WCPA 2015 ANNUAL CONCRETE PAVEMENT WORKSHOP
AN INTRODUCTION TO STRINGLESS PAVING
2D AND 3D CONTROLS

Presented by
Robbie Pope, PE
GOMACO Corp
Ida Grove Iowa
Overview

- What is 3D Paving
- Customer Benefits
- Conventional vs. 3D Work Approach
- Applications
  - Mainline Slipforming
  - Curb & Gutter
  - Sidewalk/Barrier
  - Trimming (fine grade)
  - Special Applications

System Details

- Components/Sensors
- Position Information
  - 3D Model – Digital Stringlines
- Practical Field Issues
  - From the Contractors Perspective – Best Field Practices
What is 3D Stringless?

A 3D Machine Control system that simplifies jobsite logistics, reduces costs and improves quality and safety

- Removes stringlines and pins from the jobsite
  - Removes installation, maintenance & removal costs
  - Increases work safety, especially at night
- Puts the 3D job design directly onto the machine
  - Eliminates survey setup errors in stringline influences
  - No waiting for setting-out before production
  - No dependency on setup – work wherever you have 3D data
  - Increases productivity, quality and performance bonuses
- Controls height, slope (and steer) of machines
  - Delivers a precisely-constructed product
  - Optimises amount of new material needed
  - Reduces over-trimming, overpouring
  - Improves concrete yields and material cost savings
Why are paving contractors “Going Stringless”? Because stringlines…

- …are expensive, time-consuming and error-prone to install - typically US$1.50 per pin, or > US$500 per mile (European figures, excludes surveyor costs)
- …are easily damaged during paving
- …are easily misaligned (errors increase costs)
- …are a significant site safety hazard
- …interfere with site logistics, increase concrete delivery time, haul costs, and reduce productivity.
- …greatly increase pre-production planning & surveyors workload
What are the advantages of “Going Stringless”?  
Advantages the paving contractors are seeing in 3DMC

- Good site engineers/surveyors are hard to find, and expensive
- Stringlines don’t always ‘model’ the concrete design accurately
- “Go in, pave & get out” ability minimizes machine standing time – ideal for time-critical paving operations (e.g. ‘live’ airports, roads)
- Estimated 50% survey cost reduction - one surveyor or engineer manages the 3D system
- Estimated 20% productivity increase (up to 50% in complex areas)
- Direct construction from CAD design – no intermediate rework
- One 3D model for trimming and paving = material cost savings
Working with Stringline...

- Inspect design – calculate setting-out lists for each lane
- Setup a theodolite, survey each hub or pin position with total station (or GPS if accuracy isn’t important!)
- Hammer (or drill) in each pin, minimum 1 line for each lane of concrete/asphalt
- Check pin alignment & adjust if required
- Survey and set stringline height on each pin (min. 2 men)
- Install & tension clamps and stringlines

- “Eyeball” & adjust stringlines before paving
- Move machine into position, set sensors to stringline
- Check machine position relative to stringlines
- Start Production, monitor machine position
- Ensure (or hope!) nothing disturbs or damages stringlines during paving/milling…

Reference Point

Walk left 5ft!
Walk right 1ft!
Up a bit!
Down a bit!
STOP!
The 3D Advantage

Use digital data, directly from the design

- No staking-out and stringline setup errors

No stakes, hubs or stringlines required

- Eliminates most setting-out costs
- Easier jobsite logistics, truck access
- Work easier in narrow work corridors

No waiting on surveyors, stringline crews, grade checkers etc.

- Improved machine productivity
- Work anywhere you have data, not where the stringlines happen to be ready for
- Work any time of day or night

Increased safety

- No more ‘trip hazards’, ideal for hazardous worksites (e.g. highway lane rentals)

Increased productivity

- More work done right the first time, and faster
3D Stringless Control System
Compatible with all GOMACO machines

- All machines with GOMACO CAN network controller (retro-fit kits available from GOMACO)

- Height and Steer Control for Trimmers and 1-Track Steer Curb & Gutter by 1 theodolite and 1 slope sensor

- Control for mainline slipform pavers by 2 theodolites and 2 dual-axis slope sensors
Stringless Paving Applications
Mainline Slipforming
Completed & Current Projects

Airports

- **Military**: RAF/USAF Fairford (UK); USAF Kirtland (NM, USA); USAF Lakenheath (UK); Belle Chasse Naval Reserve New Orleans, LO (USA); Homer Regional Airport, LO (USA); Travis USAF Cal USA; El Centro Cal, USA; Virgin Galactic Spaceport, New Mexico; Jacksonville USAF, Florida; USAF Andrews, Maryland

