

3D Technology Solutions in Construction

Verification of Retaining Wall System

TEAM Conference
Branson, MO
March 14, 2024

Gregory Cleveland, PE, CCM
SAM



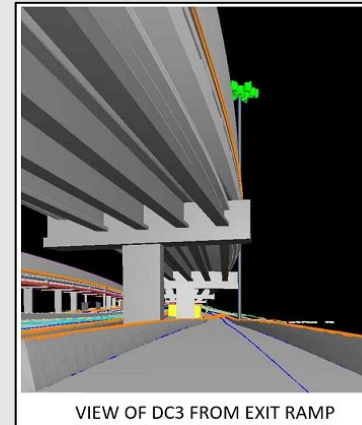
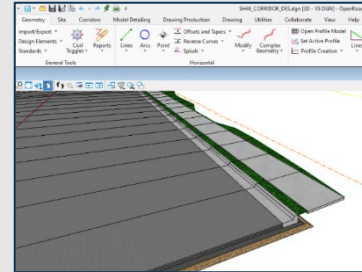
- 1** Overview of 3D Technology Solutions
- 2** Establishing TxDOT Pilot Projects
- 3** Technical Working Group and Technology Evaluated
- 4** Preliminary Findings for 3D Construction Inspection
- 5** SAM Applied Technology Group
- 6** Next Steps



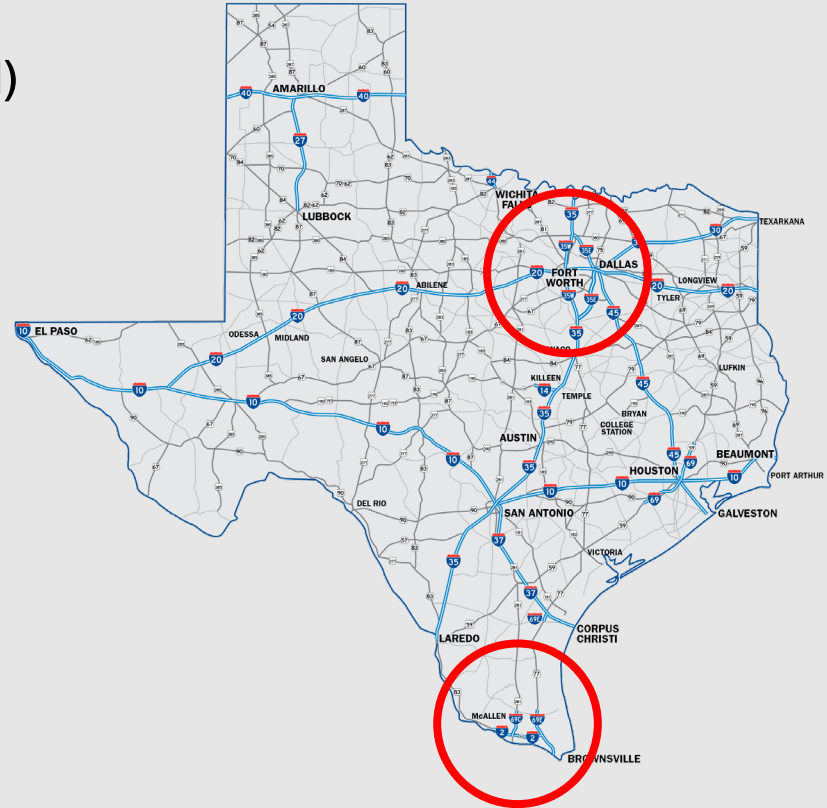
- In general, 3D technology enhances a traditional 2D view or model to provide a more realistic view
- 3D software and 3D scanning are helping to improve safety, productivity and quality during construction phase operations
- Key Benefits of 3D Construction:
 - Conceptually view project features in the field
 - Compare as-built versus as-designed
 - Make insightful decisions timely
 - Improve construction quality

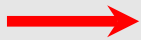
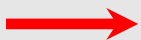
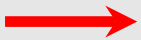


- TxDOT is embracing Digital Delivery
 - 3D plans using Bentley's OpenRoads Designer
 - Machine models for construction
- Created 3D Construction Inspection Pilot Projects
- Goals:
 - Evaluate readily available 3D technology
 - Compare as-built versus as-designed
 - Evaluate precision and accuracy
 - Assess ease of use



- **I-2/I-69C Design-Build Interchange (\$303M)**
 - TxDOT Pharr District
 - 4 DC's and associated roadways
 - Pilot: May 2023
- **Southeast Connector Design-Build (\$1.6B)**
 - TxDOT Fort Worth District
 - Widening of I-20, I-820, US 287
 - Pilot: August 2023



- Technical Working Group (TWG) Established
 - Weekly meetings at first; moving to bi-weekly
 - Coordination/communication between TxDOT Districts and Divisions (ALD/CST), DB Contractor, Surveyors, and Vendors
 - Preconstruction, Construction, Post-Construction phases
- Trimble SiteVision  Visualization tool using mixed reality and ORD plans
- Pix4D with viDOC  Photogrammetry & LiDAR based technology
- Bentley Synchro  Inspection forms tied to element and P6 schedule



- Preconstruction Phase Tasks

- Equipment delivery/setup/training takes time to learn
- ORD file transfer to Trimble Connect requires ORD experience
- Equipment site calibration
 - Compared project survey control well within 0.1 foot
 - Be aware of obstructions
 - Survey experience required



