CP ROAD MAP
shaping the future of **concrete pavement**

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ROAD MAP TRACK 5
Concrete Pavement Equipment Automation and Advancements

PRIMARY SOURCE
Improving Concrete Overlay Construction (Iowa Highway Research Board Project TR-600)
June 2010
James K. Cable, Cable Concrete Consultation

SECONDARY SOURCE
Stringless Portland Cement Concrete Paving
February 2004
James K. Cable, Cable Concrete Consultation

SPONSOR
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MORE INFORMATION
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Moving Advancements into Practice (MAP) Briefs describe promising technologies that can be used now to enhance concrete paving practices. MAP Brief 8-1 provides information relevant to Track 8 of the CP Road Map, Long-Life Concrete Pavements.

The Long-Term Plan for Concrete Pavement Research and Technology (CP Road Map) is a national research plan developed and jointly implemented by the concrete pavement stakeholder community. Publications and other support services are provided by the Operations Support Group and funded by TPF-5(185).

MAP Brief 8-1 is available at: http://www.cproadmap.org/publications/MAPbrief 8-1.pdf

"Moving Advancements into Practice"

MAP Brief 5-1:

Describing promising technologies that can be used now to enhance concrete paving practices

Stringless Concrete Paving

Introduction

Conventional concrete paving with a slipform paver requires the installation of a stringline and support posts adjacent to the roadway to establish the correct pavement alignment and profile. The stringline adds several additional feet (6 ft. +/-) of required clearance to the paving envelope, which is already wider than the pavement due to the tracks of the slipform paver.

In addition, the stringline becomes an obstacle for equipment, concrete delivery trucks, and finishing crews. If equipment access across the stringline is required, the stringline must be lowered and reset, resulting in delays and introducing the potential for errors.

Stringless paving is a technology that eliminates the installation and maintenance of stringlines and has the potential to decrease the need for surveying and increase the smoothness of the pavement profile. The benefits that can result from stringless paving include increased production, decreased construction time, and reduced potential for errors. (see Figure 1).

Several companies have developed stringless equipment control and guidance systems using technologies such as global positioning systems (GPS), robotic total stations, and laser positioning. Stringless technology replaces the traditional stringlines with an electronic tracking process that controls the horizontal and vertical operation of the slipform paver.

The construction industry has been using stringless technology for elevation and steering control of equipment for a number of years. To date, the extensive use of this technology has been applied to grading operations. However, stringless paving is an emerging technology for concrete paving because has the potential to allow contractors and owner/agencies to receive production benefits (e.g., reduced survey costs, fewer construction hours) while still meeting smoothness requirements.

Although stringless paving has not been used extensively, several projects have been completed in the United States in the past few years. The techniques and equipment used vary according to each project, but the general concepts and methods are the same.

The stringless paving methods described on the following 2 pages are specific to a research project (TR-600) conducted in Iowa in 2009. The final page of this document contains additional information about stringless paving research projects in Iowa.

Figure 1: Stringline (left) and stringless (right) pavers

STRINGLESS PAVING
for Concrete Overlay Over Asphalt
TR-600 Research Project

Developing stringless paving technology involves a three step process. The first step is collecting survey data of the existing surface (Figure 3) to develop and build a database. Step two is to design the roadway and create the proposed 3D computer model using the existing surface and proposed profile and cross sections. The third and final step (Figures 4 & 5) is to construct the proposed pavement by transferring the computer model to the paving machine, and utilizing a non-contact X,Y,Z guidance system.

Roadway Surface Mapping. In order to map the existing roadway surface, an all-terrain vehicle (ATV) was used, equipped with a laser profiler (Z coordinates) and GPS (X,Y coordinates) rover unit (Fig. 3). The utility vehicle was driven along the pavement at 5 mph, recording the existing pavement profile at 25-foot intervals along the pavement edges, wheel paths, lane quarter points, and centerline. It needs to be noted that GPS accuracy is good vertically to only one inch, so to obtain the proper accuracy in the Z coordinate, the ATV had to be augmented with a laser system. An alternate to the ATV is to survey the existing pavement with a total station. The data collected was used to produce a 3D plot of the pavement surface utilizing readily available CADD software. Data was streamed from both units to a central computer for storage using the Iowa real time network (RTN) system and its ability to correct for location and elevation.

