NATIONAL CONCRETE CONSORTIUM

www.cptechcenter.org/national-concrete-consortium

“Moving Advancements into Practice”

MAP Brief Spring 2021

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

Overview of Stringless Paving

Spring 2021

PROJECT TITLE
Overview of Stringless Paving

AUTHORS
Gabe Nelson
Snyder & Associates, Inc.

EDITOR
Sabrina Shields-Cook

SPONSORS
Technology Transfer Concrete Consortium TPF-5(437)

MORE INFORMATION
National Concrete Pavement Technology Center
515-294-8103
dfwagner@iastate.edu.

Ells T. Cackler
Woodland Consulting, Inc.
tcackler.wci@prairieinet.net

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 (see Figure 1).

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

Stringless paving is a technology that eliminates the installation and maintenance of stringlines (see Figure 2) and has the potential to decrease the need for construction staking and increase the smoothness of the pavement profile. The benefits that result from stringless paving include increased production, decreased construction time, and reduced potential for errors.

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

The construction industry has been using automated machine guidance technology for elevation and steering control of equipment for a number of years. Early on, the extensive use of this technology was applied to grading operations. However, stringless paving is now an established technology for concrete paving that allows contractors and owner/agencies to receive production benefits (e.g., reduced staking costs, fewer construction hours) while still meeting smoothness requirements.

Stringless paving technology is now widely used throughout the industry. The techniques and equipment used vary according to each project, but the general concepts and methods are the same.

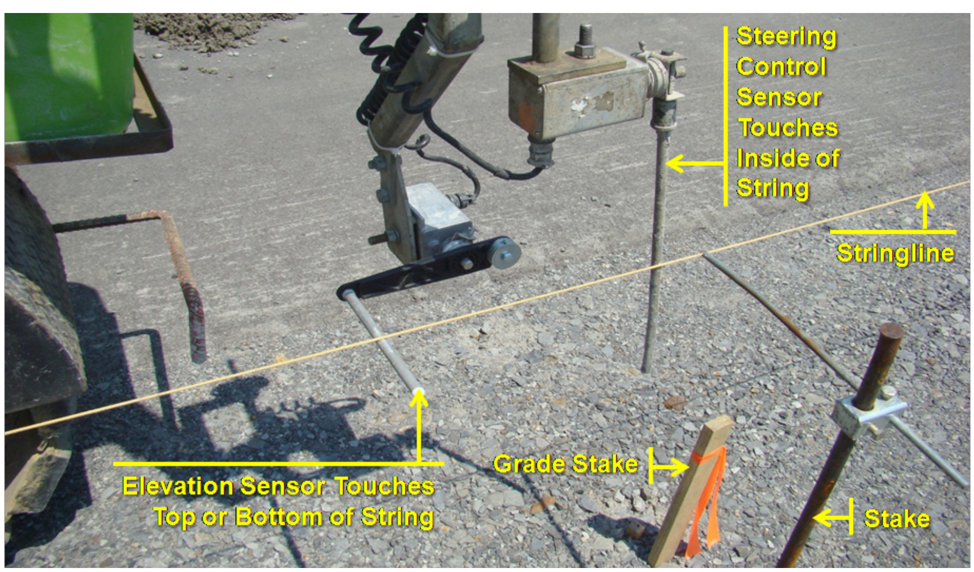

Figure 1. A traditional stringline setup. Graphic courtesy: American Concrete Pavement Association

Figure 2. A stringless paving setup. No strings means better access for paving crews. Photo courtesy: Snyder & Associates, Inc.

Stringless Paving for Concrete Pavements

Utilizing stringless paving involves a three-step process. The first step is collecting accurate survey data to develop the existing surface model. Step two is to design the roadway and create the proposed 3D model using the existing surface and proposed profile and cross sections. The third and final step is to construct the proposed pavement by transferring the computer model to the paving machine and utilizing an automated machine guidance system.

Accurate survey control and existing survey information are key to any successful digital construction site, but this is especially true when stringless paving is used. The surveyor should set accurate survey control at the beginning of pre-design survey that can be preserved through design and construction. The same survey control that is used for design should be used by the construction surveyors to set additional control that will be used for automated machine guidance such as stringless paving. The survey control is the link between the virtual construction site and the real world throughout the life of the project.

