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Laser Scanning: Enhancing Productivity and Quality in Construction Management

Bimal Patwari

CEO

Leonidas Tzevelekas

Project Manager

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Speakers Info

Bimal Patwari
President

Pinnacle INFOTECH

Bimal Patwari is the 1st generation Entrepreneur and founder of Pinnacle Infotech Solutions, the acknowledged Global leader in providing innovative BIM solutions. Bimal is recognized for his contribution to the innovative use of BIM technology to improve efficiency and quality, reduce costs and wastages .

He has received several awards and recognition from Government and other industry associations for his entrepreneurship and pioneering contribution to the construction industry.

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Speakers Info

Leonidas I. Tzevelekas
Senior BIM Project Manager

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Leonidas is responsible for developing, implementing and delivering prestigious world class BIM projects for general contractors in the Middle East. Previously, he worked at one of the biggest contractors and was involved in the construction of major terminal buildings and bridge infrastructure of mega aviation projects.

Leonidas is currently working in one of the most prestigious project in Qatar in which he is extensively involved in usage of Laser Scanning for project monitoring.

Email : leonidas@

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Key Learnings

- **Innovative use of laser scanning for**
  - Improving construction quality
  - Improve site safety
  - Getting ahead of schedule
- **Laser scanning for construction progress management**
- **Laser scanning for inspection and approvals**
- **Laser scanning for quantity estimation and contactor bill approval**

Send your questions or write to us at bpatwari@pinnaclecad.com

Laser scanning

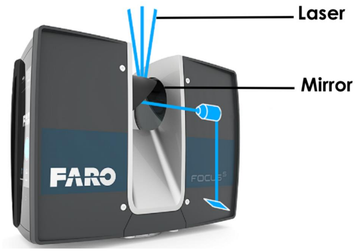
Non-Contact, Non destructive , Digital Capture of exact size and shape in 3-Dimension

Capture 3D Model

HDR Photos

Highly Accurate Field Representation

Quick Capture Project Details



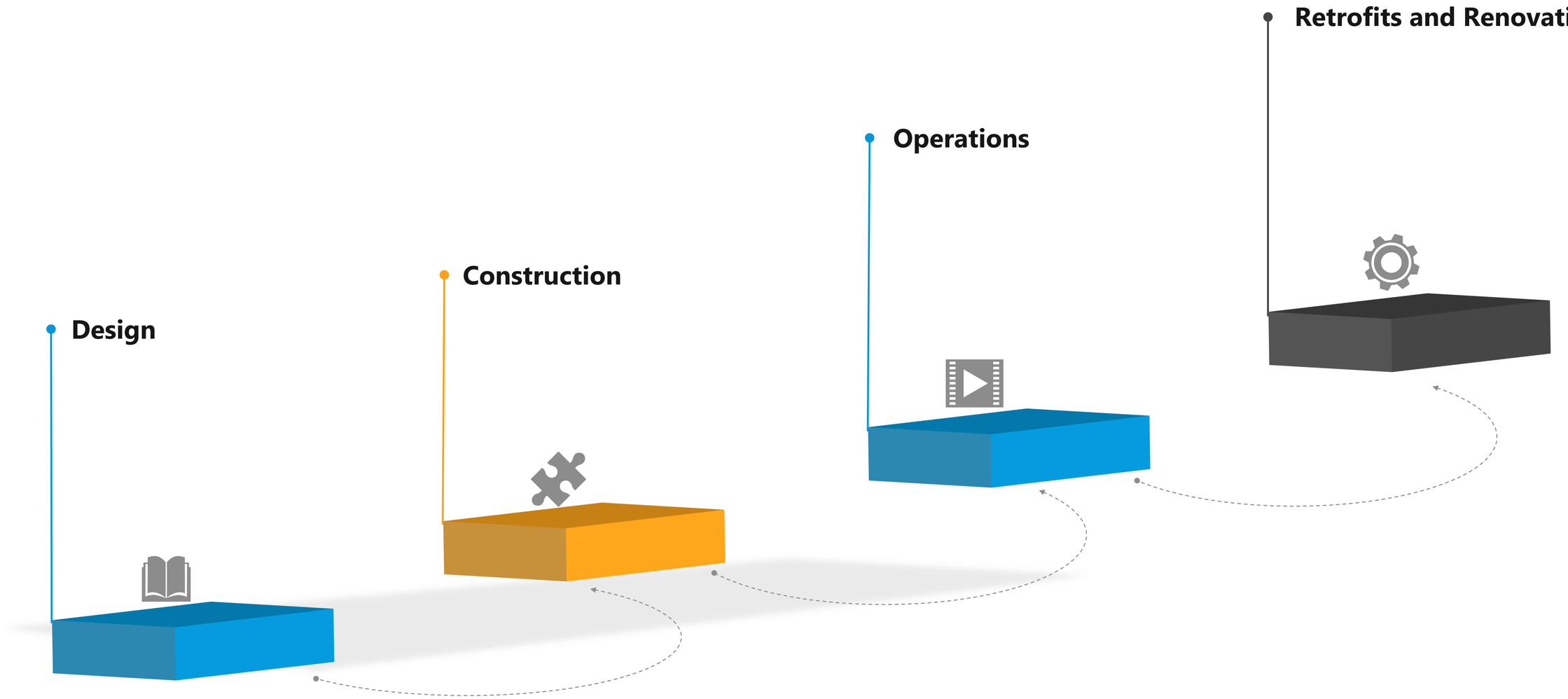
Capture RGB Values

Interoperability

Collection of Millions of Points

Measurements and Control

Laser Scanning Across A Project's Lifecycle

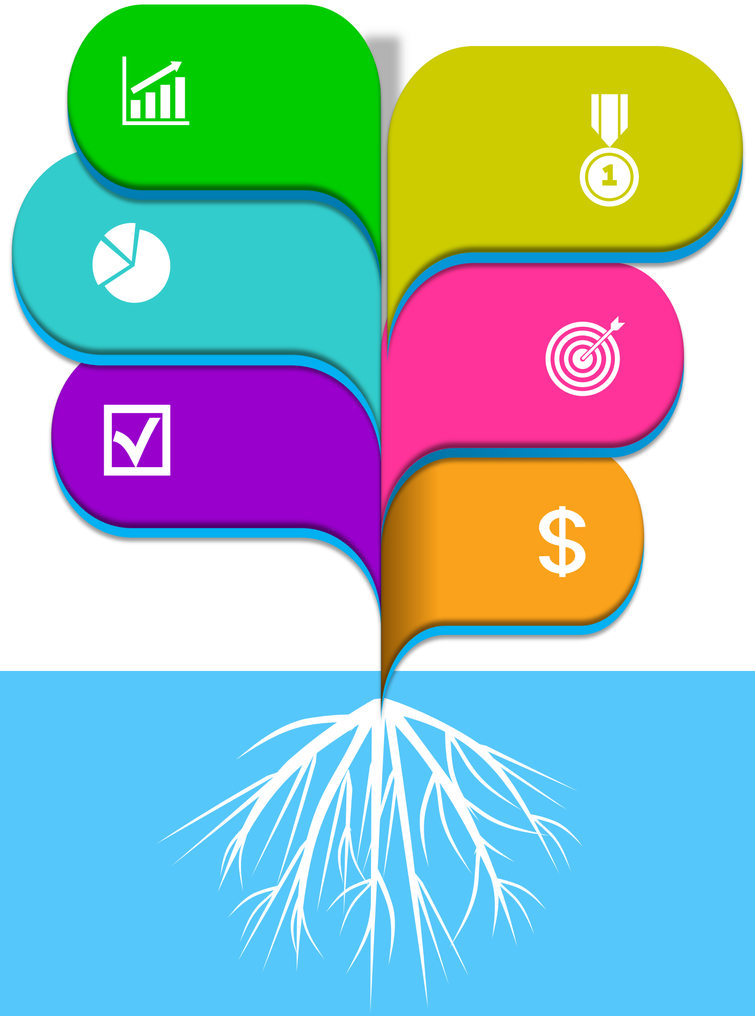


Benefits

01 Quality Improvements

03 Elimination Of Rework

05 Streamlines Coordination



02 Fast And Accurate

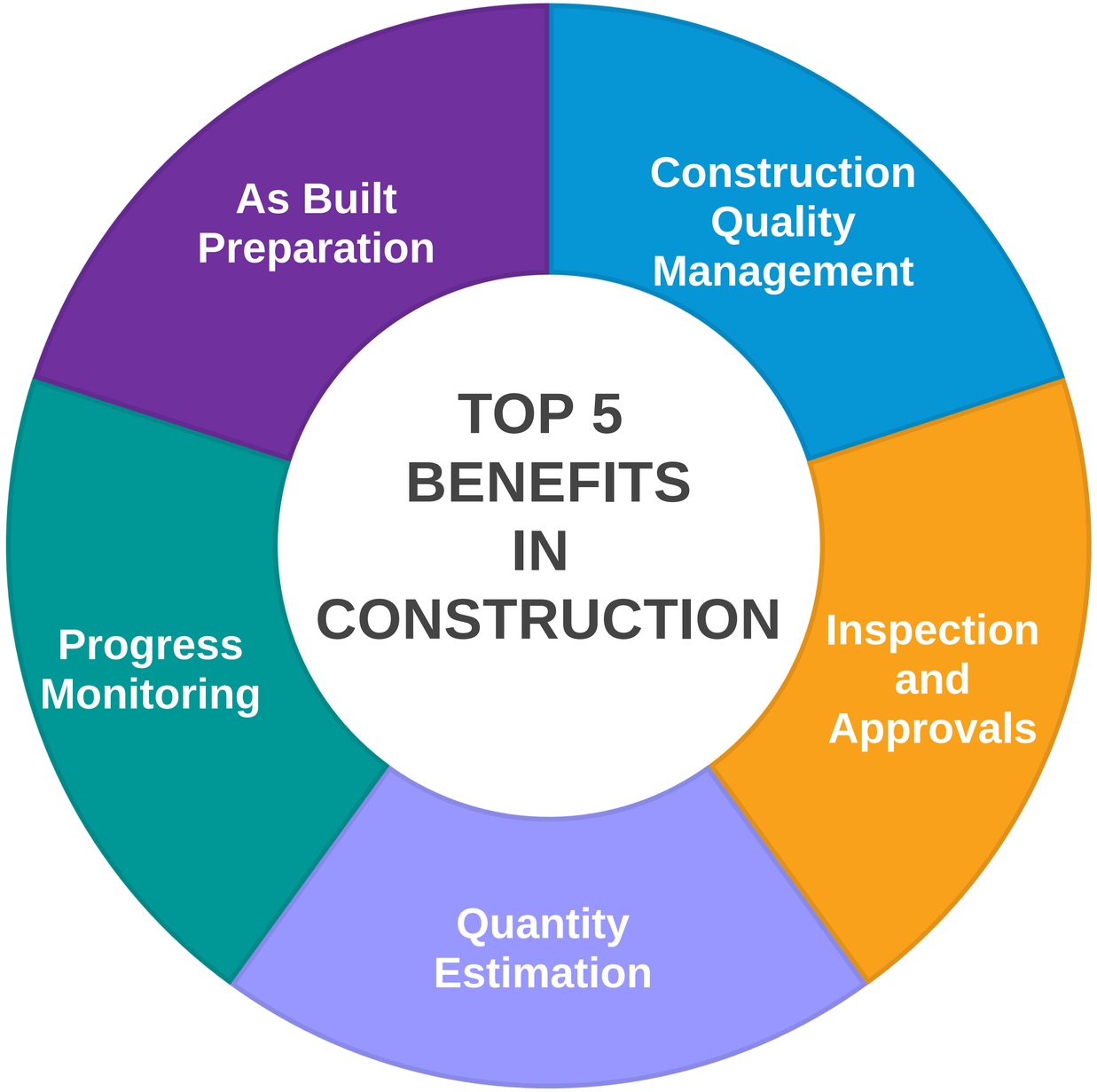
04 Eliminate Guesswork

06 Lowering Risk And Costs

Traditional Method vs. 3D Laser Scanning

- ❑ laser scanning **±2mm accuracy**
- ❑ Laser Scanning takes **70-75% less** time
- ❑ Provides full evidence of the inspection by creating **error heat map on point cloud model**

