Machine Control Technology in Milling and Paving

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Notable/Award Winning Projects

- Telluride CO Airport Project with Kiewit (2009)
- New St-George UT Airport Project with Western Rock (2010)
- Port Mann-Hwy 1 Project in Vancouver BC with Kiewit (2011)
- Circuit Of The Americas (COTA) F1 Track in Austin TX with Austin Bridge & Road (2012)
- Western Wake Expressway Raleigh NC with Lane (2012)
- Colorado Springs CO Peterson AFB Runway Project with Kiewit (2013)
- Honolulu HI Reef Runway Project with JAS W Glover (2013)
- Bowling Green KY National Corvette Museum Motorsports Park (Corvette Test Track) with Scotty’s Contracting (2014)
- Quebec Ministry of Transportation (2015)
- Bogota El Dorado International Airport (2016)
- Numerous FHWA/State DOT Intelligent Compaction Projects
Welcome!

- Paving Challenges
- Machine Control Technology
- The “D”imensions of our Industry
- Machine Control Positioning
- 3D Machine Control Accuracies
- Milling and Paving Machine Control Applications
- Costs and Savings
- Key ingredients for a successful Machine Control Project
Paving Challenges
Typical Paving Challenges

- Material yields
- Cost of Materials
  - Cost of AC
  - Limited aggregate resources
  - Transportation and Production Costs
- Project Deadlines
  - Limited access to areas of the project due to roadway or airport traffic control
  - High penalties for going over
- Additional paving/levelling course
- Additional grinding/milling
  - After paving is completed and to meet smoothness spec
Typical Paving Challenges

5 specific challenges:

1. Thickness
2. Elevation Grade
3. Cross-slope or Straight Edge
4. Differential Compaction/Longitudinal Waves (Smoothness)
5. Compaction, Density (mass/volume, lbs/ft$^3$ or kg/m$^3$)

PLEASE NOTE: Top 4 are achievable with 3D Paving!

Traditional methods require

- Placing, Grading and Maintaining “piano wire”/stringlines
- Managing Trucks and Machines around placed stringlines
What are the traditional methods?

- Placing Stringline or Wire
- Grade paint marks on surface
- Estimating/Guessing?!?
Machine Control Technology
Machine Control Technology

- **What is Machine Guidance?**
  - Machine Guidance is used to accurately position earthwork, milling and paving equipment on a project
  - Uses technology to help maintain grade
    - Rotating Lasers, Sensors, RTK-GNSS, Robotic Total Stations

- **Two types of Machine Guidance:**
  - **Indicate Machine Guidance**
    - Technology on machine indicates an on grade or cut/fill
    - Operator controls the machine manually to grade
  - **Automatics Machine Guidance**
    - Functions with the hydraulics on the machine
    - Technology on machine displays an on grade or cut/fill or raise/lower
    - Raise or Lower function is controlled automatically to grade
    - Can include horizontal guidance to a line (i.e.: steering)
The “D”imensions of Our Industry
"D"imensions – Science (wiki-answers)

- 0D = A point
- 1D = A line
- 2D = A shape with X and Y lines (square)
- 3D = A shape with X, Y, and Z lines (cube)
- 4D = A 3D shape with the addition of time
- 5D = Another possible reality caused by choice and chance
- 6D = Being able to jump between one reality and another
- 7D = All possible conceivable realities in this universe
- 8D = A different universe in which there are different particles resulting from the big bang
- 9D = Being able to jump from one universe to another
- 10D = A infinite amount of possible universes
- 11D = Being able to jump between the infinite amount of universe and realities
“D”imensions – Engineering

- 0D Point
- 1D Line (no width or height)
- 2D Flat Surface/Plane (has length and width or length and height)
- 3D Surface with Elevation (has length, width and height)
- 4D Time
- 5D Cost
“D”imensions – Construction Machine Control

- 1D – Elevation Only (level rotating laser)
- 2D – Elevation and Slope (laser, sensors)
- 3D – Elevation, Slope and Horizontal

In addition, machine control technology and machine manufacturers add their own marketing terminology to the dimensions

- 3D+, 3D-MC, mmGPS 3D, etc...
- Auto side-shift, auto steering, laser augmented GNSS, etc...
- These are all extra features
- At the end of the day, 3D is still 3D!
Machine Control Positioning
Machine Control Positioning

- **1D**
  - Measuring elevation
    - Level Laser

- **2D**
  - Measuring elevation and slope
    - Slope Laser
    - Slope sensor
    - Sonic tracer(s), Averaging Beams
  - Wheel for measuring stationing
  - Material thickness, from ground - up

- **3D**
  - Tracking and measuring of a moving target for x, y and z (Easting, Northing, Elevation) coordinates
    - Optical robotic total station
    - Or a satellite based navigation system
  - Uses an engineer design, from top – down
Machine Control Positioning

- 1D

![Diagram of Machine Control Positioning](image)

Laser Plane

Laser Transmitter

Reference Elevation
Machine Control Positioning

- 2D

Elevation (e.g.: Sonic)

