier to good prime penetration. If, however, the contractor has elected to use what is referred to as the "squeegee" method of surface finishing, then the hard-planing may be dispensed with since the squeegee method leaves a relatively open-surface texture which takes the prime favorably. In the squeegee process, water is sprinkled on the otherwise perfectly finished surface developing an extremely thin and watery slush or limerock paste on the surface. While this surface slush is still present, laborers rapidly push 5-ft rubber squeegees longitudinally along the roadway to cover the entire cross-section at least once.

In the construction of the project, valuable experience and information was gained in the use of this limerock material. The standard Road Department specifications used on the project stipulated that carbonates of calcium and magnesium should constitute 70 to 85 percent of the total content. No particular division of these two carbonates was required. Oxides of iron and aluminum should not exceed 2 percent.

In a section of the turnpike the use of Belle Glade rock, fully meeting all of the requirements of the specifications, proved to present problems not found in the same degree in the Miami limestone. Unseasonal rains during the construction period introduced conditions resulting in the breakdown of sections of pavement. Repairs, with extreme precaution taken in sealing against water, corrected the situation. The lack of any trouble with the Miami limerock proved its superior durability under the inclement weather conditions.

After the failures experienced, chemical tests were made of samples of the Belle Glade rock taken from the failure areas as well as of the Miami limerock. These tests indicated a much higher magnesium carbonate content for Belle Glade than for Miami, 4.7 percent and 0.0 percent, respectively. Since magnesium carbonate is recognized to be a deliquescent material, it is thought that this characteristic of Belle Glade rock contributed to the failure. The accepted conclusion was that specifications should be more restrictive, with the result that the revised

State Road specifications now provide that, "The material shall have a liquid limit not greater than 35 and a plasticity index not greater than 6."

EROSION CONTROL — RESEARCH ON GRASS TYPES

The fine, sandy material available for embankment construction was extremely poor soil for vegetation growth and provided little resistance to erosion under the heavy rainfalls prevalent in the area. Experiments were conducted on 1B grass test plots, working with consulting agronomists.

In the choice of seed, Pensacola Bahia (scarified) not more than one year old was favored. Applied at the rate of 50 lb per acre, it provided the best root system and proved to be the hardiest and the most drought-resistant. Its main disadvantage was its slow germination. The fastest recorded was 2 weeks and, under unfavorable conditions, germination was delayed up to 12 weeks. Common Bahia proved also to be a good seed but not equal to Pensacola.

For second choice, freshly harvested Bermuda was selected, using about 40 lb per acre. Bahia and Bermuda mixed were used in a proportion of 35 lb of Bahia to 20 lb of Bermuda.

Rye is probably of no real value insofar as erosion control is concerned. It was of little value as a nurse crop, and the fertilizer spread for its development could better be used for the more permanent grasses. With no particular advantage in the summer, it provides only color in the winter months.

Pangola Torpedo and Para are considered undesirable, the principal objection to Pangola being its susceptibility to October Aphid plant disease.

In the selection of fertilizer, a difference of opinion arose. It is generally accepted that soil analysis is desirable to determine such factors as acidity, water retention, and chemical content. Depending on these analyses, the type and amount of fertilizer was determined for various areas.

Generally, an application of 400 lb per acre of 8-8-8 fertilizer on initial seeding followed by 150 lb per acre every 60 days thereafter was found satisfactory. Since the turnpike has been in operation, there has been an unusually favorable amount of rainfall for grass growth. Coupled with frequent cutting, the grass development has been very satisfactory. For periods of less favorable rainfall, changes in seeding and fertilizing methods may be found necessary.

One of the surprising observations made in the experiments conducted was the acceleration of rapid grass growth by "cutting in" green Bermuda cuttings. Freshly mowed green Bermuda grass was substituted as a mulch in place of dried hay or straw. Applied at a rate of 3 tons per acre, the mulching was immediately cut in to a depth of about 3 in. Fertilizer and seed were then applied and lightly rolled. Placing the cuttings and seeding within 24 hours after field cutting the green Bermuda grass and with favorable rains, the period required to produce a good start in growth was reduced from about 20 to 10 days. Grass growth using green Bermuda mulch was so consistently successful under favorable moisture conditions that it would be economically justified to provide for watering under drought conditions.