Structure Members			Traditional Method (Total Station)			3D Laser Scanning			Manhours Savings
Image	Name	Total Members	Points Collected	Accuracy	Total Hours Taken	Points Collected	Accuracy	Total Hours Taken	
	Concrete Plinth	24	Points on vertices to create Geometry	1.Manually marked points create errors 2. Inspections on limited points	192 (8*24)	Millions of Points (Full Model)	1. minimize errors up to less then ±2mm 2. Inspections on every point with same accuracy	48 (2*24)	**144 hr.**
	Steel Frames	48			960 (20*48)			384 (8*48)	**576 hr.**
	Steel Truss	24			360 (16*24)			120 (5*24)	**264 hr.**


TOP 5
BENEFITS
IN
CONSTRUCTION
As Built
Preparation
Construction
Quality
Management
Inspection
and
Approvals
Quantity
Estimation
Progress
Monitoring

Types of Scanner

	Airborne Laser Scanner	Stationary Terrestrial Laser Scanner	Mobile Terrestrial Laser Scanner	Handheld (Industrial)
Ideal Usage	• Exterior mapping • Long/Linear Projects • Large scale mapping	• Interior high-density high accuracy scans	• Exterior high accuracy longer range scans	• Top-quality, high-precision • Suitable for indoor scans
Accuracy and Range	• +/- 10 CM, depending on conditions • Range 3.000 feet (typically flown at about 3,000 FT)	• +/-2MM • Range 60 to 120 meters, depending on conditions	• +/-2MM • Range 150 to 330 meters, depending on conditions	• +/-0.5mm • Range up to 110 meters, depending on conditions
Scanners				

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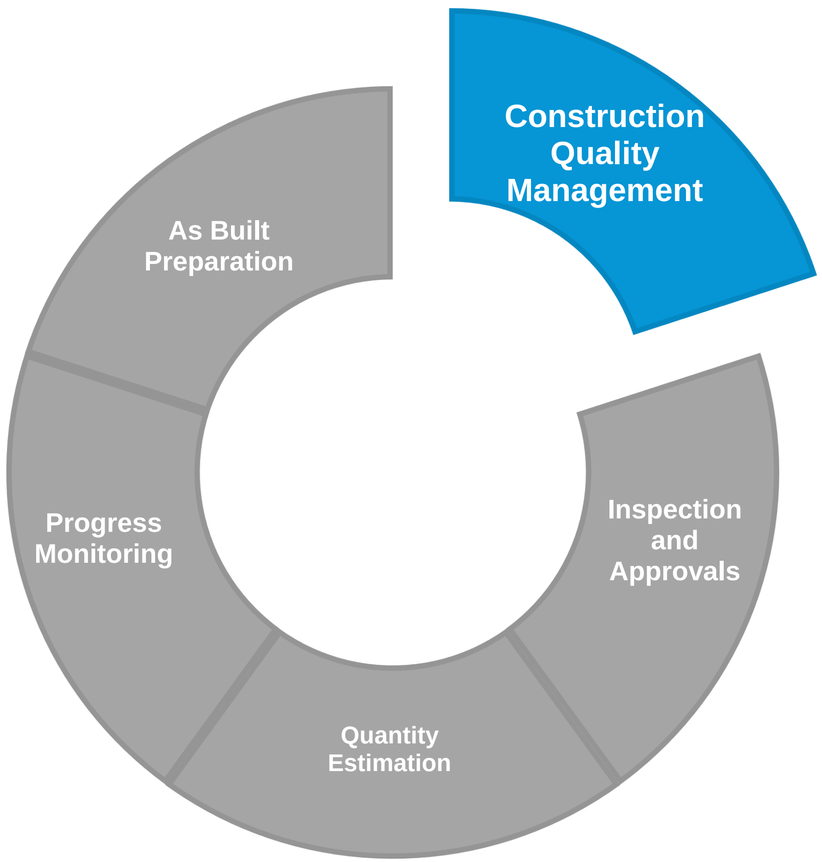
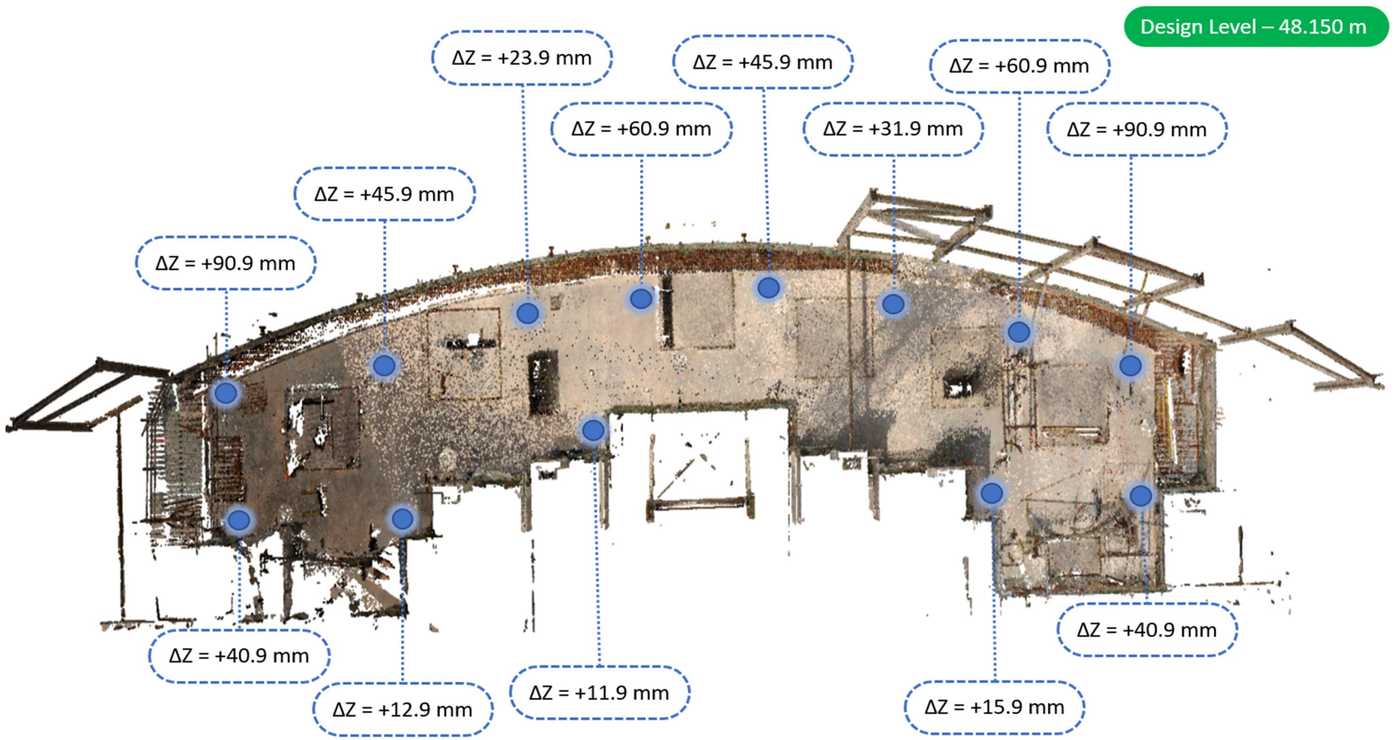
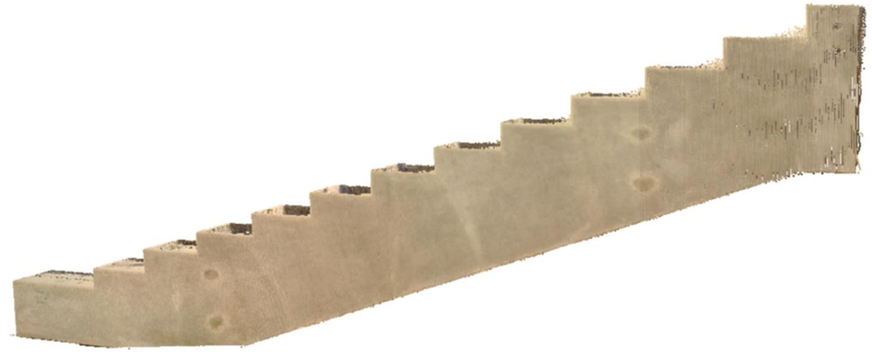
Laser Scanning Applications in Construction

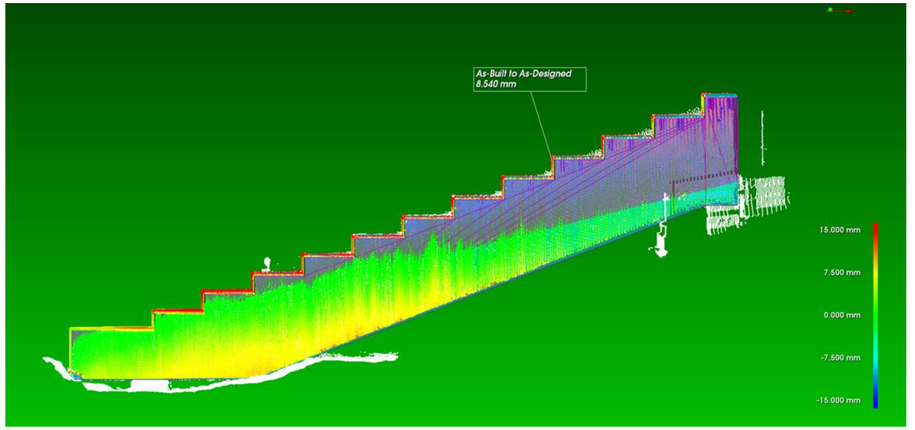


- Processing of millions of closely spaced points to capture actual level and member orientation.
- Deviation analysis extracted by point cloud facilitates erection and minimize the overall tolerance of combine structure during the erection stage.
- Improves coordination and collaboration on jobsite, leading to faster and better decision-making saving time and cost.