Slope (e.g.: Slope Sensor)
Machine Control Positioning

• 3D
Machine Control Positioning
Machine Control Positioning
Machine Control Positioning
Machine Control Positioning
Machine Control Technology
3D Positioning Technologies

- **GPS/GNSS**
  - Satellite based system
  - GPS: Global Positioning System (US DoD)
  - GNSS: Global Navigation Satellite System
    - World’s Satellite Systems used to determine the location of a user’s receiver anywhere on earth

- **Laser Augmented GNSS**
  - Must have RTK GNSS for Horizontal positions
  - Uses a laser to increase the vertical accuracy

- **Robotic Total Stations**
  - Land based system
Different types of GNSS Receivers

- Three types or grades of GNSS Receivers
  - Navigation/Recreational [Autonomous C/A, 10’-50’ (3m-15m) + H, V?]
  - Positioning [Differential C/A or L1 Carrier Phase (Real-Time or Post-Process), 0.5’-10’ (0.1m-3m) H, 2-3x more in V]
  - Precise [L1/L2 Carrier Phase. Real-Time Kinematic (RTK) or Post-Process (PP). 0.1’ (30mm) or better, 3D!]

- RTK is typical for Survey and Construction Applications (Golf Ball Accuracy or better)!
Laser Augmented GNSS

- RTK GNSS for Horizontal positions
- Requires accurate control points for a site calibration
  - Can use State Plane, UTM, etc… coordinate systems
  - Should still have control points to check systems
- Initial setup should be identical to a typical GNSS RTK project
- A laser or series of lasers are used to increase (augment) the vertical accuracy of the GNSS system
- Depending on the manufacturer, they will either use a construction type laser or fan laser
- Vertical accuracies will depend on the laser manufacturer. Expectations would be 3mm-5mm or less
- Be aware of any obstructions (e.g.: walls, trees, overpasses, etc…).
  - 100% coverage is expected. If the GNSS system goes down, there is no positioning!
Robotic Total Stations – Land Based

- Optical measurement system
  - 1/8” (0.01’, 3mm) accuracy
  - Measures horizontal and vertical angles
  - Measures distances
  - Computes 3D positions for a machine or rover
  - Line of sight required, 100% coverage expected
- Transmits data via radio link to the rover system
  - Data Controller
  - Control Box in machine control applications
Robotic Total Stations
Using a Rover on a Project

- Checking Elevation Grade behind Mill and/or Paver Screed
- Rover must be accurate
- Can be used to record and store data of compacted areas
Milling and Paving Machine Control Applications - 3D Milling
Profile 3D Milling - Only mill what is needed

- Accurate Vertical Control!
  - Remove more material
  - Remove less material
  - Longitudinal waves in the road
  - More consistent asphalt structure
Variable depth and slope milling enables milling of:

- Transitions
- Super-elevated curves
- Variable drainage slopes
- Control and Manage your Material Quantities!
The issue of differential compaction when paving:

Increased Smoothness & Decreased asphalt usage
Increased Smoothness & Decreased asphalt usage

- 3D Milling minimizes asphalt usage
- More consistent and better asphalt structure

Asphalt filling of low spots (e.g.: Leveling Course)
Milling and Paving Machine Control Applications - 3D Paving
Paving Terminology

- **2D Paving** – controlling grade (elevation/thickness) and slope independent of a model
  - 2D is Ground-up
  - 2D Systems lay a constant thickness over the base
- **3D Paving** – controlling grade and slope at a known position per a design/model
  - 3D is Design-down
3D Paving Applications

- Any project where a contractor uses stringline or wire for elevation grade
- Variable depth and slope paving applications
  - Airports, roads and commercial surfaces
  - Base material (P209, gravel, etc…)
  - Asphalt
  - Roller Compacted Concrete (RCC)
  - Concrete Treated Base (CTB)
3D Paving Applications
Advantages of 3D Paving

- Achieve the highest accuracy and smoothness levels
  - Better material management
- Eliminate the stringlines:
  - Reduce staking labor, downtime and errors
  - Reduce costly rework
  - Finish the project faster
- Pave complex designs
- Use an “Uncompacted Design” to help differential compaction issues
  - For most applications, includes “levelling course” in the same pass
Managing Differential Compaction

- 3D Designs describe the final finished surface
- 3D/Grading systems use vertical offsets to build up to this surface
- Final asphalt lift is designed to finish at this surface
- Must allow for compaction
  - “Fluff” or Compaction Factor
- Need to place the asphalt a little higher to compensate for low areas
  - E.g.: 2” compacted, placed at 2.5”
  - Compaction Factor = 2/2.5 = 0.80
Managing Differential Compaction

Paving & Rolling
Managing Differential Compaction

This surface represents long longitudinal roadwaves
This is N.T.S and is extremely exaggerated

▶ If you lay a thicker lift you get more compaction
Managing Differential Compaction

This surface represents long longitudinal roadwaves
This is N.T.S and is extremely exaggerated

- Place the asphalt to the “Uncompacted” Design
  - A little thicker over the low areas

- Rolling will leave a smooth level surface
- Consider using a 3D mill prior to paving!!!
Costs and Savings
What are the Costs and Savings