Designers can create 3D design models with digital information that is useful for stringless paving, such as proposed horizontal and vertical alignments and 3D breaklines. In order for the design information to be useful for paving contractors, the design profile must utilize the existing site survey information and contain all slope transitions. Since stringless paving guidance computers rely on exact elevations to control the paver, it is necessary for the 3D design models to tie into existing pavement exactly at surveyed elevations. Also, if models do not contain special case areas (median crossovers, slope transitions at intersections, etc.), contractors need to add information for those areas in the model before trimming and paving. In the case of concrete overlays, a proposed profile must be designed prior to paving (either by the engineer or contractor) that takes into account milling depths and specified thickness requirements.

Digital information must also be provided with a sufficient density to be useful for stringless paving. Once designers have created a 3D model of the proposed pavement, they can provide useful digital information such as horizontal and vertical alignments and 3D breaklines. Digital 3D breaklines should have spacing no greater than 5 feet in curves (horizontal or vertical) to achieve sufficient smoothness. Think of it as setting a pin for a stringline every 5 feet, only this is being done virtually (See Figure 3). A 3D breakline is necessary on each outside edge of the pour. One line is used as a reference line to control the position of the paver. The other line is used to control the slope of the paver. There may be a constant slope or crown that is controlled by the pan of the paver. If there are cross slope transitions such as in the case of a superelevated curve or a transition into an intersection, those transition locations are entered into the computer on the paving machine and adjusted based on the paver position along the reference line.

Contractors can utilize stringless paving without digital information from designers, but any digital information is helpful for contractors for bidding to verify quantities, calculate machine paving areas versus handwork, and reviewing staging. Contractors will typically review any digital information for accuracy versus the plans such as profile elevations, slope transitions, deleting crossing breaklines, and adding breaklines to accommodate paving operations that may not be in the model. Contractors also require run-ins and run-outs at the end of paving runs that are typically not contained within design models. Finally, contractors' construction surveyors must verify pavement tie-in elevations to ensure they match the model.

When the contractor is ready to pave, the construction surveyor will set additional control points to facilitate trimming and paving. The site control should contain control points with known northing (Y), easting (X), and elevation (Z) values, spaced approximately 500 feet apart, staggered on alternating sides of the roadway. The site control should tie back in to the original project survey control.

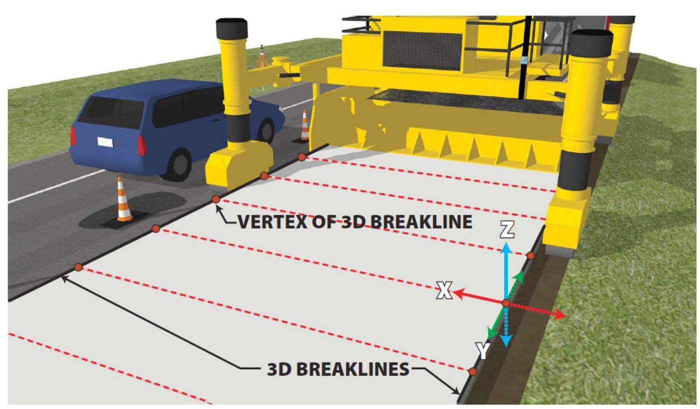

Figure 3. 3D breaklines with vertexes spaced no greater than 5-feet are necessary on each side of the paver. Graphic courtesy: Snyder & Associates, Inc.

In the case of concrete overlays, designers or contractors can use accurate survey data of the existing roadway pavement in order to optimize milling and pavement surface profiles to minimize milling requirements and material placement. Surveyors can use more traditional methods such as taking survey shots every 25’ along 9 lines along the existing roadway (edges, centerline, and wheel paths) (see Figure 4), but this method requires a surveyor to be in traffic. It is now more common to use terrestrial (stationary) or mobile (truck-mounted) LiDAR scanners to obtain highly accurate “point clouds” of the existing surface (see Figure 5). These surfaces are used by designers before bid or by contractors after bidding to create an optimized profile for construction. In the case of a concrete overlay, having an accurate 3D model of the existing pavement surface allows highly accurate quantity takeoffs of necessary milling and concrete quantities.