Leveling and Alignment Control

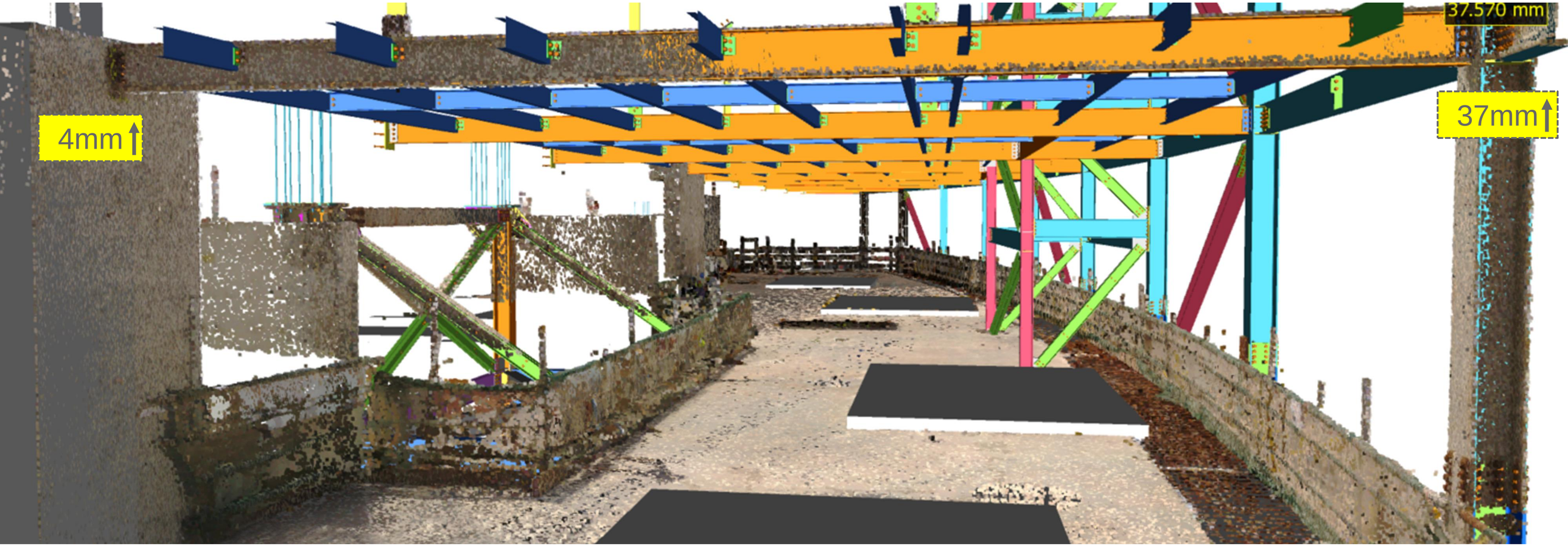






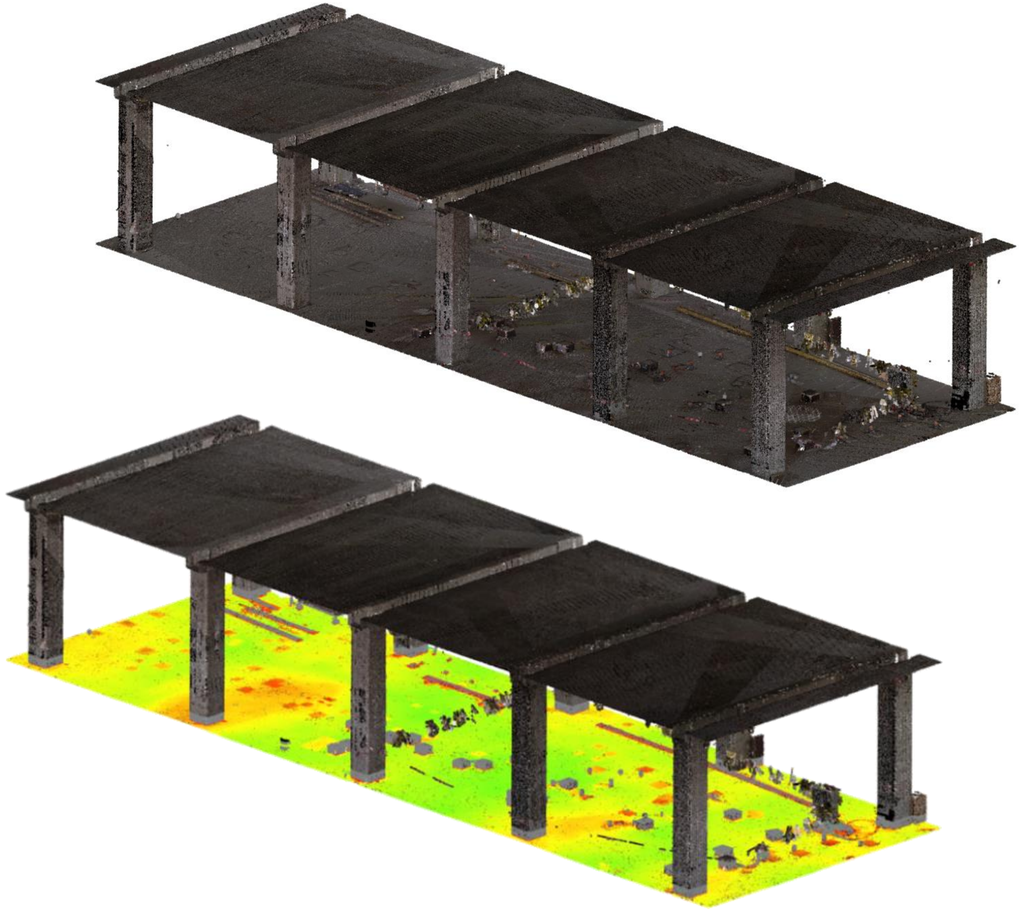
- Feedback and evaluations during erection staging. It fine-tunes and delivers precise installation of precast/prefabricated elements in the field

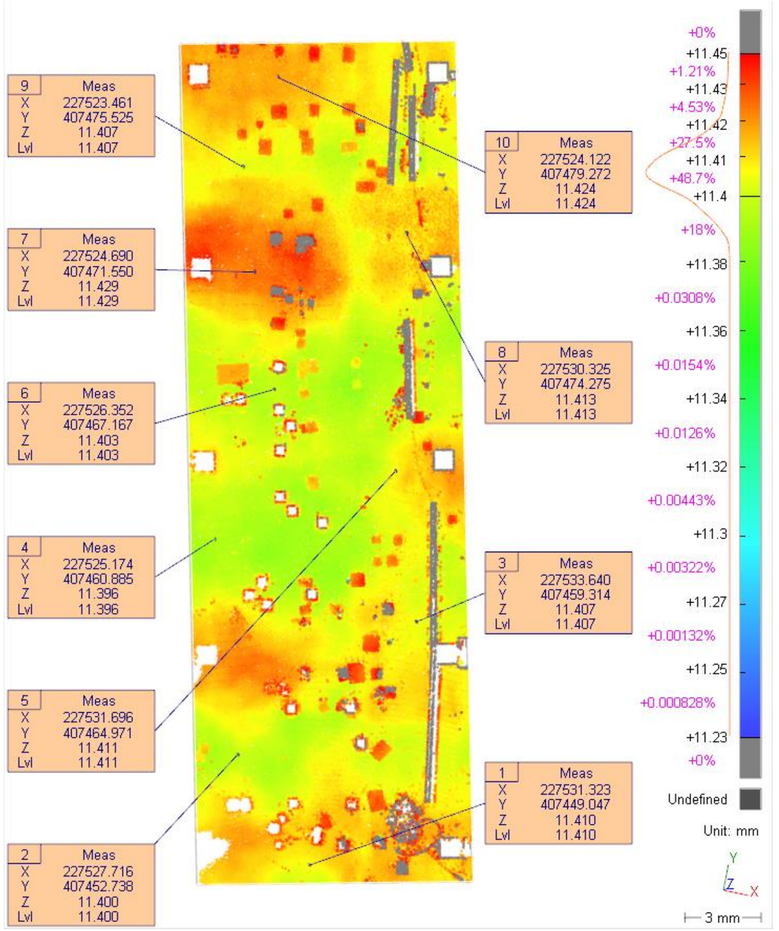
Deviation Analysis



- Steel beams are important part of main structure and needs to be in place. Laser Scanning provides the clear understanding on the geometry of the beams
- The top Steel beam is connected to the core wall from one side and with a steel column from another side which is subjected to pre-camber to set out the structure after full load consideration

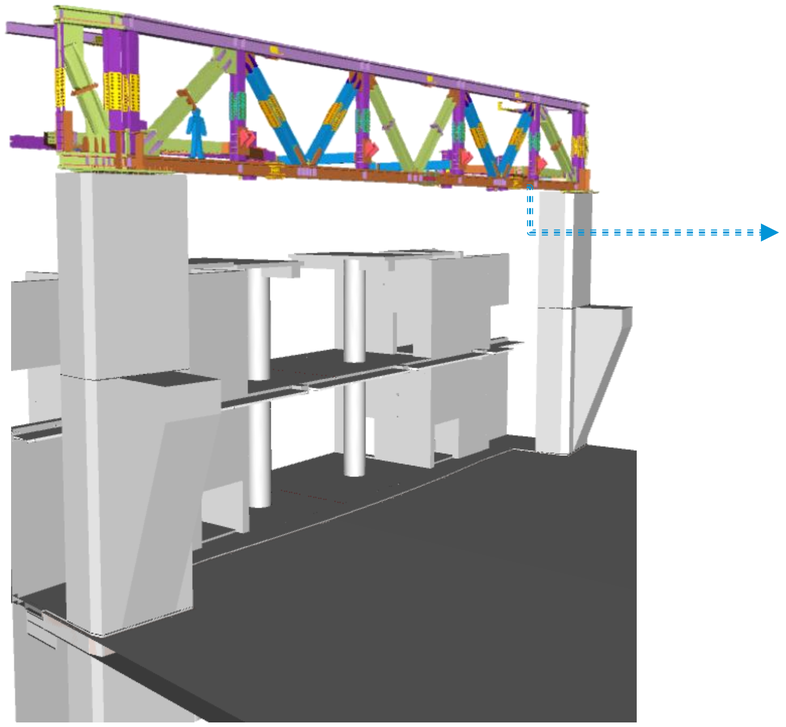
Leveling and Alignments – Slope Analysis on Slab

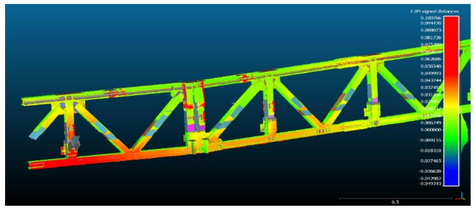


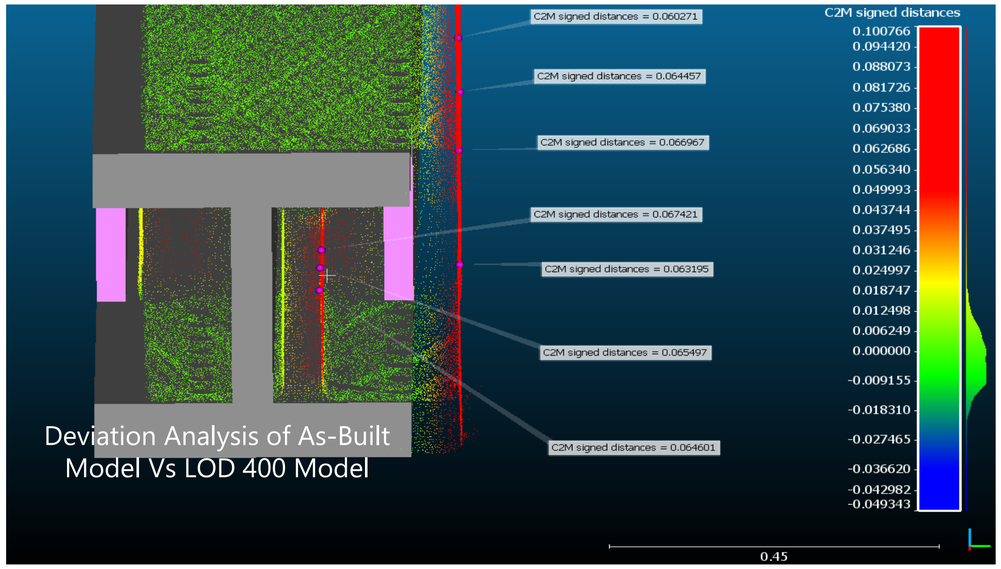


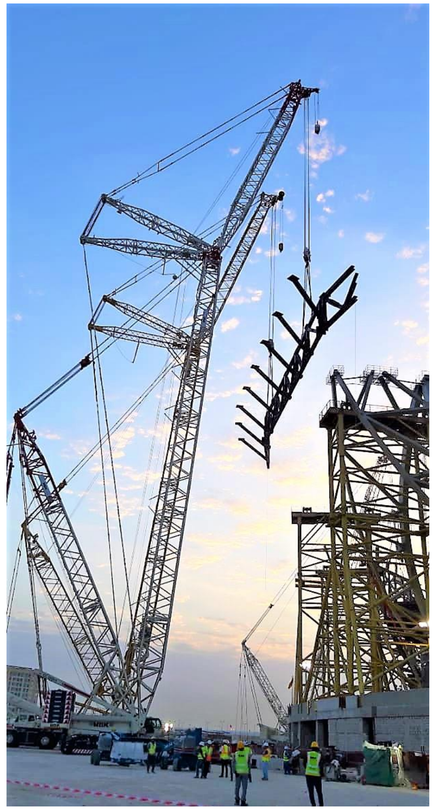
- **Slope analysis on the concrete slab shows clear understanding using heat map**