- **Civil**: Zurich & Basel International (Switzerland); London Heathrow & Stansted, Edinburgh Intl., Farnborough, Luton Intl. (UK); Paris Charles de Gaulle (France); Atlanta Hartsfield Jackson Intl., Baton Rouge; St Louis; Indianapolis; Toulouse (France); Chicago O’Hare; Guadeloupe (Caribbean); Paris Orly (France); Charlotte, NC, USA; JFK Airport, New York, USA; Fort Lauderdale FL; Baltimore – BWI; Dallas Love Field

Highways

- E40 Ghent-Brussels, Belgium (4 x 10km); I-30 Dallas-Fort Worth, USA (4 x 20km); Pacific Coast Highway Australia (4 x 11km); A1, Peterborough UK (2 x 15km); E67 Prague-Wroclaw Czech Republic (30km); E462 Brno (Czech Rep.); I-75 Atlanta, USA; I-95 Coco Beach, Florida, USA; I-15 & 201 in Utah & Salt Lake County; I-94 Detroit; I-80 Des Moines
  And numerous State and County Highways throughout Iowa

Tunnels

- Sophia Rail Tunnels, Rotterdam, 11km (Netherlands); Channel Tunnel Rail Link, 35km, London (UK), Rail Tunnel Malmo (Sweden), Finnetunnel Erfurt-Leipzig (Germany)
3D Paving in the Midwest
Projects closer to home:

- Luxa Construction
  - County Paving: Omaha subdivisions
  - Residential Paving: Schram Road, Sarpy County, NE

- T&R Construction
  - City Paving: Russell Street, Sioux Falls SD
  - Highway Paving: Highway 212, Watertown SD

- Granite Construction
  - Highway/Tollway Paving: Chisholm Trail Parkway, Fort Worth, TX
  - Barrier Paving: I-35E, Dallas TX

- MCM
  - Airport Paving: Dallas Love Field
3D for Curb & Gutter

- Providing a precise, smooth, accurate curb for new asphalt is crucial for the quality, rideability, service life and whole-life costs of the new asphalt surface.

- Installing stringline and/or forms for curb applications is costly and time-consuming, especially for tight radius work.

- Traditionally requires pre-survey, hubs and data to be provided to the stringline crew.

- This can lead to mistakes, and significant remedial costs & time.

- With 3D, machine steer, elevation and cross slope are automatically controlled without stringlines.

- 3D improves operational safety on site and increases productivity, accuracy and efficiency.
Barrier Stringless Paving

- Restricted access, ‘live’ highway possessions, urban and narrow-corridor or zero-clearance projects.
- Project logistics are made much simpler when you can banish the stringlines. Get your concrete trucks in and out faster, with no risk of damaging the stringlines and stopping production.
- Site safety and setup time for stringlines are also big concerns for projects surrounded by live traffic.
- With 3D your crews have one less thing to worry about when the pressure’s on!
Monolithic & Sidewalk

- Pave any shape in any configuration
- Prepared for Left- or Right-side molds
- 3D is as flexible and reconfigurable as your machine.
- Simply attach your new mold, set the new machine dimensions into 3D and you’re ready to go back to work.
Fine Grade Trimming

- Single sensor configuration reduces cost of 3D equipment
- Contractor can set rough grade high then 3D trim to get subgrade within 1/8”
- Exact 3D model of road design is used for both the paver and trimmer
- Contractors have seen substantial decrease in yield loss
Special Applications – Tunnel Paving

Gomaco GT-6300 Commander III 4-track Slipform Paver, 2 x 18km, 1.5m escape walkway, Channel Tunnel Rail Link, London, UK, 2003
Special Applications – Tunnel Paving

Gomaco GT-6300 Commander III 4-track Slipform Paver,
2 x 7km tunnels, ICE Finnetunnel, Erfurt-Leipzig, Germany, Nov 2009
3D Stringless Paving System Details
3D Stringless Paving Sensors (Hardware)
Components
3D Sensors – Total Stations

- 1” accuracy total station
- Fully robotic operation
- Automatic prism tracking
- Simple setup and position fix
- Can be used for any surveying tasks
- 10-12Hz measurement rate
- Backlight & heater for night operation
- Typical working Range ± 300ft
- Tracking accuracy ±0.01 at 300ft
Components
3D Sensors – GPS (for machine steer option only)

- Machine GPS
- Supports GPS & GLONASS systems for maximum operational time
- Simple setup and position fix routine
- Identical user interface to TPS – no extra training required
- Can be quickly removed from machine and used for any site surveying tasks
- True 20Hz measurement rate

Typical Tracking Accuracy:

<table>
<thead>
<tr>
<th>Position</th>
<th>±0.03FT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>±0.06FT</td>
</tr>
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</table>
Choose your sensors wisely!!!!!!

