Using NDT to Reduce Traffic Delays in Concrete Paving

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Fast track paving has centered on the use of construction materials and methods to improve the rate of placement and curing to reduce the traffic delay time. The State of Iowa has been able to make large improvements in the fast track process to meet target traffic delay constraints through material selection and construction methods. At the same time the methods for monitoring concrete strength gain and quality have not changed. In 1995, Lee county and the Iowa DOT cooperated through research project, HR-380, to construct a 7.1 mile project to demonstrate the use of maturity and pulse velocity nondestructive testing methods to estimate concrete strength gain and reduce traffic delay. The results of that work identified the pros and cons of each method and suggested specifications to meet traffic delay demands. The results also identified examples of equipment that could easily be used by project personnel to estimate the concrete strength using the maturity methods. Key words: NDT, maturity, pulse velocity, concrete strength, traffic delay.

INTRODUCTION

Fast track paving is not new to Iowa. It originated here as a way to make concrete a viable paving alternative where traffic delays were a critical factor in the selection of pavement type. Prior to 1995, research efforts in this area had centered on the mix design, and curing methods employed to reduce traffic delay and provide a concrete pavement alternative. The time of opening to general and construction traffic was still related to flexural beam tests and time after paving. This meant that five to seven days were often required to meet the specification and allow for traffic use of the new pavement.

The Iowa Department of Transportation (IDOT) and Iowa State University, Civil and Construction Engineering (ISU/CCE) researchers had conducted various small projects to evaluate the use of nondestructive testing (NDT) devices on several projects in the early 1980's. The largest of these involved the placement of a bonded overlay of Iowa Highway 3 in Franklin County in 1994. The results of that work encouraged the Lee County Engineer to approach the researchers with a proposal to evaluate the use of pulse velocity and maturity concepts to estimate the flexural strength in the construction of 7.1 miles of X-28 (Great River Road) near Keokuk, Iowa.

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PROJECT GOALS

The research team of county, state and university representatives was able to identify the following six objectives for the research:

1. Development of a knowledge base for applying maturity and pulse velocity measurements to determine concrete strength for traffic opening.
2. Identification of effective and efficient monitoring equipment that could relate concrete strength gain to time and temperature measurements in the field.
3. Evaluation of maturity measurements at various pavement depths to understand the effect of the subgrade and temperature gradients on strength gain.
4. Identification of NDT equipment and methods for rapid employment by field staff to monitor concrete strength gain and determine traffic opening times.
5. Relate the early opening to visual pavement distresses found in the first two years of pavement operation.
6. Development of an instructional memorandum for use by field staff in the operation of NDT equipment for measuring pavement strength gain.

DATA COLLECTION

This project marked the first time that maturity base curve development occurred at the project site. A curve was developed at the Iowa DOT Central Laboratory in Ames, Iowa to act as a baseline set of information. It utilized project cements and aggregates from the construction site. On the first day of construction, in late September 1995, a truck load of concrete was selected at random from those supplying material to the paver. Test flexural beams were constructed from a portion of that load and one was instrumented with the maturity meter thermocouple. Beams were placed in a wet sand bed and monitored by the maturity meter. Individual beams were tested by center point loading over the first 24 hours of cure and related to maturity time-temperature factors. This data formed the basis for opening strength decisions for the remainder of the project. A similar test utilizing the pulse velocity meter and compressive cylinders was also carried out by the Southeast Iowa DOT Transportation Center Materials Laboratory.

The research team was able to utilize maturity measuring devices (recording and nonrecording) at 500 ft (152.4 m) intervals to determine field rates of strength gain along the pavement during construction. Tests were conducted with thermocouple wire attached to wood dowels inserted at various depths in the concrete. The maturity near the concrete surface (1 in., 25 mm) was used to identify the potential time for transverse joint development/sawing. Maturity at the midpavement depth (3.5 in., 90 mm) was used for make the decisions on pavement opening to traffic by local officials. Monitoring of each site was continued until the pavement estimated strength exceeded 500 psi (3.41 MPa) that required for opening to general traffic.

The maturity concept was employed on the mainline paving which consisted of a slipformed slab measuring 7 in. (180 mm) in depth and 22 ft (6.7 m) in width, on an existing granular base. Paved bikeway shoulders measuring 5.5 ft (1.7 m) in the urban area and 4.0 feet (1.2 m) in the rural areas were also monitored for strength gain using the maturity measuring devices.