Deflection Monitoring of Long Span Structures - Steel Trusses



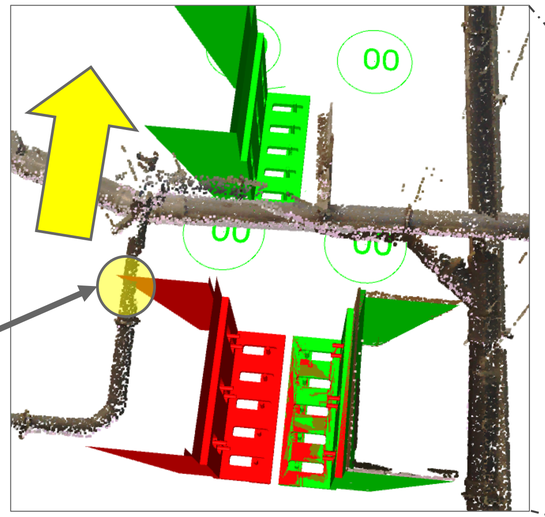




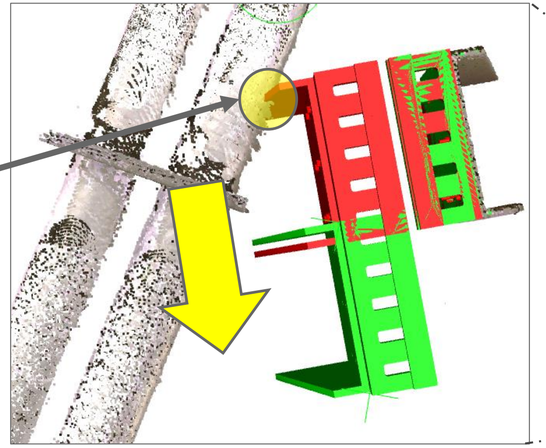


- ❑ **Defective construction is easily identified by reviewing the point cloud in conjunction with high resolution of 360 color photos obtained by 3D Laser Scanning**
- ❑ **Insight into a construction project by analyzing and comparing what has actually been built against the design model**

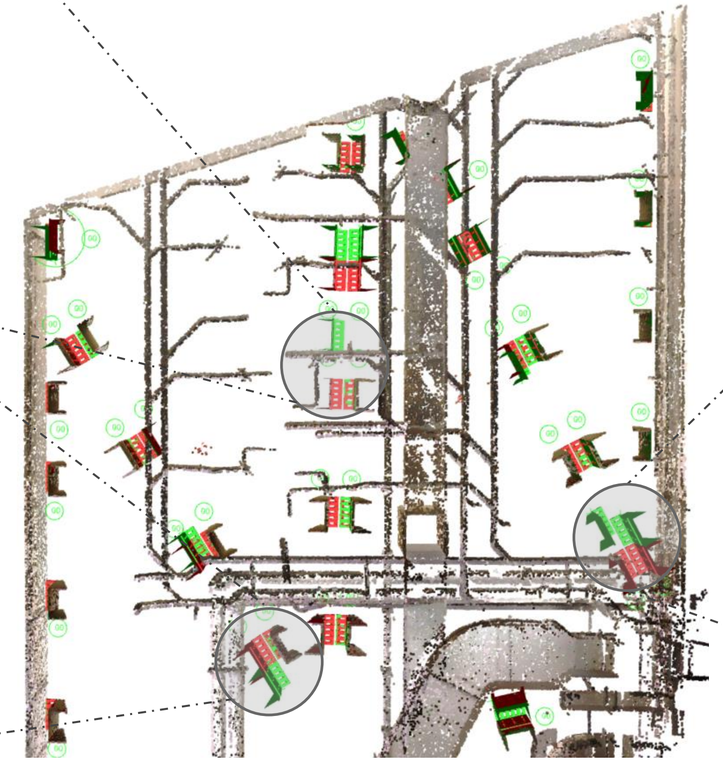
Façade Brackets Coordination

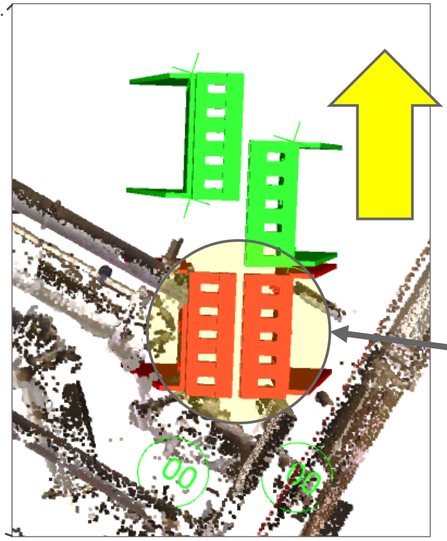


Clashing



Clashing





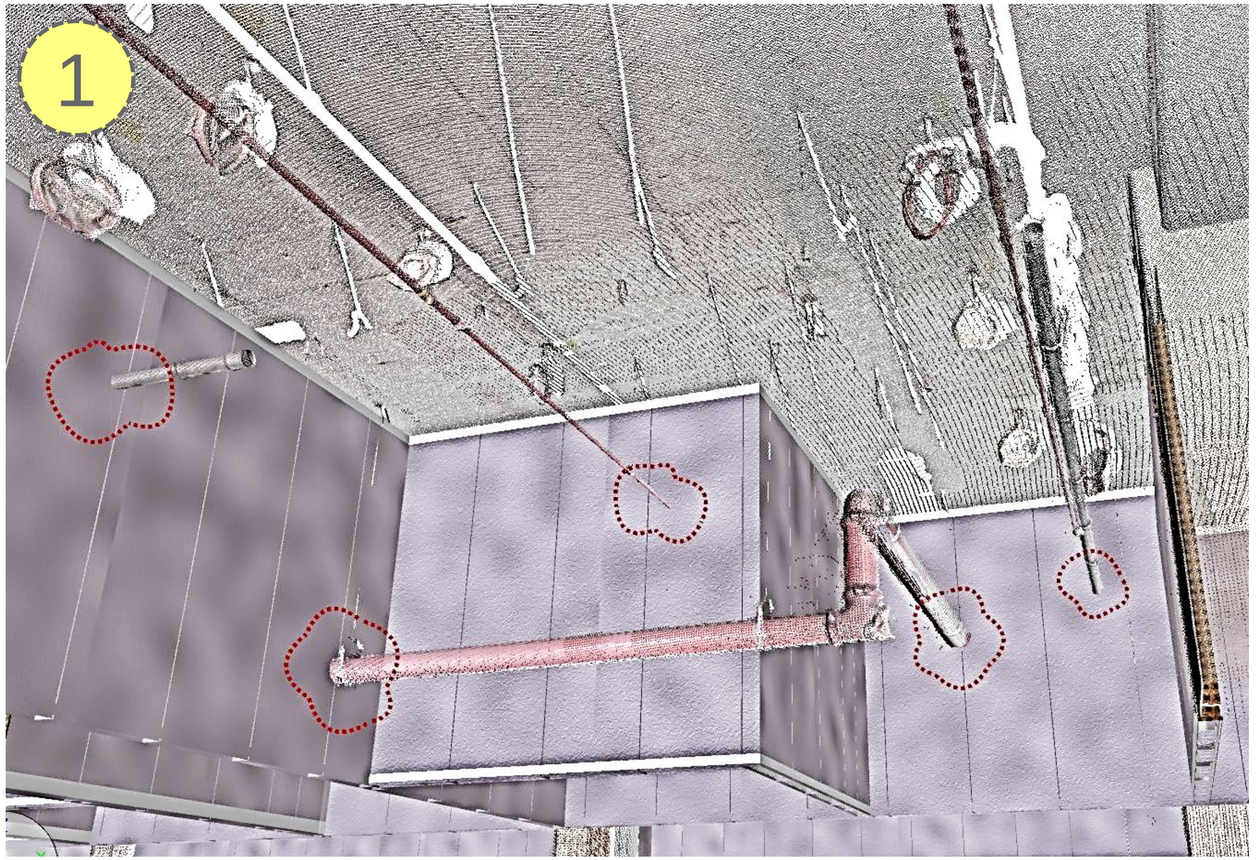
Clashing

Bracket shifted to remove Clashes

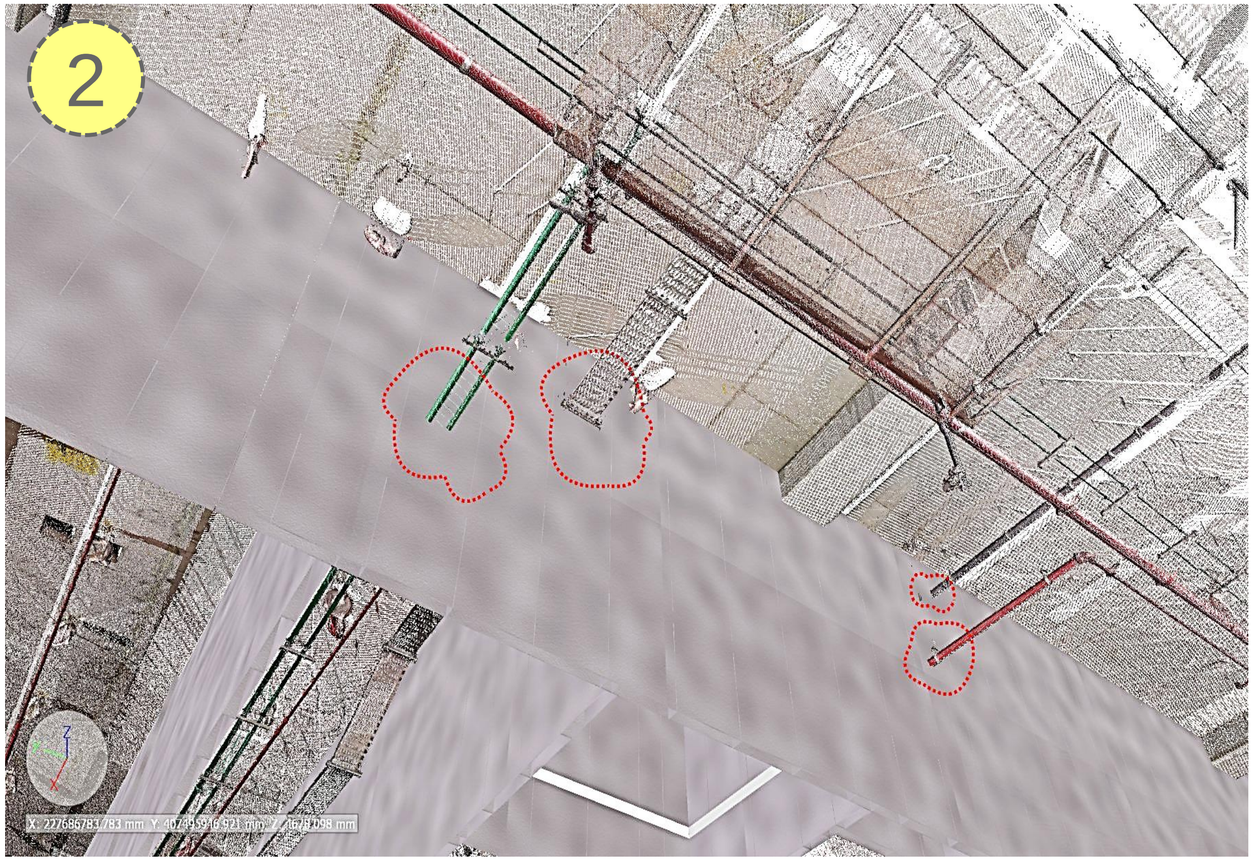
Bracket Location After Design Change clashing with As-Built CHW pipes