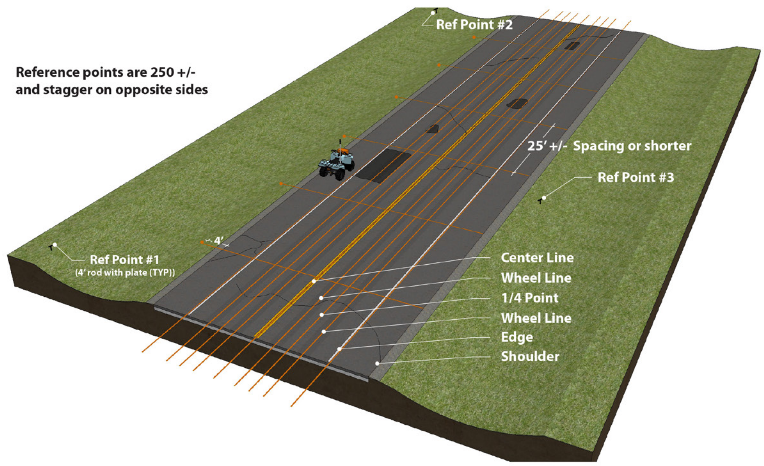

Figure 4. Nine-line profiles collected by total station

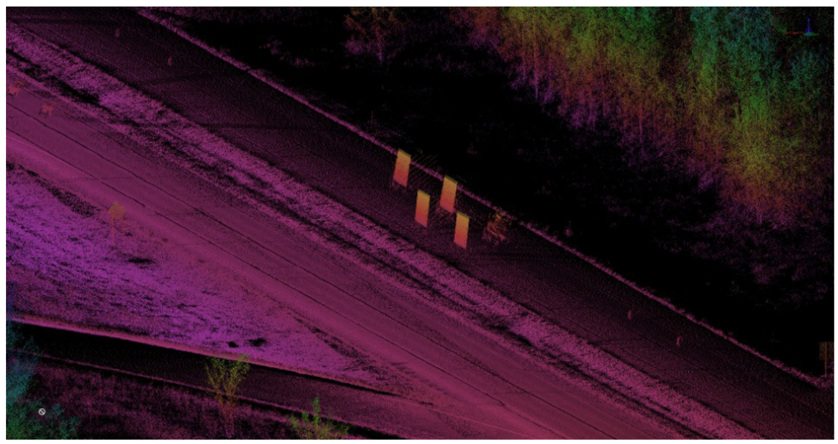

Figure 5. Point cloud data from a Mobile LiDAR scanner. Graphic courtesy: Iowa Department of Transportation

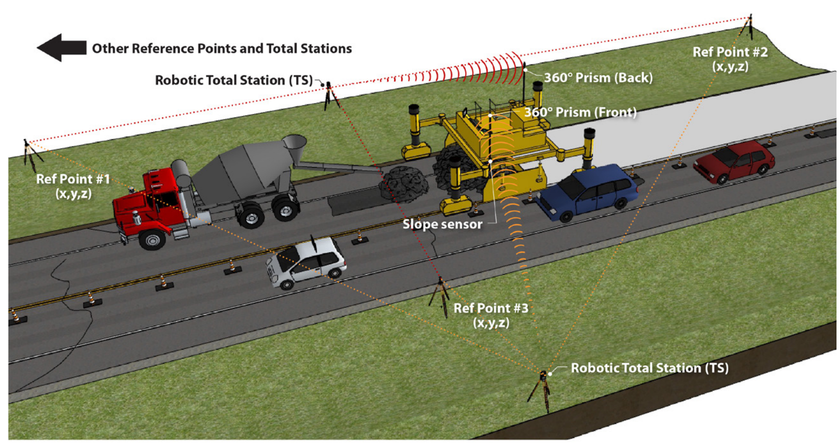

Figure 6. A typical stringless paving setup using robotic total stations. Graphic courtesy: Snyder & Associates, Inc.