Maturity data was collected by two persons. The first person stayed with the paving operation and installed the recording meters at the beginning and end of each day's placement. They also placed the thermocouples at the 500 ft (152.4 m) intervals for measurement with the handheld digital thermometers. The second person used the digital thermometers to both collect data from the current day installed thermocouples and those installed on previous days. Access was gained by the use of an all terrain vehicle on the new slab. This system proved to be the answer to working with a fast moving paving operation in a narrow right of way.

An elaborate system was developed by the research staff to gain access to the pavement for use of the pulse velocity geophones. This involved insertion of three sections of large metal tubing in the pavement, removal of the concrete in the tubes, removal of the tubes, measurement of the pulse velocity and filling of the holes with fresh concrete. This process did not prove to provide sufficient and accurate information for this type of operation and the process was discarded after the first day of paving.

SUPPLEMENTAL TEST RESULTS

In addition to the maturity and pulse velocity data, information on the relative humidity and ambient air temperature was collected with handheld devices on this project. The results of that data collection were inconclusive in regard to developing a relationship to maturity values.

Visual distress surveys were conducted at three times during a two year period to determine the potential impact of early pavement opening to general/construction traffic. Minor cracking was found in areas of the shoulder where the joint had not been formed in a timely manner. Longitudinal and corner/diagonal cracking were noted in isolated outer wheel path areas and is attributed to uneven settlement of the subgrade between the original roadway and the shoulder widening unit.

Deflection testing of joints at 0.2 mile (0.3 km) increments indicated joint transfer values of greater than 80% in all areas but three. These values are very good for nondoweled pavements such as the test pavement. Three low values found in shoulder widening areas of the subgrade may be the result of inconsistencies in the support across those longitudinal subgrade joints.

Midslab deflection testing resulted in the calculation of subgrade soil support "k" values of 97-225 psi which is representative of this soil type. These same measurements were used to backcalculate the thickness of the concrete. In all cases it indicated, as did the field measurements during construction, that 7 in. (305 mm) was constructed.

CONCLUSIONS

The research resulted in many advancements for the Iowa DOT, the concrete paving industry and the traveling public. They are summarized in terms of the original objectives of HR-380.

1. Information DataBase Development
   - a. Mainline and shoulder construction maturity data is now available for multiple days of construction on this project during one time of the construction year.
   - b. Data from other Iowa DOT Centers has provided the administration with knowledge of the implications of using maturity for new construction, pavement repair and reconstruction and development of an Instructional memorandum.
   - c. Data from the Lee County project was limited minimal changes in air temperature and humidity.
   - d. The Lee County project did emphasize the importance of curing methods during the first 24-48 hours after construction, on the rate of slab strength gain.
2. NDT Equipment Selection
   - a. Pulse Velocity is not recommended for use in pavement strength gain monitoring due to equipment/space needs, field construction limitations and operator training requirements.
   - b. Recording maturity meters should be applied for research purposes only due to their susceptibility to weather damage and theft.
   - c. Digital thermometers are very successful in the collection of maturity data by one person. They can be used with or without the application of special connectors to the thermocouple wire.
3. Maturity Depth and Location Measurements
   - a. Place thermocouple wires near the pavement surface to estimate strength relative to transverse joint development decisions.
   - b. Place thermocouple wires near the pavement middepth to estimate pavement strength relative to traffic opening decisions.
   - c. Thermocouple installation should be made at a location 1 ft (305 mm) from the pavement edge and along wood dowels inserted to the appropriate depth to aid in construction and traffic operation decisions.
4. Pavement Visual Distress Relationships
   - a. Transverse cracking in paved shoulders was attributed to not forming the joint early enough after paving.
   - b. Minor longitudinal and corner/diagonal cracking in the mainline pavement, outer wheelpath, was attributed to irregularities in the subgrade construction.
5. Maturity Instructional Memorandum Development
   - a. I.M.383 date October 28, 1997 includes the results of this research effort, Iowa DOT enhancements of early versions of the I.M. developed in 1995-1996 and comments solicited from field staff by the research team.
   - b. Development of maturity curves at the project site at the beginning of the project are recommended for project control. Validation curves at scheduled intervals or when any of the project materials changes, is recommended.

This project has resulted in the development of a new tool for Iowa in the search for meeting the public travel demands with proven materials and sound engineering.