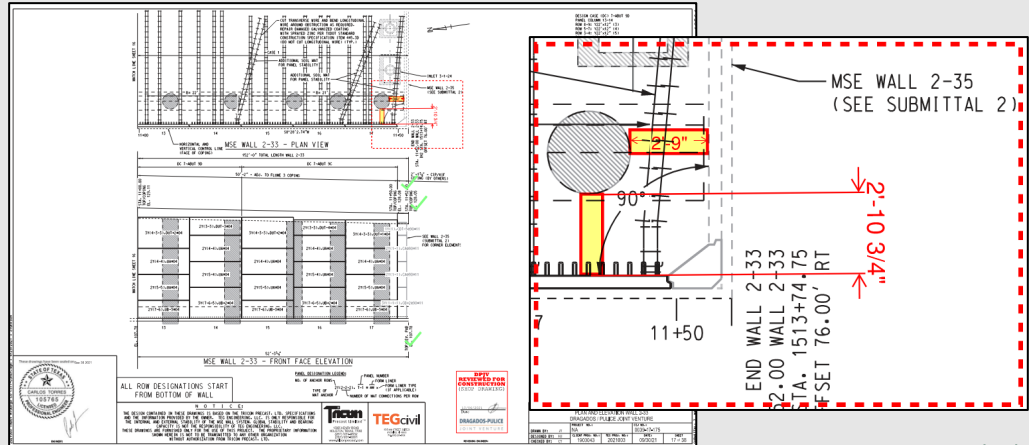
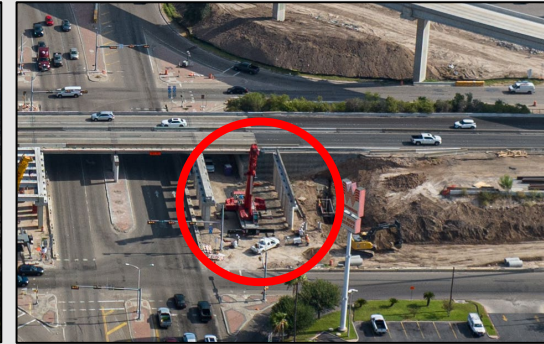
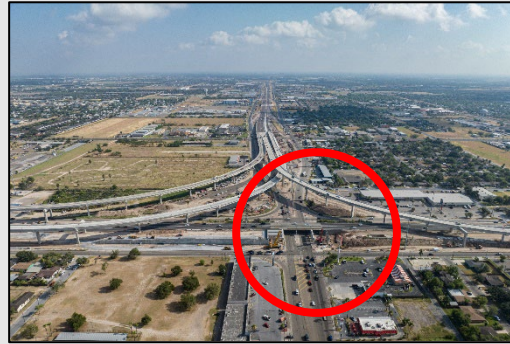
Trimble SiteVision User Guide

Site Calibration Report				Point Residuals			
Horizontal Calibration Parameters				Residuals sign: Calculated-Control			
Translation north:	16610148.646 ft			GNSS Point	Calculated Point	Grid Point	
Translation east:	1090005.445 ft			Point	CP-2020	Point	CP-2020 Control
Rotation:	-0°08'51.1"			Latitude	N26°11'55.73280"	Northing	16604200.509 ft
Origin northing:	-80003995 ft			Longitude	W98°09'15.44914"	Easting	1088669.720 ft
Origin easting:	-954.705 ft			Height	20.880 ft	Elevation	107.652 ft
Scale factor:	1.0000288842					Horiz. residual	0.023 ft
						Vert. residual	0.032 ft
						3D residual	0.039 ft
Vertical Calibration Parameters							
Vertical shift at origin:	5.510 ft			Point	CP-1002	Point	CP-1002 Control
Slope north:	-0.495 ppm			Latitude	N26°11'55.73280"	Northing	16594513.258 ft
Slope east:	-0.284 ppm			Longitude	W98°13'35.93711"	Easting	1073940.073 ft
Origin northing:	16604200.509 ft			Height	36.939 ft	Elevation	120.464 ft
Origin easting:	1088669.720 ft					Horiz. residual	0.055 ft
						Vert. residual	0.011 ft
						3D residual	0.056 ft
Residual Differences Between GPS and Known Coordinates							
Summary							
	Maximum residual	Root Mean Square residual	Point				
Horizontal	0.124 ft	0.064 ft	CP-20	Point	CP-2016	Point	CP-2016 Control
Vertical	0.046 ft	0.026 ft	CP-15	Latitude	N26°11'55.73280"	Northing	16598420.250 ft
Three-dimensional	0.126 ft	0.069 ft	CP-20	Longitude	W98°09'15.44914"	Easting	1097659.421 ft
				Height	20.462 ft	Elevation	103.774 ft
						Horiz. residual	0.041 ft
						Vert. residual	0.015 ft
						3D residual	0.044 ft
				Point	CP-16	Point	CP-16 Control
				Latitude	N26°14'04.51526"	Northing	16614403.728 ft
				Longitude	W98°10'37.24278"	Easting	1090175.344 ft
				Height	20.880 ft	Elevation	104.484 ft
						Horiz. residual	0.066 ft
						Vert. residual	-0.041 ft
						3D residual	0.078 ft

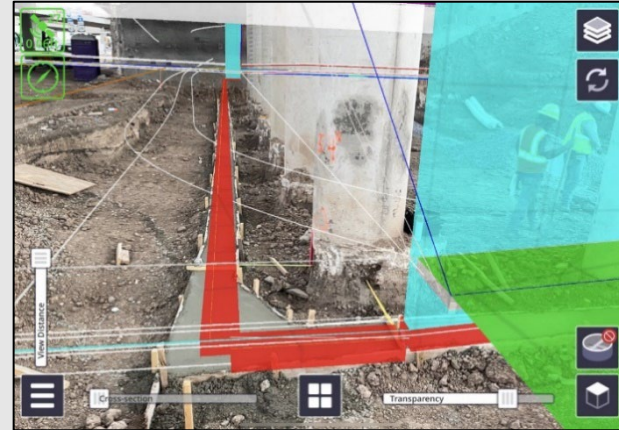
Site Calibrations with SAM and DB Contractor Surveyors