Prevalence of muck and marl in certain areas permitted sweetening of the surface layer of soil, mixing it with the muck where no amount of seed, mulch and fertilizer would produce acceptable grass growth.

FINE SAND MATERIAL

With respect to design problems encountered in fine sandy materials, one is both notable and unusual. It had been determined from past experience that precast-concrete pipe joints cannot be mortared up to complete sealed water tightness. Furthermore, any settlement in these pipes that might (and frequently does) occur would tend to fracture joints, leaving small but very dangerous cracks. The fine uniform-sized grains of sand (sugar sand) become free-flowing, particularly when saturated. As a result, sand seepage through pipe cracks had, on occasion, severely undermined pavement areas causing failures.

Several alternate methods of construction were considered to correct this problem. The use of rubber-gasketed joints was rejected because of the high cost of gasket material and lack of experience proving the durability of this material. Concrete box culverts, as small as 3 ft by 3 ft, were adopted because no unfavorable experiences had been encountered with this type of construction. Since contractors had forms for State Road standard boxes and these standards had been adopted by the Turnpike Authority, the cost of these boxes apparently would be only slightly more than concrete culvert pipes. This was later borne out when bids were received and prices for box culvert concrete and reinforcing steel were unusually low.

WIND TESTS ON SIGNS

Through the initiative and sponsorship of the Reynolds Metals Company and in cooperation with the Florida State Turnpike Authority, wind load tests were run by the Housing Research Laboratory Hurricane Test Center of the University of Miami. The purpose of the tests was to determine the behavior of signs with different types of support subjected to variable wind intensities. Since the turnpike is in an area subject at times to hurricane winds, the tests assumed a degree of importance. With only a limited amount of testing time available and the testing equipment consisting of a stand-mounted surplus aircraft engine of 1200 horsepower, it was decided to test a 4-ft by 4-ft sign face made of 1/8 in. thick aluminum sheet alloy 6061-T6. The posts tested were 4-in. I, 4-in. H and 3-in. I, all alloy 6063-T6. The sign face was fastened to each post with four $\frac{5}{16}$- by 1-in. 2024-T4 aluminum bolts secured with an elastic stop nut. Base restraint was accomplished by portable concrete cylinders, 23 in. in diameter and 14 in. deep, clamped to the floor.

Tests were made with single 4-in. I and 4-in. H-posts and double 3-in. I and 4-in. I-mountings. Mounting heights from top of base to bottom of sign were 54 in. and 72 in. Signs were rotated with respect to the axis of the wind pressure. Strain gages were attached to the posts just above the concrete support and oriented so as to measure stress in bending and torsion.

The single 4-in. I-beam did not possess the required strength to support the sheet sign at either the 72 in. or 54 in. height. With wind velocity at approximately 40 mph, the sign assembly would develop a resonant vibration and begin a severe oscillation, with the sign face twisting as much as 40 deg from normal, coupled with the top of the supporting column swaying about 10 in. from side to side. Subjected to three or four minutes under these conditions, the flange on the supporting beam would crack. As the recommended distance for eye level visibility of signs is 54 in. from bottom of sign to base, the 72-in. distance between base and sheet sign was only tested on a single 4-in. I-beam.

The single 4-in. H-beam provided a good support and showed low stress concentrations at the base. The angle of twist at 105 mph was not more than 10 deg from normal. The swaying motion was slight. A small flutter at each edge of the sheet sign resulting at high wind intensities indicated conditions approaching the fundamental frequency.

The double 4-in. I-beams support showed the lowest stress concentration at the base. Deflection and twisting under wind velocities of 105 mph was small, approximately only 3/4 in. This arrangement showed the best resistance to wind pressures.

The double 3-in. I-beam support was quite similar in behavior to the double 4-in. I-beam, although the stress concentration at the base was somewhat higher.

A test was made with wind pressure applied on the rear of the sign in an attempt to break the bolts attaching the sign to the support. At wind velocities up to 105 mph, no bolts were broken.

Conclusions

The 4-in. H-beam proved to be the strongest of the single-beam supports tested with low stress concentration at the base at velocities up to 105 mph.