Sensor selection specific for the application & tolerances at hand!
PZL-1 (Positioning Zone Laser)

- Transmits Unique Laser Zone Signal
- 500 Foot Diameter
- Auto-Leveling
- 4 Channel Operation
- Alkaline Batteries, NiMH Rechargeable, & External Power
PZS-MC
(Positioning Zone Sensor for Machine Control)

- Receives & Decodes the Laser Zone Signal
- 360° beam Detection
- Rugged, Shockproof Design
- IPX6 Waterproof
- DC8V~DC32V Power Supply
3D-MC Platform

- Used in 2D & 3D applications
- Touch screen
- Windows XP
- Operator selectable views
Is Position Enough?

No, we need to know both **Position** (North, East, Height) and **Attitude** (crossfall, mainfall, heading).

We’re interested in regulating the **entire mold**, which is a 3D surface – for PCCP this is not the same as dozers, graders or asphalt pavers.

A plane is usually defined by a minimum of three points...

...but we can’t attach three prisms to the mold. Impractical for various reasons (line of sight, cost of instruments, operation etc..)

We needed a solution to find the machine’s **Attitude**...
Measuring “Attitude”

High accuracy dual-axis slope sensors provide Crossfall and Mainfall

Heading is calculated from the ‘history’ and reference to a Steering Reference Line in the project model.
Components
MSS1200 Slope Sensor

- Solid state, no moving parts
- One-step calibration
- Dual axis (cross & long slope)
- CAN Bus 2.0
- Range ± 60°
- Accuracy ± 0.1°
- Temp. Range: -4°F to 140°F
3D Stringless Sensors
Typical options for Pavers

1-Sensor Solutions: TPS (3D control) or GPS for steer only (2D)

- GOMACO “OFFSET PAVER” (Curb & Gutter, Barrier, Sidewalk) and any single steer paver (GT-3200, 3600, C3)
- GOMACO RCC Screed Pavers
- Fine Grade Trimming: 9500 and 9000

2-Sensor Solution: TPS (3D control) and GPS for steering assist

- Same as above but now features greater steering control, especially for controlling machine in reverse for backing online (over header)

2-TPS (dual total station)

- GOMACO Commander III, GP-2400, GP-2600, GHP-2800, GP4000
  2/4 – Track Concrete Pavers
1 TCA Option – 1-Track-Steer Trimming

Reference (Hub)

Machine Computer

Radios

360° Prism

Slope Sensor

Total Station #1 (Guidance)

Total Station #2 (As-builts & Leapfrog)

Reference (Hub)
1 TCA Option – 1-Track-Steer C&G

360° Prism

Slope Sensor

Machine Computer, Radios

Rear Steer disabled

Total Station #1 (Guidance)

Total Station #2 (As-builts & Leapfrog)

Reference Point (Hub)

Reference Point (Hub)
“GPSAssist” Option – For C&G & Barrier

- GPS Rover Antenna
- 360° Prism
- Machine Computer
- Radios
- MNS1200
- Rear Steer enabled
- Total Station #1 (Guidance)
- Total Station #2 (As-builts & Leapfrog)
- GPS Reference Station
- Reference Fixpoint (Hub)
2 TCA Option – All-Track-Steer C&G or Barrier

- 360° Prisms
- Machine Computer
- Radios
- Rear Steer enabled
- Total Station #1 (Guidance)
- Total Station #2 (Guidance)
- Total Station #3 (As-builts & Leapfrog)
- Reference Point (Hub)

GO...ACO
Measurement – “GPSAssist” Option

- **GPS Reference Station** (onsite or CORS)
- **GPS Rover** (Position/Orientation only)
- **GPS RTK Corrections via Radio Link (cm accuracy fix)**
- **Total Station** (Guidance & Accurate Height)

- c. 20km max (12.5 miles) with repeater
- c. 20,000km (12,500 miles)
- c. 200m (600ft)
Curb Machine (mmGPS)

Curb & Gutter – 3D-mmGPS
1. PZS-MC Sensor
2. GX-60 Control Box
3. MC-R3 GPS Receiver
J.K. Williams

- Location: Sydney, Australia
- Machine: Gomaco Commander III
- Application: Housing Development
Dual TS Option only - Mainline Pavers

360° Prism
Machine Computer
Radios
Slope Sensor

Reference (Hub)
Total Station #1 (Guidance)
Total Station #2 (Guidance)
Total Station #3 (As-builts & Leapfrog)
Why two Total Stations for Mainline Pavers?