Laser Scanning For Coordination between Services

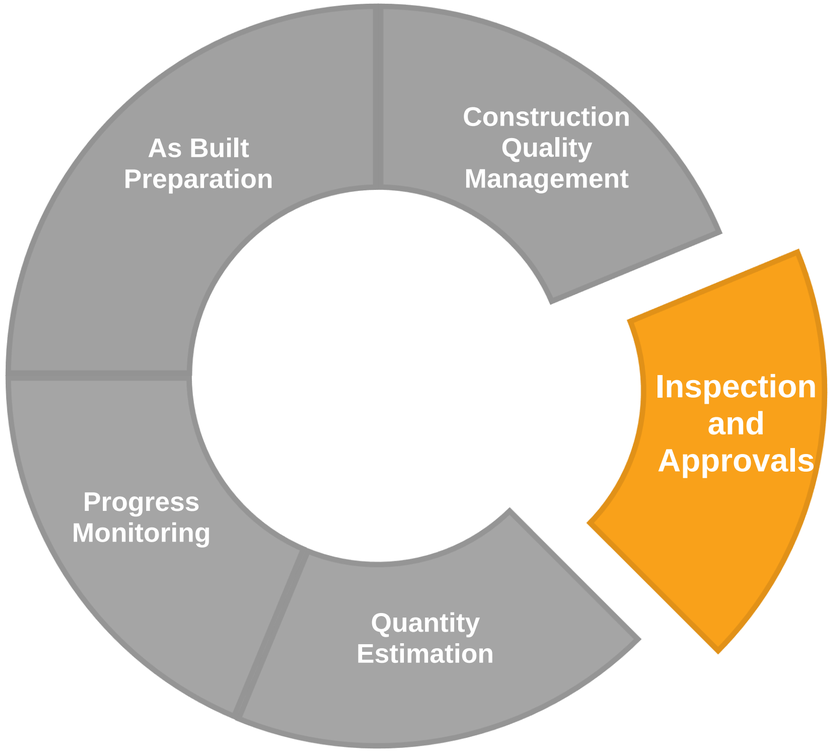
Coordination b/w As-Built MEP Services and As-Design AAC Panels



Clash between
As Built Fire Protection Pipe & As Design AAC Panels for Cutouts

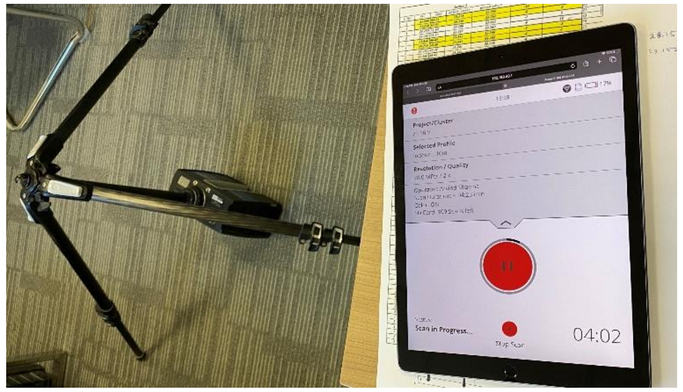


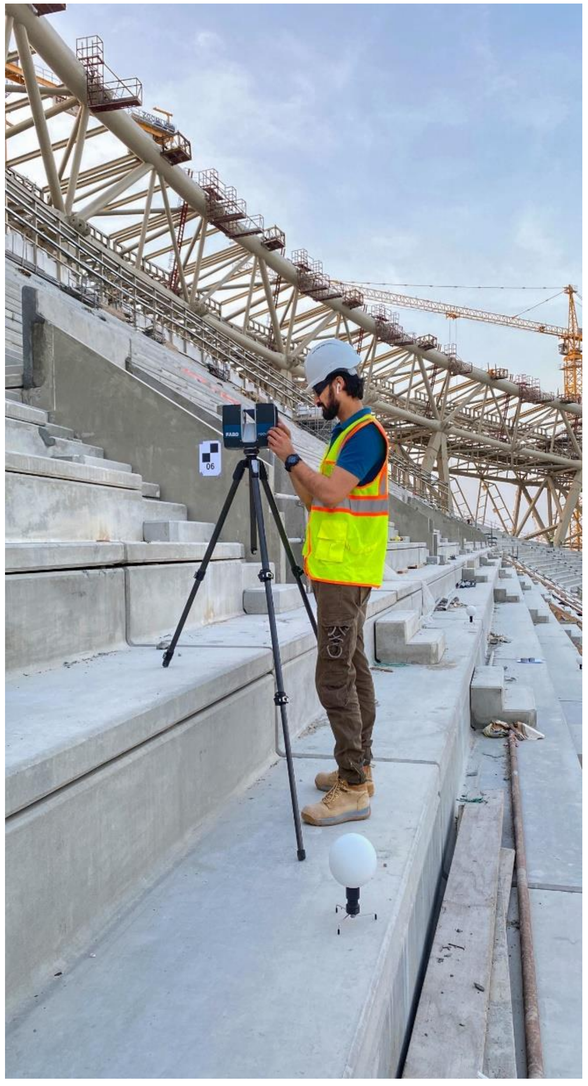
Clash between
As Built Drainage, Mechanical, Fire Protection Pipe, Cable Tray and As Design AAC Panels for Cutouts



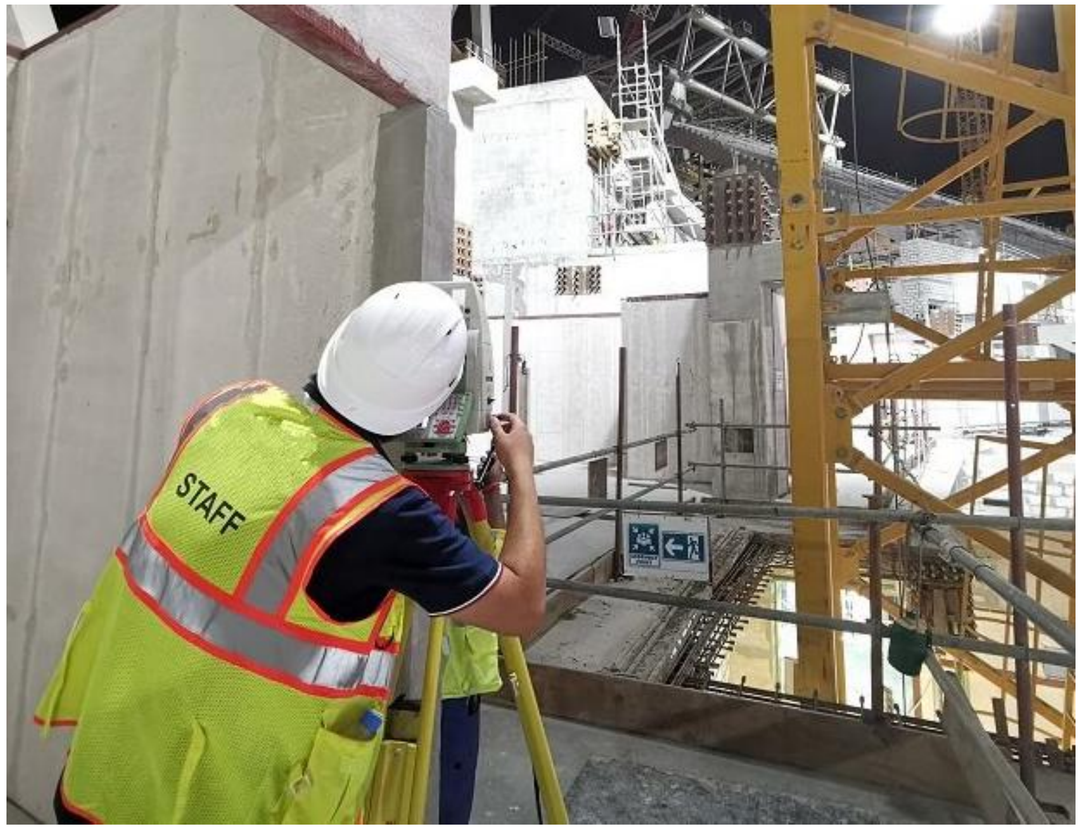
The overlay of the LOD 400 models versus the collected point cloud creates a composite model that clearly reflect the deviations between the as-designed and as-built stage.

Scanners Locations and Accuracy Control





Digital Inspection Methods



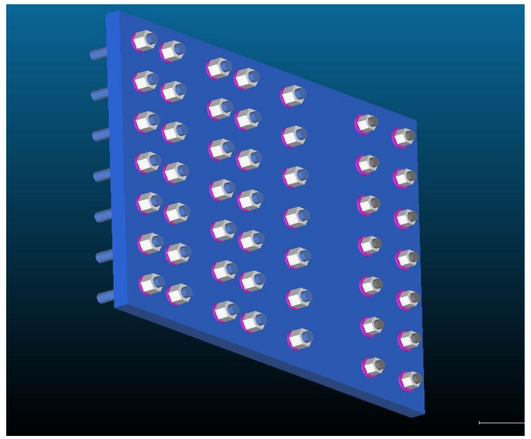
Traditional Method –Total Station

Point Cloud Output from Laser Scanning

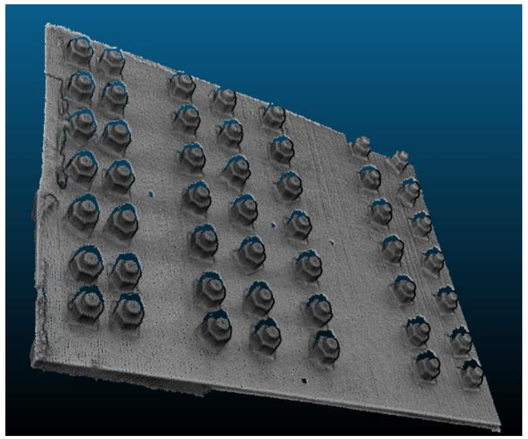
	Name	Traditional Method Total Station	3D Laser Scanning	Manhours Savings
Time	Embedded Steel Plate Bolt Verification	2*12(No. of Plates) = 24 hr.	3 hr.	21 hr.