- What are the project specifications?
- Is the project a mill and fill?
- Are you being paid by the square area or by volume?
- What are the material overruns? 6%? 8%?
- What is the smoothness pay scale factor?
  - 100% pay or deduction?
  - Ride Bonuses?
- Will you drop the mill in the cut and perform the typical “blow and go”?
- If the project is still uneven after milling, how do you manage quantities?
- Will you be placing a levelling course before mainline paving?
- How long are you responsible for the project after completion (warranty)?
What are the Costs and Savings

- Project Example:
  - 8000’ long, 150’ wide, 4” thick (compacted)
  - Target Asphalt Density 145 lbs/ft³, 29000 tons placed at $125/tons
  - Asphalt Cost: $3,625,000
  - Placing an additional ¼” of material = $226,500 or +6% (+1810 tons)
  - Setting stringline or wire can cost from $5 to over $10 per foot
  - At $5 per foot, and paving 6 passes (25’ wide), two lifts
  - $40,000 per line x 7 lines = $280,000 per lift!
    - Cost to place line increases to re-place or to place at night
    - Extremely time consuming!
    - Reoccurring cost
What are the Costs and Savings

- Using 3D technology can help you manage quantities
- Quality of the surface typically cannot be achieved using traditional methods
- 3D milled or graded surface is a smooth surface and ready for paving
  - You can control the depth you mill to along the whole project and not just at the end gates or perhaps using an averaging beam
- On a profile 3D mill project, you remove what you require to make the surface smooth
  - Place the desired asphalt thickness on top
- On a variable depth 3D mill project, you control the depth of the drum to meet specifications
  - You will know the amount of asphalt required to fill the project
Key ingredients for a successful Machine Control Project
Key ingredients for a successful MC Project

- Consult with a qualified manufacturer and supplier prior to the project
- Training and Support from a qualified distributor
  - Plan and prepare for training prior to production on the project
- Contractor is committed in using technology
  - Should have a person on staff to be responsible
  - Product Solutions Investment and an Investment to change how you work
- Contractor follows all machine manufacturer recommendations for operating the machines equipped with Machine Control
  - E.g.: Paving By The Numbers, etc… for pavers
  - There is no “magic” button when technology is install, you still need to know how to pave
Key ingredients for a successful MC Project

- Use the correct technology for the project application(s)
  - Will GNSS signals be obstructed? How about line of sight for the total stations?
  - Are there any obstructions?
Key ingredients for a successful MC Project

- Use the correct technology for the project accuracy requirements
- How does the 3D technology work with the existing paving control system?
- Machine is in optimum working condition
  - Any wear or “slack” on the machine will affect results
- Consider other machines for machine control and not limit to just one. Look at the whole spread including compactors (IC)!
  - One machine is productive, multiple machines are MORE productive!
Key ingredients for a successful MC Project

- **Project Survey Control** must be accurate
- Greater than ½ the project specifications
- Consider “PROJECT SPECIFIC (i.e.: within the site)” of first order accuracy
  - Highest achievable accuracy of Survey
  - Use a Digital Level system to reduce or eliminate human errors!
- If you are 3D milling or 3D paving, mm accuracy is a must
  - There is no reason for poor survey control accuracy
- Should be no more than 500’ (150m) apart for Total Station Machine Control (can be less for Laser type Machine Control)
  - You need to know the technology ranges and/or limitations
- Surround the project
Key ingredients for a successful MC Project

- Use Digital Level (Vertical)
- Total Station (Horizontal)
Key ingredients for a successful MC Project

- 3D Design or Model must be accurate
- Optimized and densified for Machine Control
- Built for Machine Control applications
- The design is critical
- If the design is wrong the surface is wrong
  - If YOU are milling or paving, this is your last chance to get it right!
Key ingredients for a successful MC Project

- 3D Designs for Roads, Corridors, Runways/Taxiways:
- Use the Parametrics (Template-Based Road Design) *
  - Horizontal Alignment (HAL) & Vertical Alignment (VAL)
  - Templates (X-Sections) – Alignment based
  - Superelevations and Widening
- * This is the most accurate way to describe a road
Key ingredients for a successful MC Project

- If using a GNSS based system, check-in to a control point or more to verify the setup is still within project specifications
- If using Lasers, ensure they are calibrated as per the manufacturer specifications
- If using Robotic Total Stations, calibrate and collimate the instruments as per the manufacturer specifications
- Once the Robotic Total Station (s) is (are) setup, check-in to a Control Point to verify the setup is still within project specifications
Key ingredients for a successful MC Project

- As-built or existing surface data accuracy should be equal or better than the technology being used
  - If the MC technology can achieve 3mm to 5mm (0.01’ to 0.02’), as-built data accurate at 10mm to +20mm (0.03’ to +0.07’) is not ideal
  - The data can be used for a 3D design and/or to verify was has been milled or placed
Questions?
THANK YOU!
Thanks for your Participation

Please complete the evaluation to provide your feedback on this session and suggest topics for future events.

Remember to mark these upcoming events on your calendar!

March 7-11, 2017
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