The single 4-in. I-beam would reach a critical point of resonant vibration between 40 and 50 mph wind velocity and would fail after a few minutes under these conditions.

The double standard using 3-in. and 4-in. I-beams provides better support for the signs than the single standard, as the double standard reduces the flutter at the corners of the sheet signs. If flutter is not considered objectionable, the single 4-in. H-beam is the preferred support.

No mounting bolts were broken in any of the tests.

LOCATION OF SERVICE AREA IN MEDIAN

The location of service areas in the median between opposing traffic lanes represents a departure from the previous concept of turnpike service area design. Accepted practice dictated a location on the righthand side of either roadway, serving traffic only in the one direction. Serving traffic in only one direction requires double capital investment and double operating costs that are economically justified only on roads carrying large traffic volumes. On the Florida Turnpike, volumes of traffic were such that recommendation was made to place the service areas in the median strip, separating roadways to provide sufficient area. Several disadvantages of the median location were recognized and an effort made to minimize these objections.

The major question involved the left-turning movement from the high-speed inner or left lane of approaching traffic. Unquestionably, the reduction of speed and particularly a sudden change of mind by the patron, accompanied by an attempt to re-enter the left high-speed lane near the gore of the service entry road at relatively slow speed, could prove to be extremely hazardous. To overcome this disadvantage, the design provided for a full width deceleration lane contiguous with the inner lane for a minimum distance of 800 ft extending back from the gore. The ramp alignment from the gore into the service area is arranged to permit a reduction in speed of 40 to 45 mph opposite the gore to 15 to 20 mph through the service station and parking area. Leaving the service area, a full length acceleration lane is contiguous to the inner or left main traffic lane.

The curvature of the main roadway around the service area affords good rear-view mirror visibility. Large roadside signs are provided at points 2 miles, 1 mile, ¾ mile and ½ mile ahead of the gore directing service area traffic to the inside lane. This affords the patron full opportunity to comprehend the approaching diversion with enough time to make any necessary weaving movement. Following the point of full width deceleration lane, a sign bridge is erected over the entire 36-ft width of roadway. Internally illuminated signs indicate the lanes to follow for through traffic and the lane leading to the service area. At the gore there is a large sign directing decelerating lane traffic to the plaza ramp.

The condition created for traffic movements under this arrangement is no different from that found on many urban expressway layouts. With the construction of multiple-lane expressways, traffic habits have been changed wherein passing on the right is almost as common as passing on the left. Weaving of vehicles for lane changing on expressways has introduced traffic movements on such expressways which are quite similar to movements with left turnoffs into service areas.

Operating experience to date has shown no major deficiences in the planning for safe traffic movements through the deceleration lanes. There have been no traffic accidents at these points from causes that are even remotely attributable to the basic objection to this type of movement.

Similar locations of service areas are found on the Kansas and Kentucky Turnpikes. That adoption of the center service has been justified from a traffic operating standpoint is shown by absences of traffic accidents on these other turnpikes.

The advantages of the center median plaza are largely in its favor. Initial costs for facilities were substantially reduced. Operating expenses are cut almost in half due to the opportunity to serve both lanes of traffic with one facility. This was reflected in the receipt of one of the highest food concessionaire commission bids on record. The facility provides a paved turn-around area for police, maintenance and administrative personnel. It is located so as to be readily visible to approaching traffic.

EFFECTED SAVING IN NAVIGATION REQUIREMENTS

The turnpike crosses the St. Lucie Canal, a waterway connecting Lake Okeechobee with the Atlantic Ocean. The original Federal permit, June 30, 1954, provided for a 90-ft horizontal and an 80-ft vertical clearance.

On March 8, 1955, an amending application prepared by the bridge division of the Florida State Road Department requested approval on a reduction on the vertical clearance from 80 ft to 55 ft. Only one protest was filed to this request. The Arundel Corporation, a large dredging concern, maintained a repair and overhaul base near Indiantown on the St. Lucie Canal upstream from the proposed bridge site. This location was only one of several regional bases located up and down the East Coast and in the West Indies. A check of their fleet of equipment revealed only two dredges would be unable to navigate through the limitations of a 55-ft vertical clearance. Both of these units would require a 70-ft clearance. Neither unit had ever put into the Indiantown base for overhaul, and it was uncertain that it would be desirable to do so at any time in the future.