Laser Scanning for Inspection Purposes

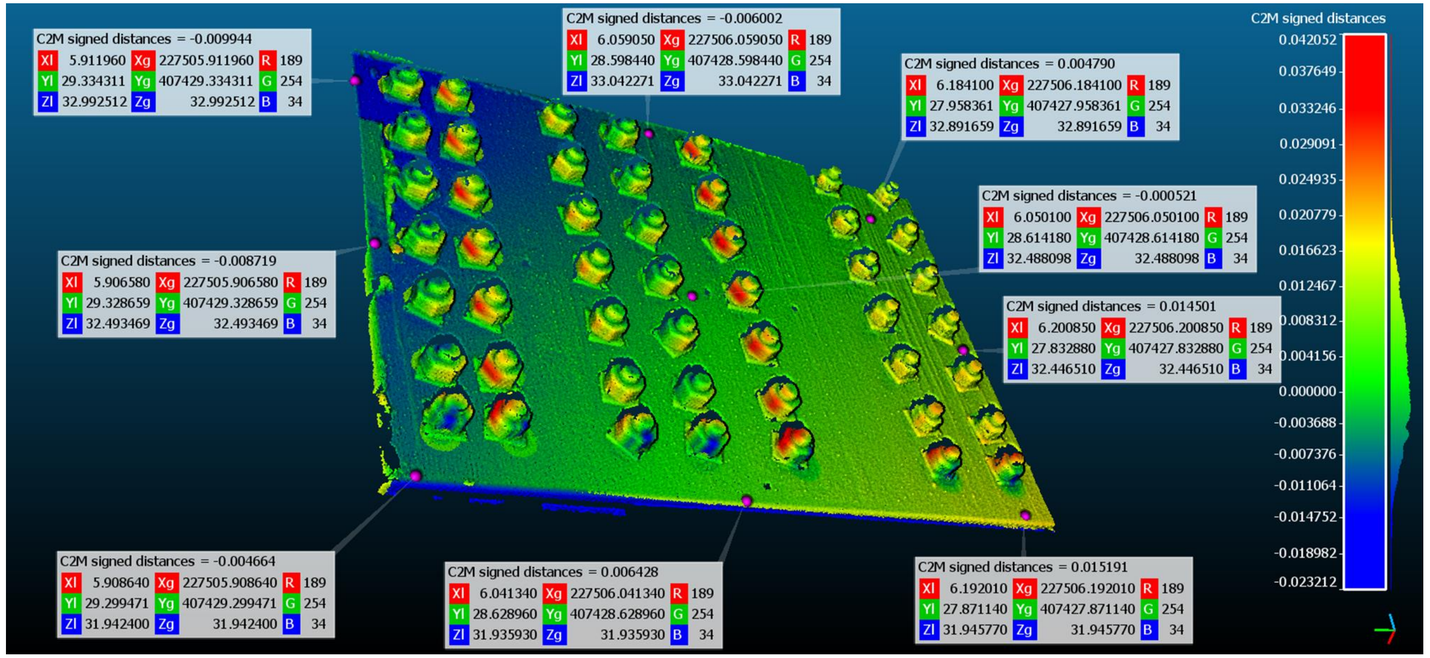
Inspection of Embedded Plates



On-Site Scanning of Steel Part



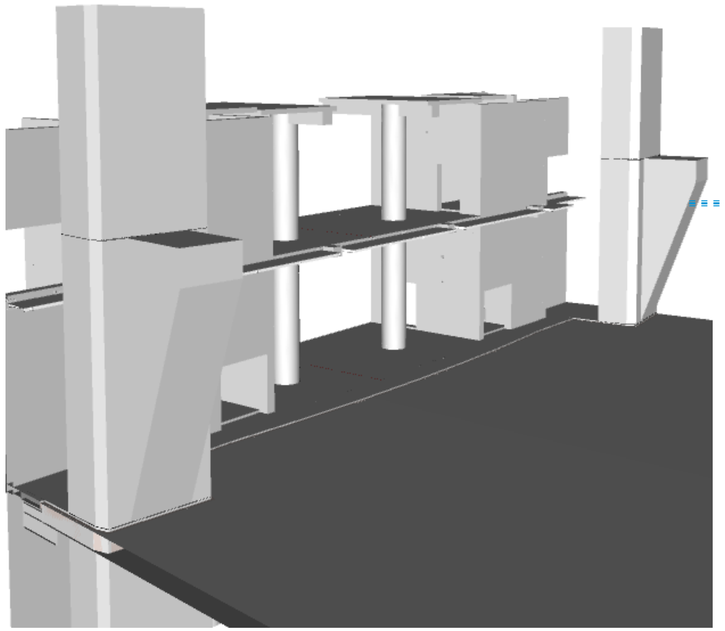
Point Cloud Model



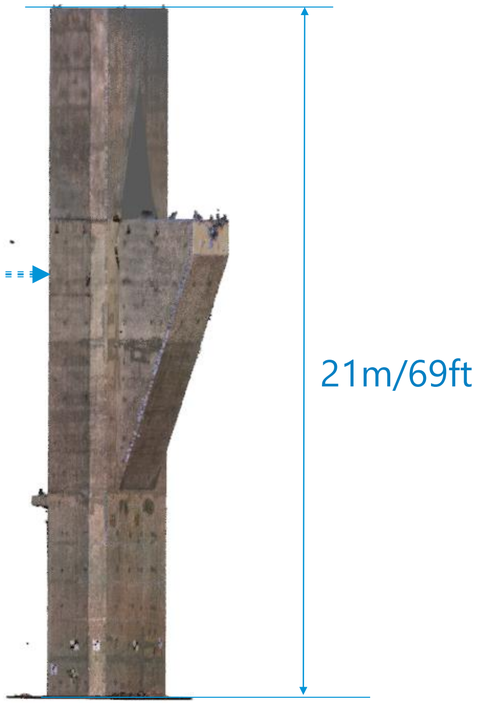
Deviation Analysis of As-Built Model Vs LOD 400 Model

Pinpoint analysis & verification of steel elements before assembly & installation using 3D laser scanning

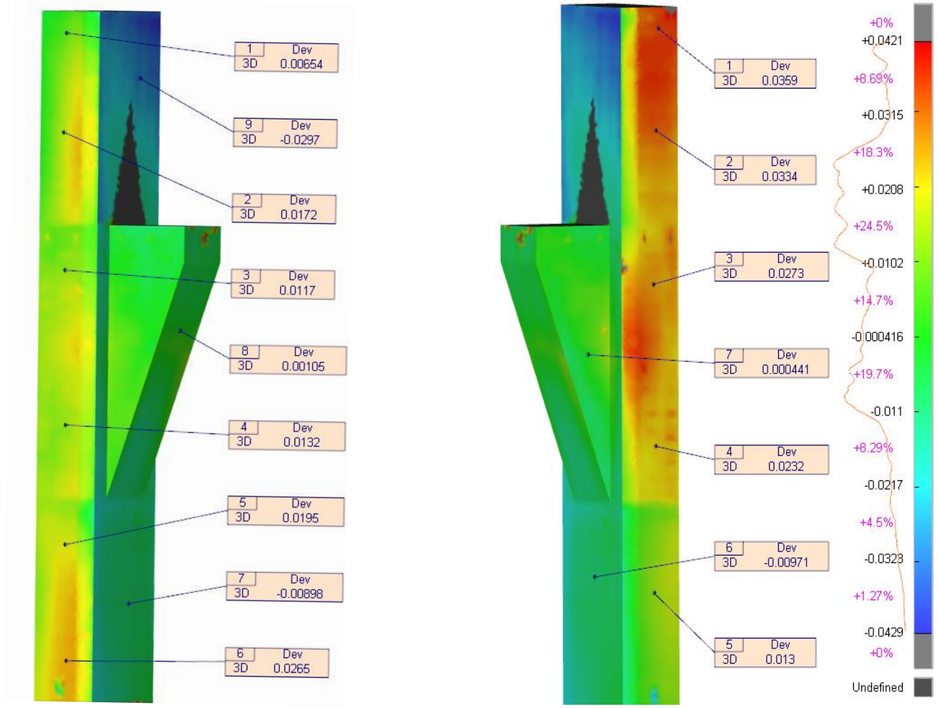
Deflection Monitoring of Long Span Structures - Concrete Buttresses



Concrete Buttresses BIM Model



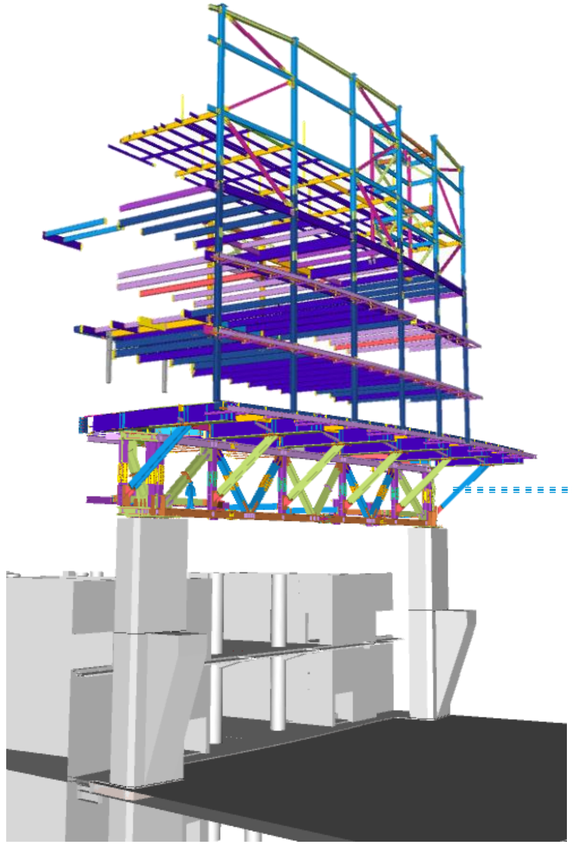
Concrete Buttresses Point Cloud

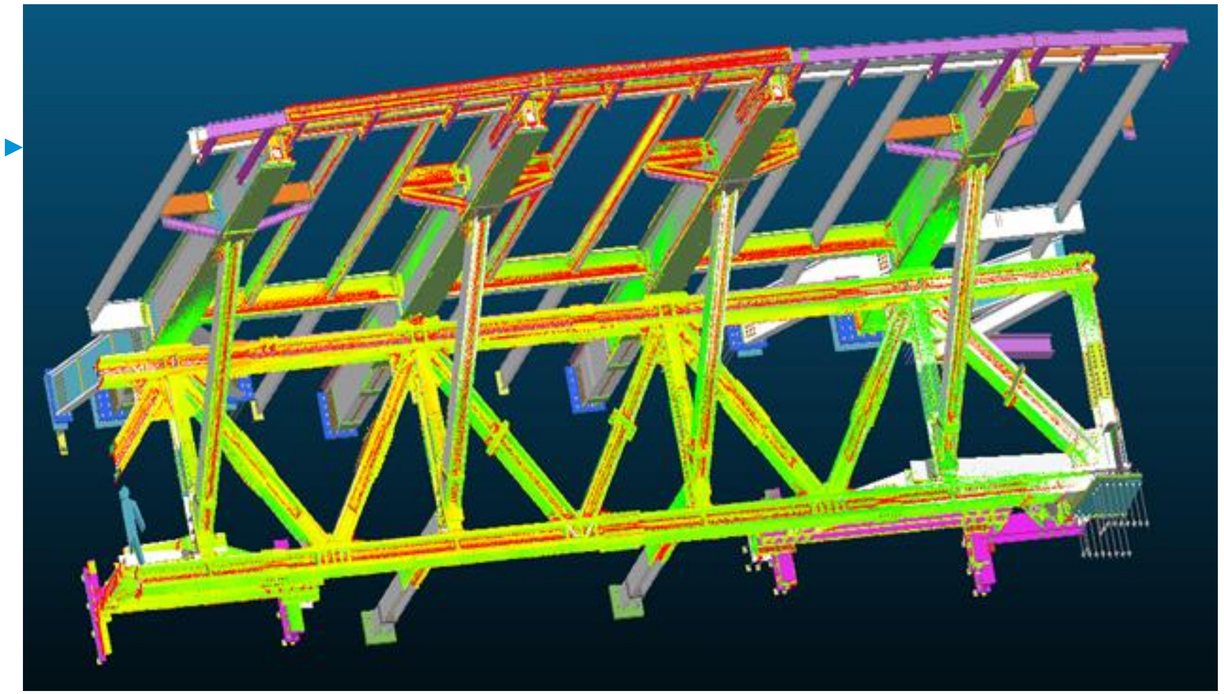


Deviation Analysis of As-Built Model Vs LOD 400 Model

- ❑ **Generation of point cloud versus design BIM Model overlays capturing outputs of deflection mode paths of long span structures**
- ❑ **Detailed representation of structural elements deformation under various stages of a Project**