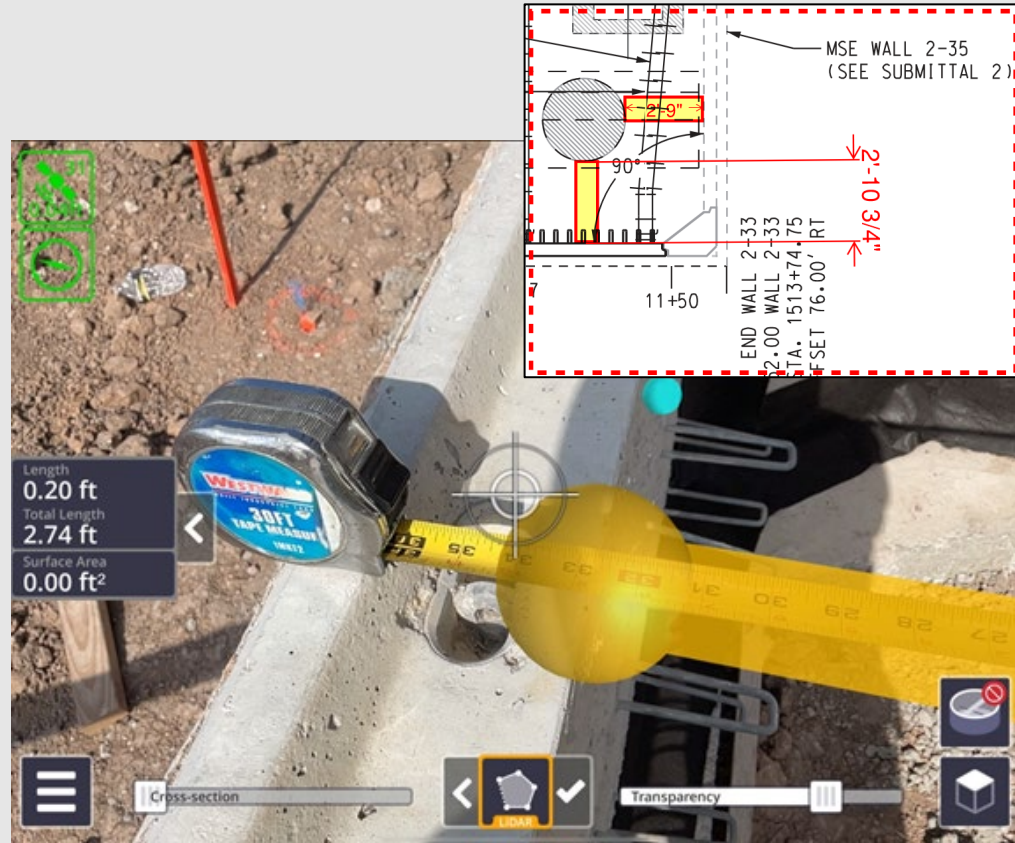
- Preconstruction Phase Tasks
 - Retaining Wall 2-33 & 2-35
 - Review bridge plans and retaining wall shop drawings
 - Measurements to the back of proposed retaining wall panels from the drilled shaft extensions



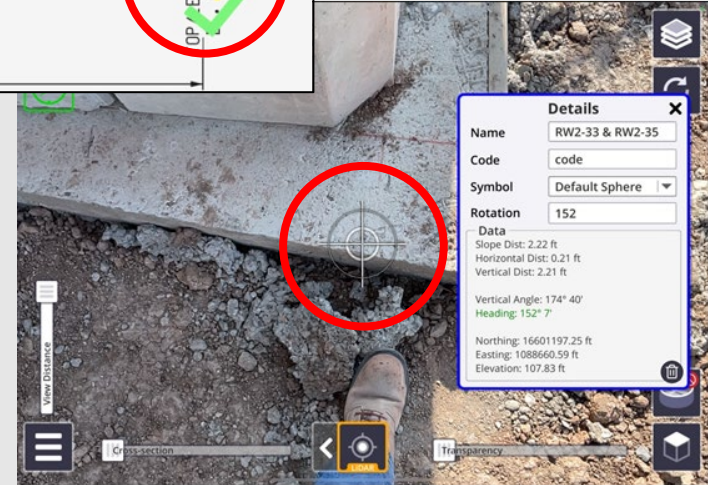
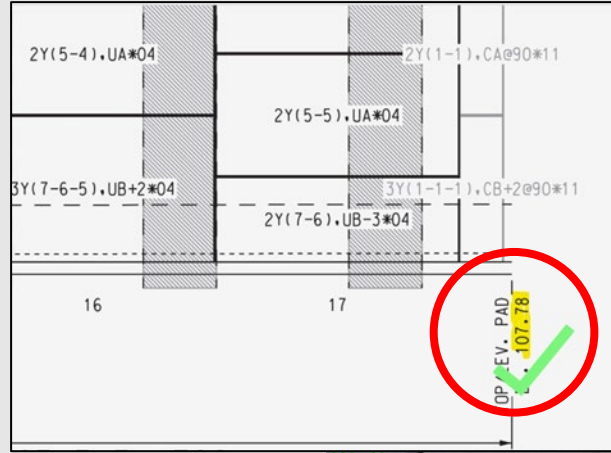
- Construction Phase Tasks
 - Verify leveling pad layout
 - Measuring tape was used to verify Trimble measurements
 - Pulled tape from the edge of the drilled shaft to the proposed back of panel
 - Trimble depicts leveling pad is at the right location



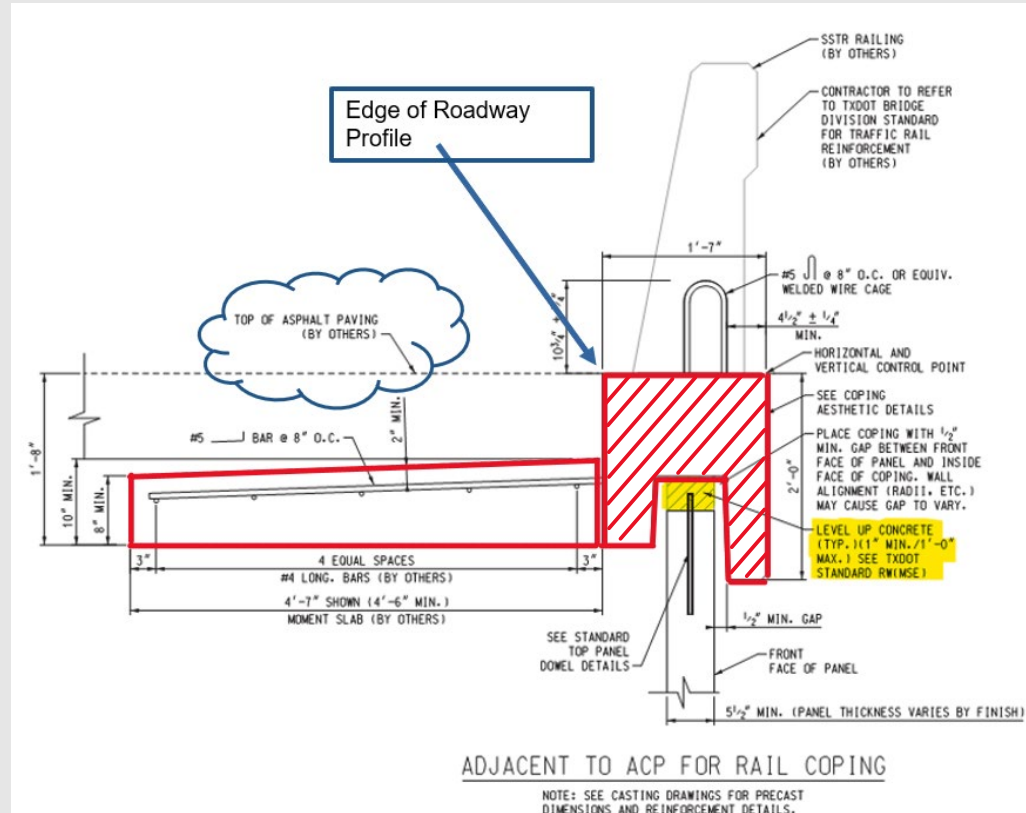
- Construction Phase Tasks
 - Verify placement of panel
 - Plan dimension is 2.75' (2'-9")
 - Trimble measurement is 2.74'
 - The placement of the panel is acceptable