There are two main guidance systems for concrete paving: total station guidance and laser augmented global positioning systems (GPS). For the total station system, two total stations continually provide independent coordinate information to the paving machine (see Figure 6). Prisms mounted on the paving machine reflect signals back to the total stations, giving them its X, Y, Z position (see Figure 7). This information is then transmitted from the total stations to the computer on the paving machine. The paving machine computer processes its 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 position, thickness, and cross slope.

In order to properly pave concrete pavement, the entire mold is regulated by determining the position (X, Y, Z) of the prisms in relation to the reference line and the attitude (heading, crossfall, and mainfall) (see Figure 8). The heading is calculated from the relative position of the paver from the reference line in the project model and the position history. The crossfall and mainfall are calculated from highly accurate, dual-axis slope sensors located near the prisms. Similarly, when GPS guidance systems are used, the prisms are replaced with special GPS sensors (see Figure 9). This guidance system uses GPS for the horizontal alignment of the paver. GPS by itself cannot achieve the vertical accuracies necessary for concrete paving. In order to achieve sufficient vertical accuracy, the system utilizes rotating lasers (see Figure 10) set on control points at known elevations to achieve the design elevations. The contractor should consider the site constraints (line of site from the control points, tree cover, etc.) in order to ensure the selected system is able to pave the project to the required specifications.

Figure 7. A total station pointing to a prism on the paving machine. Photo courtesy: Snyder & Associates, Inc.

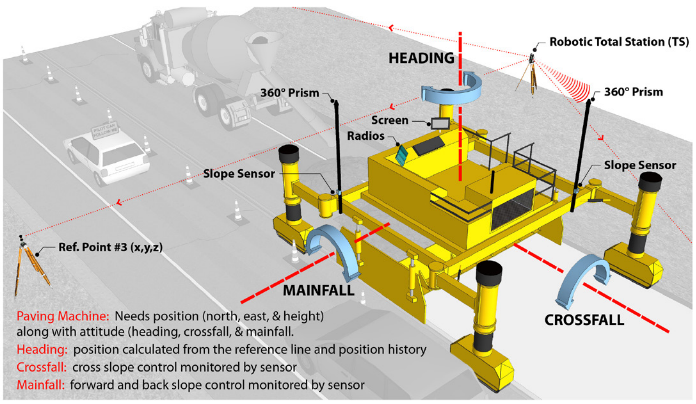

Figure 8. Stringless guidance system of a concrete paving machine. Graphic courtesy: Snyder & Associates, Inc.

Figure 9. A paving machine utilizing laser-augmented GPS. Photo courtesy: Snyder & Associates, Inc.

Figure 10. A rotating laser on a control point. Photo courtesy: Snyder & Associates, Inc.

Best Practices for Utilizing Stringless Paving

In summary, there are numerous benefits for owner agencies that allow stringless paving, including the following:

- Shorter construction timelines—contractors do not need to wait for construction surveyors to set paving hubs, do not need to wait for crews to set stringlines before trimming and paving, and have added flexibility to move to locations on the construction site that are ready for paving.
- Increased safety—there are no stringlines for crews and inspectors to trip over.
- Improved site access—no stringlines mean better access across the construction site.
- Optimization of quantities—stringless trimming and paving allows for greater control of concrete quantities, resulting in lower costs to owner agencies.
- Improved smoothness—stringless paving results in smoother pavements due to greater profile controls than what traditional stringlines allow.
- Owner agencies can successfully allow contractors to utilize stringless paving on full depth concrete paving and overlay projects. Agencies and contractors should follow these best practices in the areas of contracting/specifications, surveying, design, construction, and inspection.