The ground reference system should contain reference points with known X,Y,Z values, spaced approximately 250 feet apart and on alternating sides of the roadway. The Z value should be obtained through electronic three-wire leveling just in advance of the construction to verify the overlay design assumptions and assure that the final product will meet the designer and contractor requirements.

ATV with GPS and laser profiler

The data management method involved the use of a NMEA string that provided X,Y,Z coordinates of each point in latitude, longitude, and elevation. The data was then translated into state plane coordinates and elevation from sea level in feet by the ISU/GIS laboratory staff.

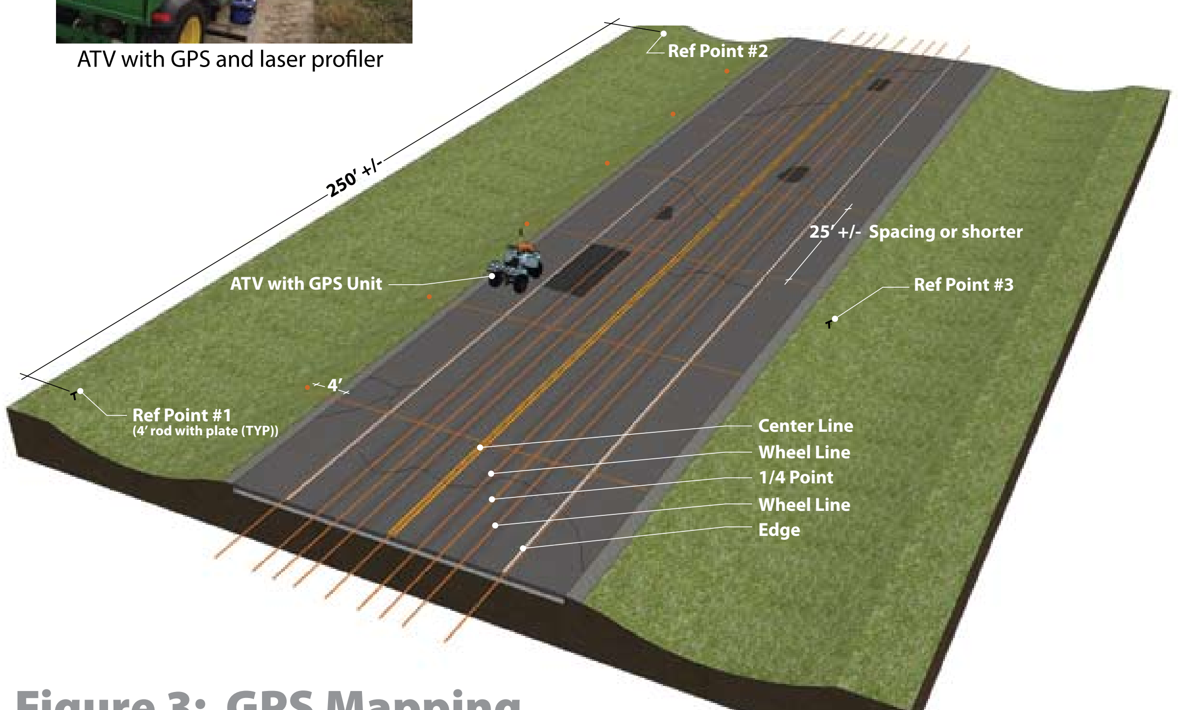

Figure 3: GPS Mapping of Existing Surface Pavement (x,y,z)