- Construction Phase Tasks
 - Verify elevation of leveling pad
 - Plans elevation = 107.78'
 - Trimble elevation = 107.83'
 - Leveling pad is 0.05' above plan elevation
 - Elevation of leveling pad is considered acceptable



- Construction Phase Tasks
 - Review Edge of Roadway Profile
 - Prior to paving operations
 - GNSS measurements performed
 - Interface between coping and hot-mix pavement
 - Comparison made to elevations from as-designed cross-sections



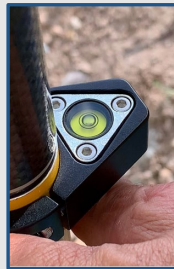


Benchmark # 2

Actual Elevation = 110.01'
GNSS Elevation = 110.00'

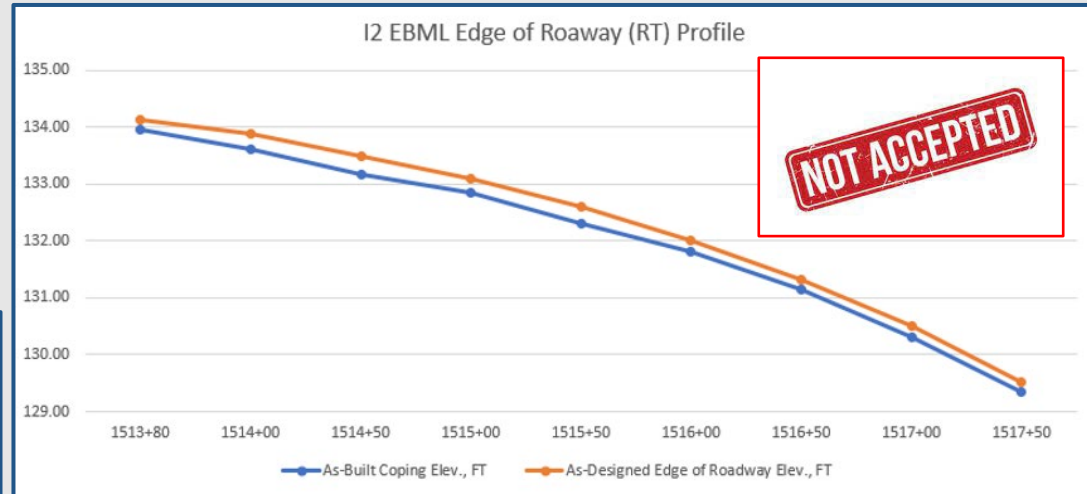
Benchmark # 3

Actual Elevation = 108.61'
GNSS Elevation = 108.62'



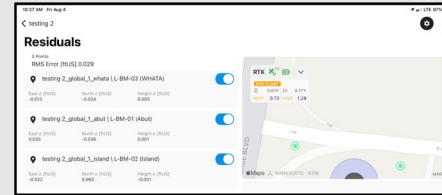
- Construction Phase Tasks
 - Edge of Roadway Profile Review
 - Actual profile is 0.23' or 2.76" lower than as-designed
 - Critical Hold Point Inspections
 - Elevation of leveling pad
 - Tolerances between panels
 - Coping level up concrete

Station	As-Built Coping Elev., FT	As-Designed Edge of Roadway Elev., FT	As-Built to As-Designed Delta, FT
1513+80	133.96	134.14	-0.18
1514+00	133.62	133.89	-0.27
1514+50	133.17	133.49	-0.32
1515+00	132.85	133.10	-0.25
1515+50	132.31	132.6	-0.29
1516+00	131.81	132.01	-0.20
1516+50	131.14	131.32	-0.18
1517+00	130.32	130.50	-0.18
1517+50	129.34	129.53	-0.19
		Average --->	-0.23