Machine width & frame flex
String-line control ‘emulation’
Maintains correct mold alignment

Two total stations provide two independent front & rear control;
to the center point of the mold at the rear (P1) and front (P2) of the machine

We get an accurate heading

Benefit: Fully independent front and rear control
(draft, level, position etc.)
Concrete Paver (mmGPS)

Wide-track Concrete Paver – 3D-mmGPS
1. PZS-MC Sensor
2. GX-60 Control Box
3. MC-R3 GPS Receiver
Stringless Control System for Placer/Spreaders

System Components

Machine
Computer

Radio

Slope
Sensor

360° Prism or GPS available also depending on desired accuracy!

Reference Point

Theodolite #1 (Guidance)

Reference Point

Theodolite #2
Optional for Leapfrog
Replacing the Stringline by Modelling the Project...
Before you order the Concrete Trucks!

Preferable Pre – project check list!

1. Establish Control FIRST!
2. Maintain control network and have quality check continuously throughout the entire time frame of the project!
3. Know or define where the existing project (roadway) is today X,Y,Z
4. Know where the proposed project will be upon completion (model of proposed) – Your yield is at stake!
5. Do a quality check BEFORE you pave! (i.e. dry run the machine)
6. Make corrective actions to the surface prior to paving if necessary!
Traditional methods
A few modern technologies you may consider!
3D Design Modelling – Information Used
Leica – Open to User’s preference
   Data typically used: 3D Polylines
Topcon – Office Magnet, Pocket 3D
Trimble – Trimble Business Center:
   Data used: Profile and Alignment
(The use of TIN files is not recommended for PCCP)
Practical Issues…
In the field!

- How do we know what is going on without seeing the stringlines?
- How do we know where we are in reference to the model?
- What is the contractor doing to verify placement?
- How does the Owner/Agent get involved in the Quality Process?
Practical Issues
Adjusting the Machine

- If the level needs vertical adjusting...
- ...just like stringline control we can adjust all leg heights, and draft independently, without stopping paving
- Digital Offsets, no hand cranking and forgetting
Practical Issues
Adjusting the Machine

- If position needs horizontal adjusting...
- ...just like stringline control we can adjust position at front and rear independently, without stopping paving
Calibration
Why and when to Calibrate?

- **Why**
  - Precise paving
  - Optimal machine performance
  - Optimal concrete thickness & cost savings
  - Prism locations, relative to Mould "Origin", must be determined
  - Slope sensors must be accurately adjusted (relative to machine & each other!)

- **When?**
  - At first installation (commissioning)
  - At EVERY subsequent change of the machine (width change, disassembly/reassembly)

- **Risks if ignored?**
  - Mis-matched slope sensors can cause machine "twisting"
  - Poor concrete surface finish
  - Risk of structural damage to machine (leg barrels, tracks are stressed) → “jumpy” machine
  - Machine will not pave at correct elevation or position
Calibration Procedure

- **Goal:** determine an accurate ‘plane’ surface (usually the Mold underside)
- **Time Required:** 30 to 60 min based on skill and experience.

**Abbreviations:**
- **LR** = Left Rear of Mold
- **RR** = Right Rear of Mold
- **LF** = Left Front of Mold
- **RF** = Right Front of Mold
- **Pri** = Front Mast Prism
- **Sec** = Rear Mast Prism

**Diagram:**
- Tripod set low
- Approx 30’ (10m)
- Rear of Machine
- Centerline
Slope Sensor Calibration

- The measured mold points are used to adjust the attached slope sensors for draft control of the mold so before we calibrate we want to level the mold as reasonably as possible with a 4’ level.
In Summary

Each project is unique BUT what are the limiting factors of using 3D Paving Technology?

No single type of contractor and/or scope of construction work limits the use of 3D Technology in Paving
Does it make sense to use it that way?
Thank you for your attention!

Please feel free to contact me at any time by any of the listed means below:

Robbie Pope, PE
GOMACO Corporation
3D Controls Engineer
(712) 364-3347 Office
(712) 371-3991 Cell
rpope@gomaco.com