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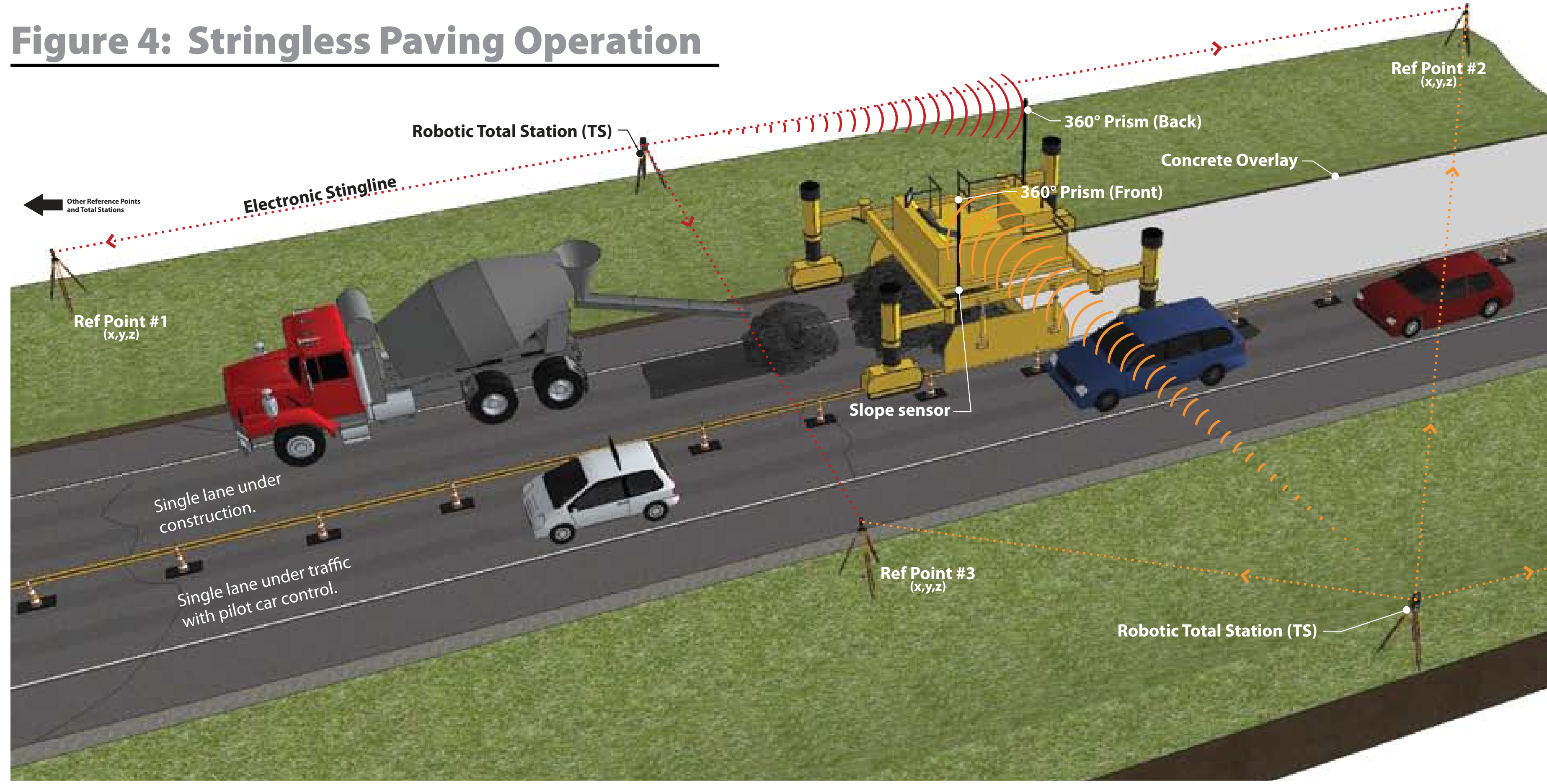
Figure 4: Stringless Paving Operation



Slipform Paver Machine Controls. The 3D model provided the design surface of the proposed overlay. The stringless paving method selected, utilized multiple robotic total stations with prisms mounted on the paving machine. Vertical control reference points were established earlier at 250-foot intervals on alternating sides of the roadway. This kept the paving equipment, crews, and terrain from interfering with the line of sight between the paving machine and reference control points. In order for the robotic total station to establish correct X,Y,Z coordinates, the station needed to have a triangulation system which required a clear line-of-sight to at least three reference points. The clear line-of-sight is sometimes referred to as an electronic stringline. Modifications to the paving machines are required to add electronic/hydraulic controls.