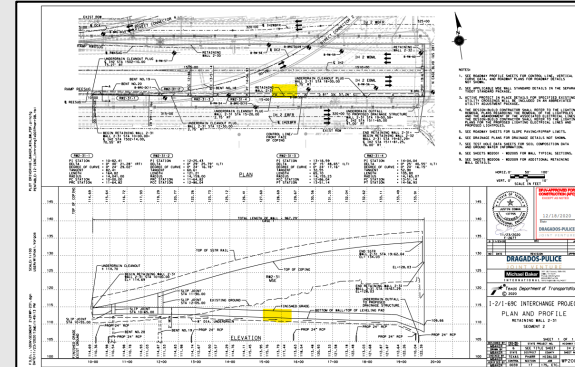


- Preconstruction Phase Tasks

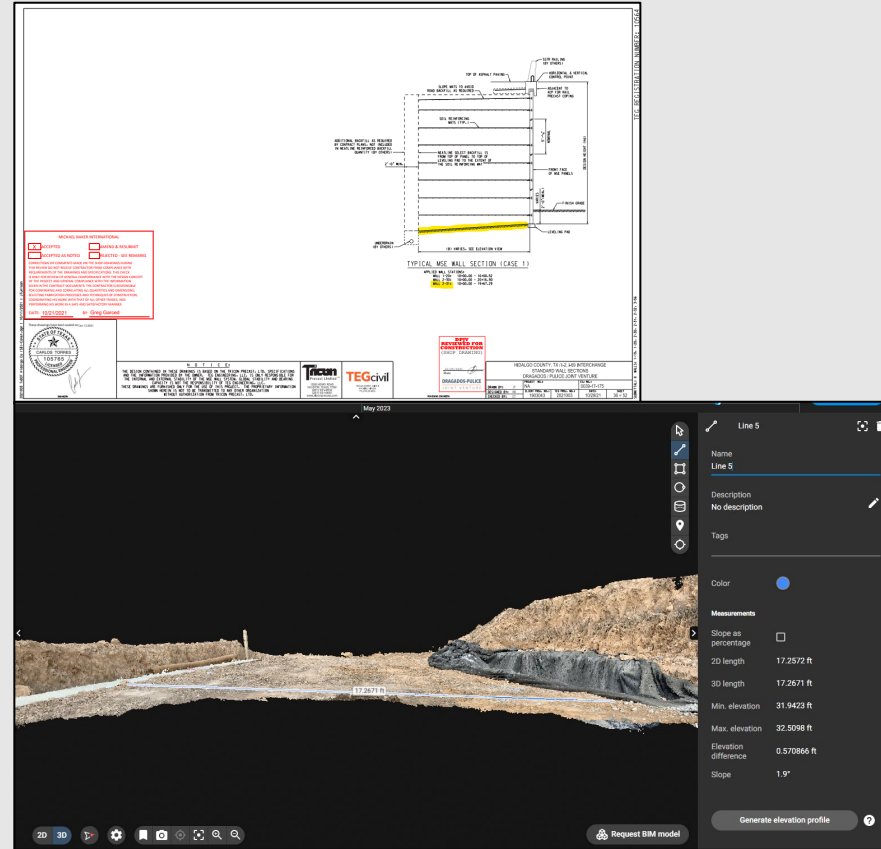
- Equipment used viDoc RTK Rover, iPad Pro and the Pix4D application
- Obtained localization file from DB Contractor and scanned benchmarks to verify calibration of equipment
- Calibration was an issue and worked with Vendor to resolve
- Scans of retaining wall features to verify prior to panel placements



- Construction Phase Tasks
 - Verify levelness of leveling pad
 - Spec: no more than 1” plastic shim height is used
 - Scan performed and measured
 - Slope = 0.2%
 - Elevation difference = 0.39” < 1”
 - Leveling pad is considered level



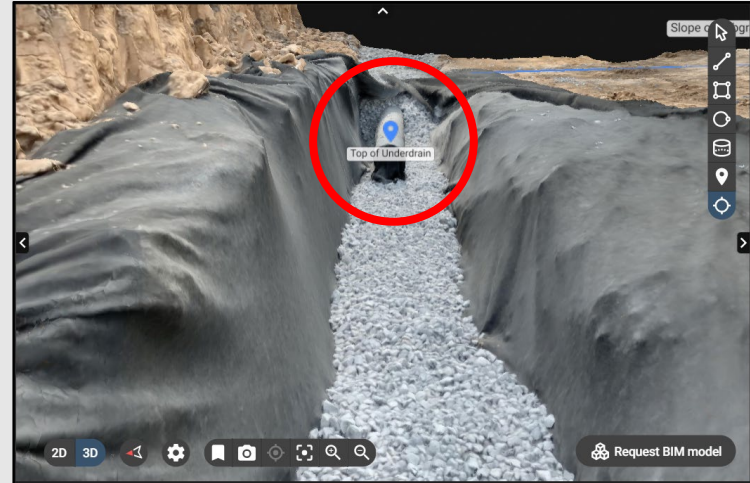
- Construction Phase Tasks
 - Verify slope direction of subgrade
 - Line was drawn between top of leveling pad toward the underdrain area
 - Elevation difference = 0.57'
 - Subgrade is sloping correctly



- Construction Phase Tasks
 - Verify underdrain is lower than subgrade
 - Measured using point feature with elevation difference = 1.24' lower



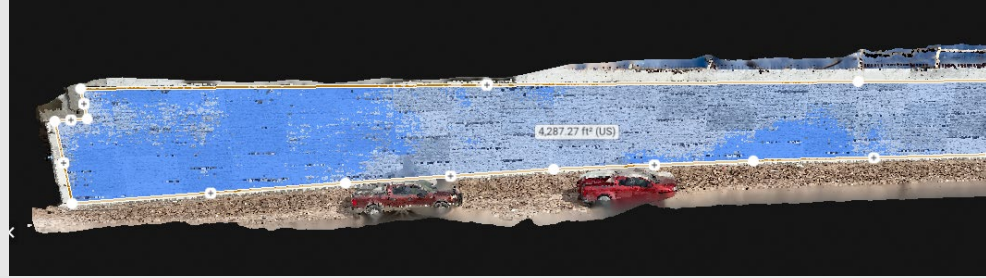
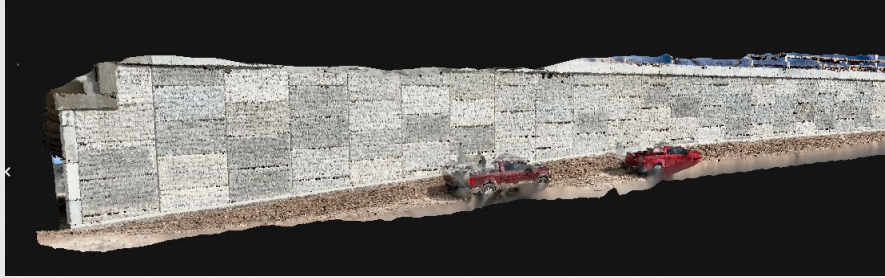
- Pix4D also takes hundreds of geotagged photos while scanning



Pix4D (Preliminary Findings)