Deflection Monitoring of Long Span Structures - Post Erection Analysis

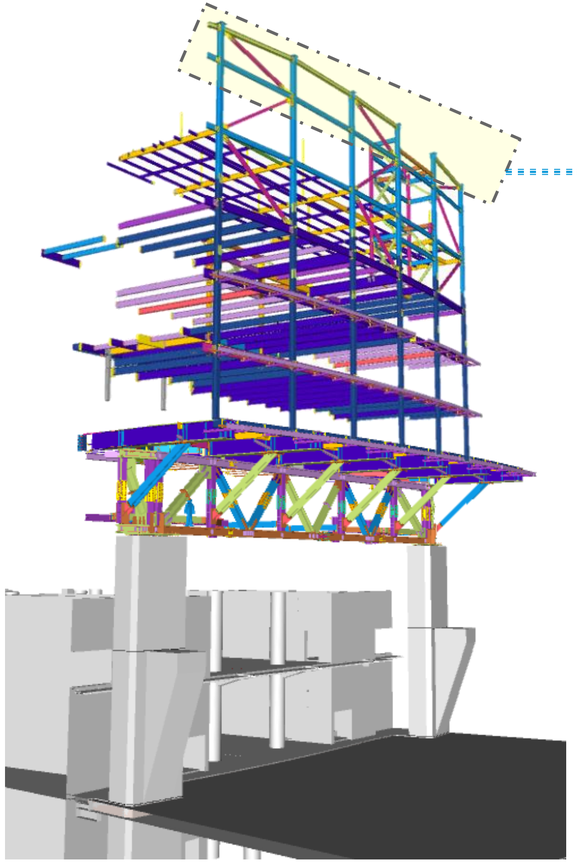


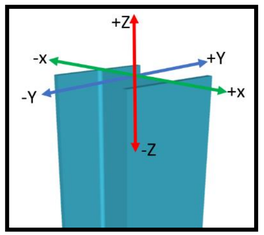


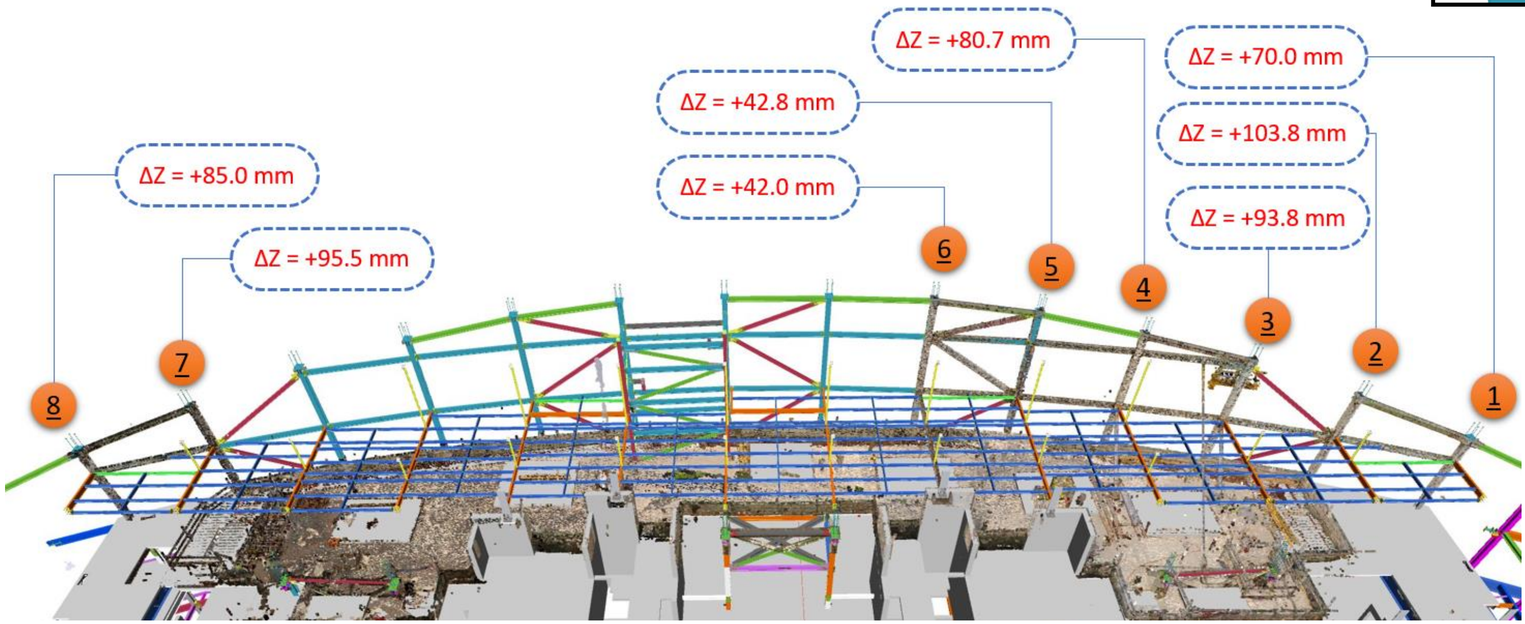
Deviation Analysis of As-Built Model Vs LOD 400 Model

- **Continuous deformation under construction/service load enables to evaluate and validate all assumptions made by designers against serviceability criteria of structural codes**

Deflection Monitoring of Long Span Structures - Post Erection Analysis





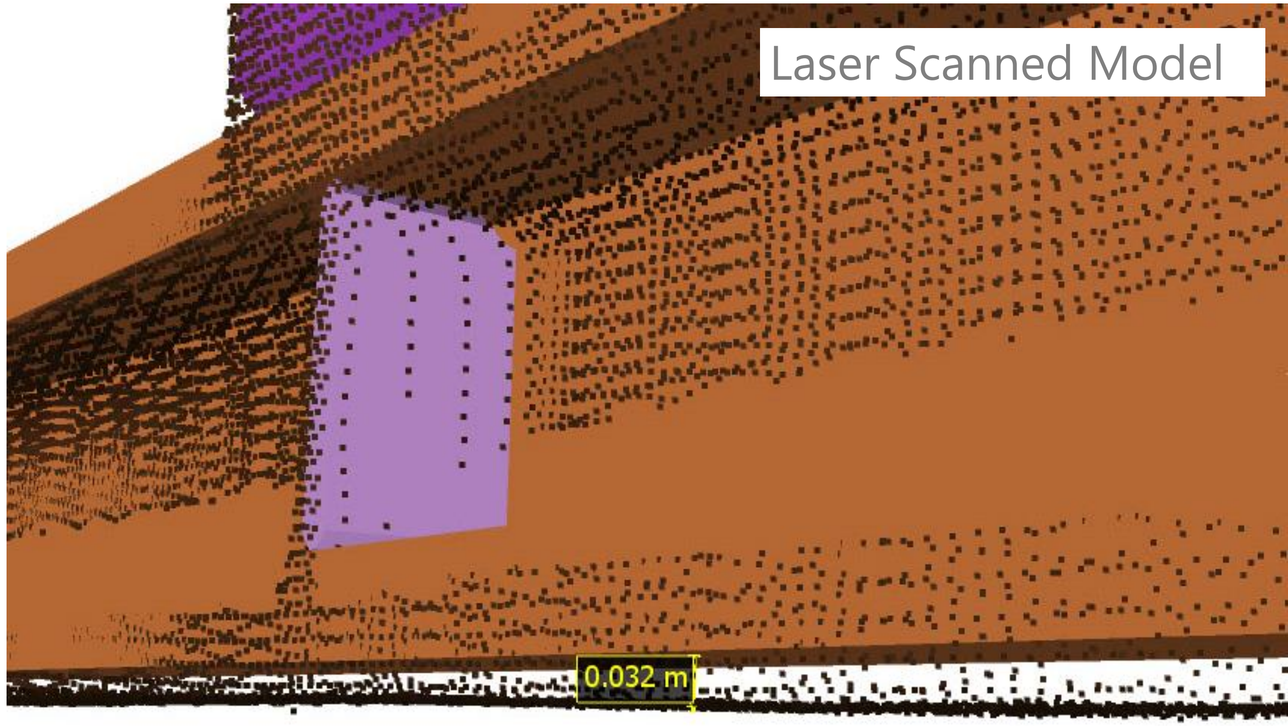


- **Comparison of point cloud versus the BIM model is made using a point to point verification software that proved extremely powerful in the deviation analysis workflow we used**
- **General Contractors and inspectors used the same methodology for their internal quality assurance and quality control procedures**

Thickness Measurement of Fire Proofing

Conventional Method

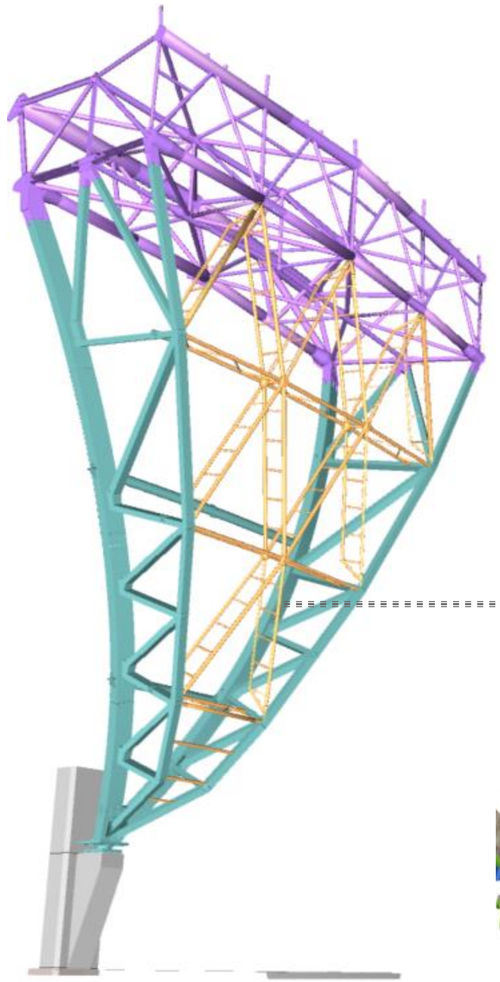
In Conventional Method, thickness of various fire proofing is measured by Fireproofing Thickness Gauge