During stringless paving operation, two total stations continually provide independent coordinate information to the paving machine. Prisms mounted on the paving machine reflect signals back to the total stations, giving them it's X, Y, Z position. This information is then transmitted via radio signal from the total stations to the computer on the paving machine. The paving machine computer processes it's exact position in relation to a computer model of the new pavement. The onboard computer then adjusts the elevation of the machine on each of the four corners of the pan to achieve the correct pavement thickness, crossfall, and mainfall.

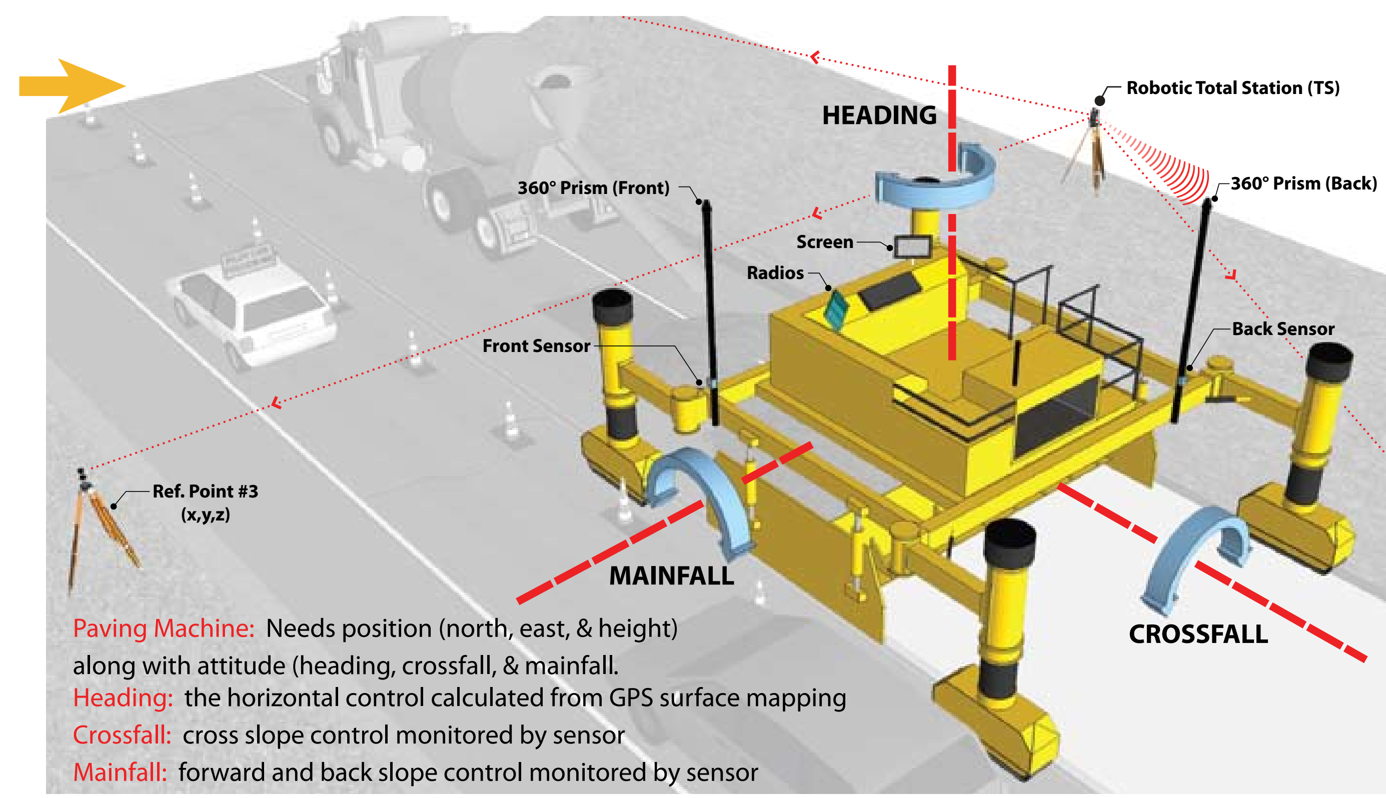


Figure 5: Paving Machine Control

Research Conducted

To examine the practicality of stringless paving with slipform pavers, the National Concrete Pavement Technology Center and the Federal Highway Administration (FHWA) completed field research in 2003 on two stringless paving projects in Washington County, Iowa. As part of these projects, a research team monitored the guidance and elevation conformance to the original pavement design. The evaluation included guidance from GPS and laser technology.

Due to the speed of paving and the rapid changes in terrain, the laser technology was abandoned for the projects. Total control of the guidance and elevation controls on the slipform paver were moved from stringline to GPS. The evaluation was a success, and the research team concluded that the GPS control proved to provide excellent x, y guidance for the slipform paver. However, GPS vertical control did not allow for smoothness incentives.

In 2009, the Iowa Highway Research Board and FHWA conducted research on four concrete overlay projects in Iowa to evaluate overlay construction techniques and methods. Due to improved stringless paving technology, this project included additional research that evaluated stringless paving on two of the four concrete overlay projects (US 65 in Worth County and V18 in Poweshiek County).

The goals of the 2009 research were to develop ways to establish profile grades and machine control before or immediately after contract letting, to evaluate machine control systems to minimize paving train widths, and to meet or exceed smoothness requirements.

Conclusions

The following sections describe the results of the 2009 research projects on stringless concrete paving in Iowa.

Roadway Surface Mapping

- The results of roadway mapping indicate that current "off-the-shelf" GPS technology does not provide adequate vertical (z) accuracy for mapping the pavement surface when measured with a rapidly moving device. Slow moving (<5mph) GPS data collection and other proprietary software and systems do have the potential for mapping the pavement surface with an (x, y) accuracy adequate for paving machine control.