Pix4D (Preliminary Findings)



Site Localization

Plumbness Review

Name
Plumbness Review

Description
No description

Tags

Color ●

Measurements

- Slope as percentage
- 2D length 0.43307 in (US)
- 3D length 10.0689 ft (US)
- Min. elevation 112.848 ft (US)
- Max. elevation 122.913 ft (US)
- Elevation difference 10.0689 ft (US)
- Slope 89.8°

Screenshot for Annotations report



- Bentley Suite of software include many packages
- To support 3D Construction Inspection, the pilot project focused on two key aspects
 - Form Building Technology
 - Dashboard Functionality
- Proof of concept
 - Develop Construction Inspection forms
 - Use Dashboards to present key project metrics

SYNCHRO | The construction solution

SYNCHRO Field	SYNCHRO Control	SYNCHRO Perform New	SYNCHRO Cost New	SYNCHRO 4D
Mobile field management Tablet and phone workflows For...	Project management Task- & model-based workflows For...	Project performance Optimised site operations For...	Cost management Project- & portfolio-level costs For...	Plan & virtual construct Model-authoring & workflows For...
Field Staff including <ul style="list-style-type: none">• Superintendents• Foremen• Field Engineers• Inspectors who need to quickly capture and access data in the field	Project Admins including <ul style="list-style-type: none">• Project Managers• Project Directors• Doc Controllers• Safety & Quality Managers who need to better manage all docs, data and tasks in one place	Site Managers including <ul style="list-style-type: none">• Superintendents• Foremen• Project Managers• Safety & Quality Managers who want real-time access to field performance to keep projects in control	Cost Managers including <ul style="list-style-type: none">• Bid Mgrs - Biz Dev• Estimators• Cost Managers• Project Managers To more easily manage contracts and project budget in order to better manage risk and cash flow	Planners & VDC Mgrs including <ul style="list-style-type: none">• Planners/Schedulers• Estimators• VDC Engineers• Project Managers that optimize resources and deliver projects on time and budget

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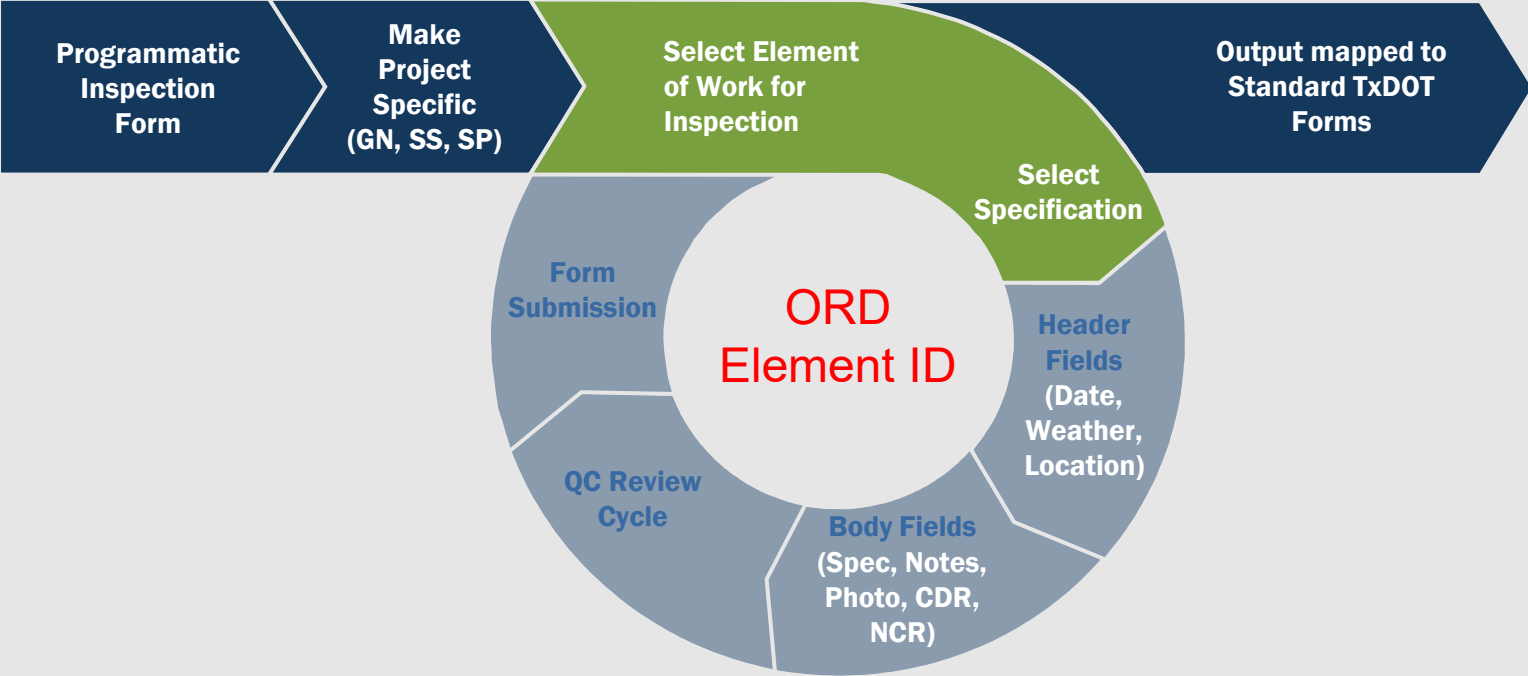


- Construction Inspection Forms

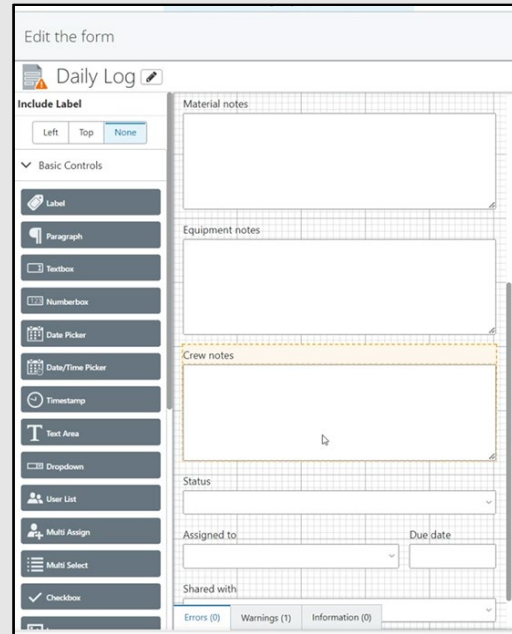
- **Core features:** date, location, weather, schedule, element of work, specification requirements, observations, photos
- **Enhancements:** conforming/non-conforming work, P6 schedule, % complete, safety, environmental, record keeping, tied to other work (e.g., testing)