On May 20, 1955, the Turnpike Authority and Arundel Corporation representatives met with the District Engineer, U. S. Corps of Engineers, at Jacksonville to reconcile the differences involved.

The dredging company advised that alterations to each dredge superstructure, to permit navigation through a 55-ft fixed vertical clearance, would involve a cost of $9,500.

As a result, the Turnpike Authority offered and the dredging company accepted an agreement in which the Turnpike Authority agreed to establish a reserve fund of $20,000. A sum of $10,000 would be paid the dredging company at the time each dredge in question made its first trip to the Indiantown repair yard. No payments would be made for subsequent trips. The dredging company withdrew its protest and the permit for the amended application was granted.

The Turnpike Authority estimated the saving in reducing the clearance effected a reduction in cost of $1,000,000.

LOCATION PROBLEMS

The matter of limited-access express roadway location entails many unusual and difficult problems. The selection and determination of the final alignment deals in many matters, both simple and complex, that tax the imagination of the engineer and require resourcefulness and broad understanding of unusual degree. In the construction of the Sunshine State Parkway, numerous instances, each measured in varying degrees, affected practically every station of the line.

Typical of these influences were the considerations that resulted in the abandonment of the initial alignment through the central and northern sections of Broward County and the selection of a completely new location. Before financing the project, agreement was reached with landowners in south Broward County, establishing an alignment generally following section or quarter-section lines to reduce major land severance. This did not include agreement with the Dania Seminole Indian Reservation.

In the square-mile section north of Broward Boulevard and west of Route 7 (US 441), the original alignment cut diagonally across in a northeasterly direction from the southwest corner. This property had been subdivided and was one of the choice remaining areas of major size close to Fort Lauderdale available for high type development. The owners protested of the severe damage that would be suffered and suggested continuation of the turnpike alignment along the westerly boundary in a northerly direction. Further to the northeast and after crossing Route 7, a section of relatively open land was crossed. Inconspicuously located in the center of this section was a group of pole-mounted radio antennae surrounding a modest transmitter building. Tropical Radio Corporation, owners of the installation, did not own the entire section but, in order to achieve reasonable alignment, it was concluded that a corner of their property would have to be taken and perhaps a few of of their mast poles relocated. When overtures were made to the radio company along these lines, a most formidable group including outstanding radio communications engineers from Bell, RCA and Tropical descended upon the Authority in a mass protest. The arguments included the fact that this was a receiving station for the Caribbean area, Central and South America. The driving of large trucks past the front of the installation across the directions from which signals were being received would cause interference in an intolerable degree, which would essentially require complete relocation of the facility at a cost of $1,000,000. The companies jointly owning the radio company indicated they would sue for recovery of such damages if the Turnpike Authority persisted in its plans. Although the outcome of such a suit would be uncertain, the Turnpike Authority knew it would be faced with substantial delays as a result of such suits being instituted.

Farther to the northeast, the alignment was located through the town of Oakland Park, a marginal class community, with a minimum of damage to property improvements. It developed that the town volunteer fire station (one truck, vintage 1920) would be on one side of the turnpike completely cut off from half of the town. Another grade separation on a secondary street adjacent to the fire station would be required at a cost of $100,000.

As a result of these and other less pertinent considerations, a line shift to the west was made and new aerial photography taken. This new line was located largely on open ground but discussions with the major property owner, south Florida's largest dairyman, indicated that this alignment would essentially preclude continuation of dairy operations on his two largest farms and damages would be claimed accordingly. As an alternate, however, this property owner suggested a third alignment, again somewhat more westerly, still crossing both major farms, but this time in a manner that would leave the remainder essentially intact and operable. As further inducement, four separate parcels of land owned by the dairyman were offered without cost to the Turnpike Authority. The value of these parcels was appraised at from $250,000 to $300,000. Consultation with the traffic engineers developed the fact that the loss of traffic revenue because of westerly relocation away from the population would be insignificant compared to the savings effected and capitulation was complete.