Contracting/Specifications

- Agencies should review their standard specifications to remove references to stringlines and prescriptive equipment requirements. Concrete paving specifications should be performance based, i.e. thickness and smoothness requirements.
- Agencies should not require nor disallow stringless paving or requiring certain types of stringless paving equipment (total station guidance versus GPS). Allow the project requirements (specifications) and site constraints (tree cover, site access, paver clearance) to drive the contractor to select certain types of equipment to meet the requirements.
- Agencies should share as much digital data as possible. Specifications should clearly state if the digital information is being provided as information only or is being provided as a contractual deliverable.
- Specifications should require contractors to submit a contract control plan when automated machine guidance is used. The contract control plan allows the agency and contractor to be on the same page regarding what equipment will be used and the contractor's plan to achieve the contract specifications, what survey control will be used, and quality control practices.

Surveying

- Agencies should set accurate survey control at the beginning of the project development process that can be undisturbed from pre-design survey through design and construction.
- The tie-in point to existing pavement must be accurately surveyed and design profiles need to tie in exactly. Construction surveyors should verify tie-in elevations early in the construc-

tion of the project so there is time to make adjustments if necessary.

- Agencies should carefully document the pre-design survey control and the accuracy of the existing survey information. Provide this information to the construction surveyor and contractor during bidding. This transparency creates trust in the design information.

Design

- Even if digital information is not a contractual deliverable and is provided for information only, digital information is useful for contractors for bidding and creating their own 3D models that are necessary for construction.
- Designers should provide digital design data such as horizontal and vertical alignments, existing and proposed surfaces, and 3D breaklines in universal file formats that can be read my multiple software packages such as LandXML and DXF file formats.
- 3D breaklines are very useful for stringless paving. Breaklines should have vertexes no more than 5 feet apart in curves (both horizontal and vertical). Designers should have a quality control process for digital data.
- The electronic files should not have crossing breaklines and should have breaklines on each lane line to allow contractors sufficient data to stage the paving. Accurately model cross slope transitions at intersections and superelevated curves.
- It is important for agencies to have up to date computer-aided design (CAD) standards and that the standards are consistently followed. Layer/level naming within the file should be intuitively named to allow contractor users to isolate the data they need.
- Designers should properly document all electronic files and the data contained within the files. A handoff meeting between the designer and the contractor is useful to review the digital information and relay to the contractor which areas of the project were especially difficult to model.

Construction

- The construction surveyor should verify the site control early in the project and set adequate control for the equipment being used. Typically, control points will be necessary every 500 feet staggered on both sides of the roadway. Horizontal and vertical tolerances should be as close as possible to avoid introducing unnecessary errors into the paving.
- Contractors should verify all digital information is consistent with the signed and sealed construction documents. If the contractor finds discrepancies, contact the engineer in charge to follow up with the designer.
- Properly set up and calibrate the stringless paving equipment each time the paver is brought to a new site or the width and cross slope are modified.
- Contractors should trim with the same model that is being used for paving to identify any issues with the models or problems with the tie-in elevations.
- Contractors should have a total station or laser augmented GPS rover dedicated to quality control. Contractors, along with agency inspectors, should check grades and depths while paving in order to quickly identify problems. In the case of a total station setup, contractors check the depth by taking shots on the finished pavement surface with a pole connected to a prism (see Figure 11).

Inspection

- Inspectors should read and understand the contract control plan for automated machine guidance. Verify the contractor is following all specification requirements related to setting survey control.
- Inspectors should verify the contractor is checking the pavement elevation at the frequency called for in the specifications.
- Agencies need to provide inspectors with appropriate equipment and training to be able to check pavement elevations (or provide inspectors with survey support). Paving must be checked with a total station. GPS rovers that some agencies provide inspectors do not have the vertical accuracy required to check pavement.
- If an agency does not provide inspectors with survey equipment or support to check stringless paving, the agencies standard specification should require the contractor to set stakes at sufficient intervals to support inspection.

Conclusions

Stringless paving provides numerous benefits to owner/agencies and contractors including smoother concrete pavements, increased safety for construction surveyors and paving crews, better site access and improved construction staging, and optimization of materials resulting in lower costs. Owner agencies should support the use of stringless paving by updating specifications to allow its use, developing procedures to provide contractors with quality digital data, and training inspectors on how to properly inspect stringless paving.

Figure 11. Checking finished elevations behind the paving machine. Courtesy ACPA 2013