Item Series	Item	Item Description	Section	Reference	Requirement
400	416	DRILLED SHAFT FOUNDATIONS	Materials	Safety	Has proper protection been placed around drilling site?
400	416	DRILLED SHAFT FOUNDATIONS	Materials	416.2	Concrete mixture design is approved for installation
400	416	DRILLED SHAFT FOUNDATIONS	Materials	416.2	Approved water-reducing admixture is used when using casing that will be
400	416	DRILLED SHAFT FOUNDATIONS	Materials	416.2	Does mineal drilling slurry meet Table 3 requirements?
400	416	DRILLED SHAFT FOUNDATIONS	Materials	416.2	Slurry testing performed, if applicable
400	416	DRILLED SHAFT FOUNDATIONS	Materials	Record Keeping	Tag for the reinforcing steel
400	416	DRILLED SHAFT FOUNDATIONS	CONSTRUCTION	General Notes	Casing is required for 18" Drilled Shafts
400	416	DRILLED SHAFT FOUNDATIONS	CONSTRUCTION	416.3	Drilled Shaft Installation Plan Submittal and Review are completed
400	416	DRILLED SHAFT FOUNDATIONS	CONSTRUCTION	416.3	Drilled Shaft location tolerances:
400	416	DRILLED SHAFT FOUNDATIONS	CONSTRUCTION	416.3	Vertical plumbness is 1in. per 10ft. of depth
400	416	DRILLED SHAFT FOUNDATIONS	CONSTRUCTION	416.3	Center of shaft located under column is within 1in. of horizontal plan posit
400	416	DRILLED SHAFT FOUNDATIONS	CONSTRUCTION	416.3	Center of shaft located under footing is within 3in. of horizontal plan posit
400	416	DRILLED SHAFT FOUNDATIONS	CONSTRUCTION	416.3	Has embankment at bridge ends been installed prior to installing drilled sh
400	416	DRILLED SHAFT FOUNDATIONS	CONSTRUCTION	416.3	Do drilled shafts passing through the structural volume of retaining walls m
400	416	DRILLED SHAFT FOUNDATIONS	DRY DRILLING	416.3.1	Shaft has been excavated through all anticipated materials encountered to
400	416	DRILLED SHAFT FOUNDATIONS	DRY DRILLING	416.3.1	Was satisfactory found material encountered at the plan elevation?
400	416	DRILLED SHAFT FOUNDATIONS	DRY DRILLING	416.3.1	If not, has engineer approved any adjustments made to the bottom of shaft
400	416	DRILLED SHAFT FOUNDATIONS	DRY DRILLING	416.3.1	Has there been any caving condition, ground water seepage, or soil squeez
400	416	DRILLED SHAFT FOUNDATIONS	SLURRY DISPLACEMENT METHOD	Environmental	Are measures in place to contain slurry runoff?
400	416	DRILLED SHAFT FOUNDATIONS	SLURRY DISPLACEMENT METHOD	416.3.4	Was slurry mixed on-site in a reservoir of sufficient capacity, and allowed t
400	416	DRILLED SHAFT FOUNDATIONS	SLURRY DISPLACEMENT METHOD	416.3.4	Was a head of slurry maintained at or near ground level during and after e

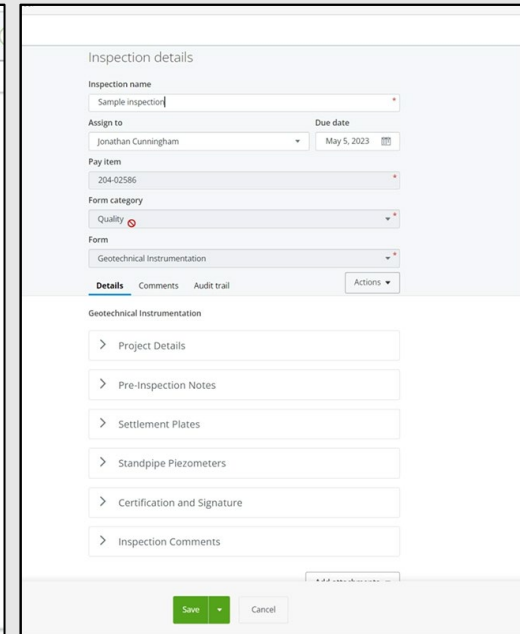




- Construction Inspection Forms
 - Using Synchro Form builder
 - Creating OV and IQF inspection forms for:
 - Item 416, Drilled Shafts
 - Item 423, Retaining Walls
 - Not duplicating efforts with CST
 - Adding form enhancements



The screenshot shows the 'Edit the form' interface for a 'Daily Log' form. On the left is a 'Basic Controls' sidebar with options: Label, Paragraph, Textbox, Numberbox, Date Picker, Date/Time Picker, Timestamp, Text Area, Dropdown, User List, Multi Assign, Multi Select, and Checkbox. The main workspace contains three text areas: 'Material notes', 'Equipment notes', and 'Crew notes' (which is highlighted with a dashed orange border). Below the text areas are fields for 'Status', 'Assigned to', 'Due date', and 'Shared with'. At the bottom, there are status indicators for 'Errors (0)', 'Warnings (1)', and 'Information (0)'.



The screenshot shows the 'Inspection details' form. It includes fields for 'Inspection name' (Sample inspection), 'Assign to' (Jonathan Cunningham), and 'Due date' (May 5, 2023). Other fields include 'Pay Item' (204-02586), 'Form category' (Quality), and 'Form' (Geotechnical Instrumentation). Below these are tabs for 'Details', 'Comments', and 'Audit trail'. A section titled 'Geotechnical Instrumentation' contains expandable sections: 'Project Details', 'Pre-Inspection Notes', 'Settlement Plates', 'Standpipe Piezometers', 'Certification and Signature', and 'Inspection Comments'. At the bottom right are 'Save' and 'Cancel' buttons.