- The vertical (z) coordinates of the existing surface can be obtained by laser augmentation on the same all-terrain utility vehicles that capture the GPS (x, y) coordinates. The alternative is to survey the surface with total stations.
- Profile mapping is possible with 3D computer software, such as AutoCAD and MicroStation, for the surface profiles of the existing road surface and the design model of the overlay surface. This information can be used to develop cross-sections, check minimum overlay depths, and calculate concrete quantities for theoretical yield purposes.

Slipform Paver Machine Control

- The stringless paving control system performed to expectations in line, grade, and cross-slope control to match the designer model for the surface of the finished pavement overlay on each of the two test projects.
- To meet the smoothness requirements for incentive pay, it is recommended that model and machine control elevations be developed in the 0.01-0.05 ft plus or minus range.
- Regardless of the brand, modern slipform pavers that have recent constant-flow hydraulic systems and up-to-date electronic controls can be outfitted with the stringless paving system used in this project from Leica, Inc.
- Success of the stringless system rests on the slipform paver controls and the ability to set very tight vertical control for the guidance system on the ground.
- The control system will replicate what the designer puts into the final surface model.
- The Leica system used in this research performed equally well on one- and two-lane paving situations. In one-lane situations, the outer edge is controlled by the model on the second pass, and the centerline of the first pass is "locked" to existing elevations of the first pass.
- Designer knowledge of the existing surface alignment and surface elevations is critical to development of the final design model.
- GPS- and GPS/laser-controlled slipform operations do exist but were not evaluated in this research due to the decisions made by contractors in control equipment selection.
- Sensor selection for the paving equipment should be left to the discretion of the contractor based on the tolerances established in the contract documents for the concrete depth and quantity.

For More Information

To find out more about stringless concrete paving implementation and demonstration projects, contact the National Concrete Pavement Technology Center, 515-294-8103, dfwagner@iastate.edu.