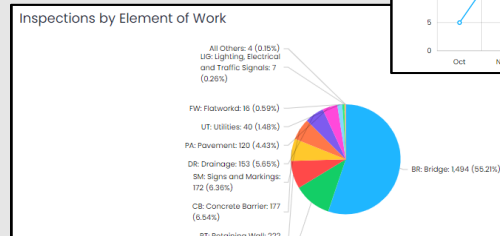
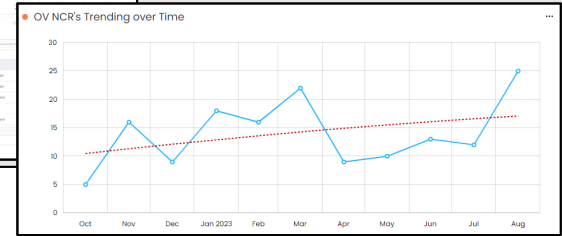
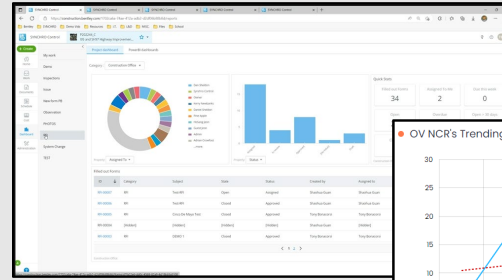


- Synchro Dashboard Development

- Dashboards created using metadata from inspection forms

- Examples will include:

- Approved Inspection Reports
- NCRs/CDRs trending over time
- Draw Request by Work and Activity ID



Project Schedule

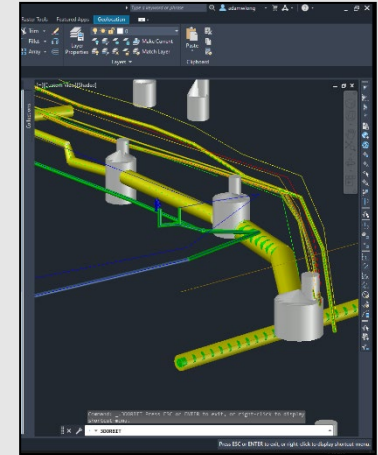
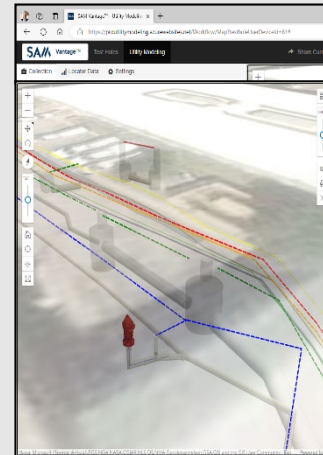
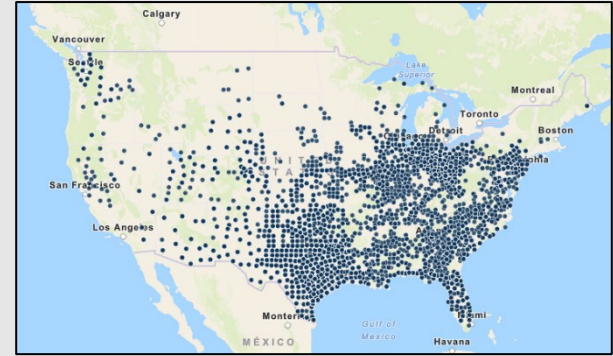
Work Date	Schedule Activity ID	Activity Name	Scheduled Start Date	Scheduled End Date
08/28/2023 03:59 PM	RD08915	Embankment - (089/90)	11/3/2023 08:00	11/28/2023 16:00
08/28/2023 01:46 PM	BR120154	Drill Shafts (Bent) - BR12-01	3/30/2023 08:00	5/25/2023 16:00
08/28/2023 01:44 PM	BR120259	Drill Shafts (Bent) - BR12-02	4/4/2023 08:00	5/25/2023 16:00
08/28/2023 01:40 PM	BR111237	Drill Shafts (Bent) - BR11-12	5/18/2023 08:00	5/19/2023 16:00
08/28/2023 10:36 AM	RW-S2A-21A-1	ERW-CNI-608 (RW-S2A-21A) - 05B - P1	5/22/2023 08:00	6/15/2023 16:00
08/28/2023 10:10 AM	RD07818	Rdwy Finishing (Perm Rail/Barrier/Etc.) (078.1)	1/9/2026 08:00	1/29/2026 16:00

Draw Request Information

Work Date	Estimated % Complete	Schedule Activity ID	Element Name
12/14/2022 12:00 AM	25	BR1080650	Bridge 108 B
06/16/2023 12:00 AM	100	BR1042517	DS-96-3525
09/18/2022 12:00 AM	20	TSS2	F-SHAPE BAR
09/08/2022 12:00 AM	20	TSS2	LPCB PLACED
05/18/2023 12:00 AM	25	RD1170	PERMANENT ROAD WIDENING EXCAVATION
05/25/2023 12:00 AM	100	BR1080647	R108 bent 6 cap



- SAM is the largest combined geospatial solutions and inspection services provider in the nation
- SAM Applied Technologies (AT) Group consists of Software Programmers, Surveyors, & Engineers
- Key Services:
 - Application Design and Implementation
 - Security and GIS Website Deployment Services
 - Mobile Application Development
 - Custom Programming and Workflow Design







- I-2/I-69C (retaining wall, DC-1, UAS)
- SEC Connector (TWG, columns/drainage, other technology)
- Approval for proof-of-concept forms and dashboard
- Possible long-term activities:
 - Merge LiDAR scans into Bentley ORD to document progress
 - Develop Quick Reference Guides (QRG)
 - District Training Materials
 - Develop testing forms
 - Tie inspection, testing, progress, and payment to Element of Work





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Bentley OpenRoads Designer
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Thank you!