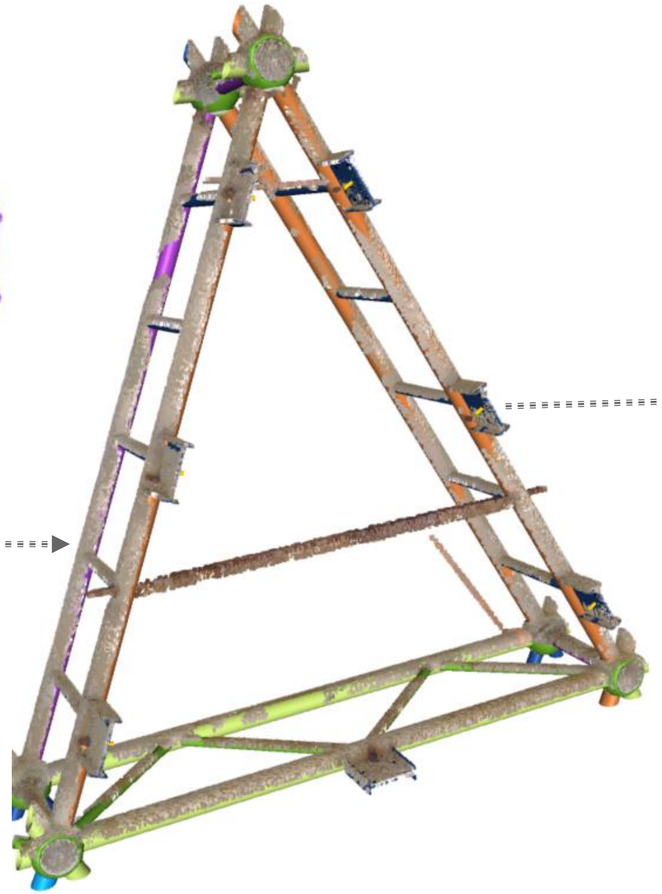


Laser Scanning Method

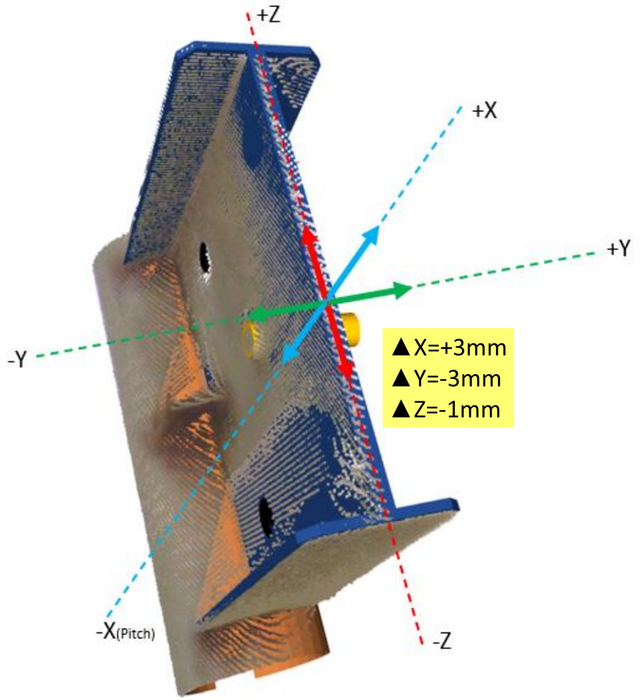
Laser Scanning provides clear As-Built model after application of fire proofing. Thickness can easily be measured in BIM environment

Laser Scanning for Inspection





Vessel Steel

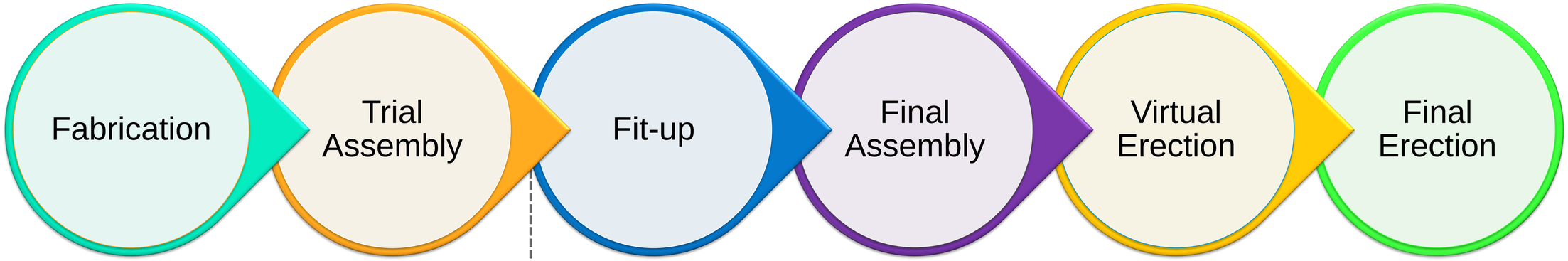


Façade Bracket

Façade Erection

- ❑ **Façade Bracket installed in place within the allowable tolerance**
- ❑ **It helps to validate the installation procedure for huge number of brackets**

Roadmap of Steel & Facade Structure Delivery

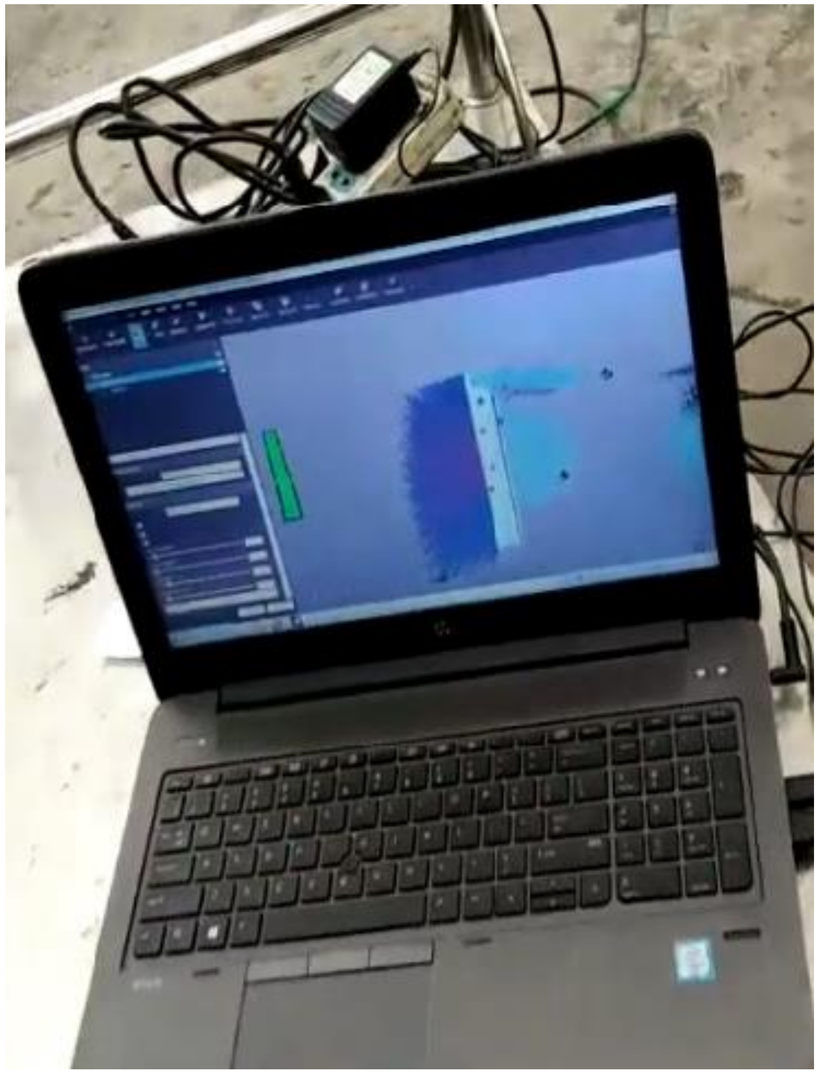


Off-Site Scanning Controls

On-Site Scanning Controls

Fabrication

- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection

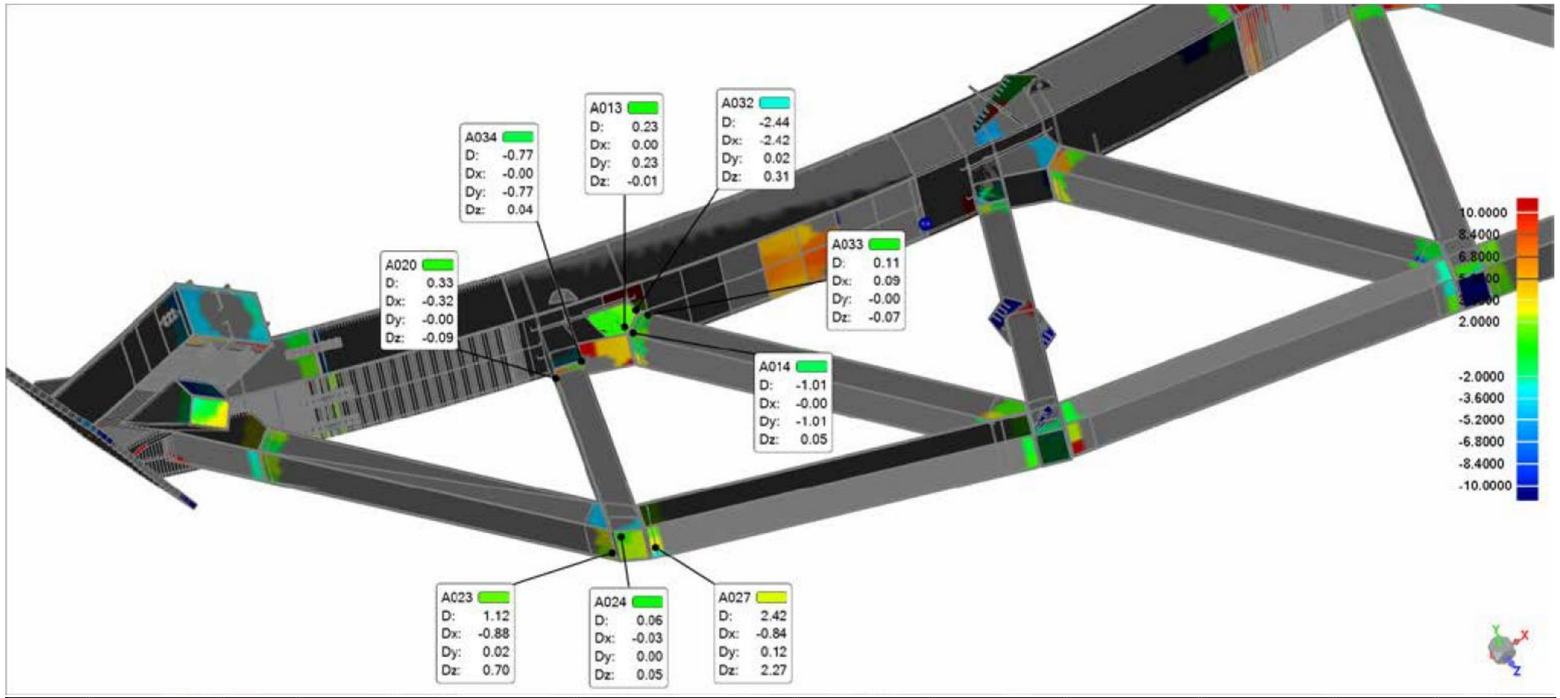


Generative Model

3D Laser Scanning for Web Chord

Trial Assembly

- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection



Item	Deviation	State	Tolerance	Refer X	Refer Y	Refer Z	Deviation X	Deviation Y	Deviation Z	Test X	Test Y	Test Z
A013	0.23	Pass	±3	84864.06	-322.24	-831.09	0.00	0.23	-0.01	84864.06	-322.01	-831.10
A014	-1.01	Pass	±3	84906.49	-313.96	-667.05	-0.00	-1.01	0.05	84906.49	-314.97	-667.00
A020	0.33	Pass	±3	83632.94	-441.40	-726.14	-0.32	-0.00	-0.09	83632.62	-441.40	-726.22
A023	1.12	Pass	±3	82811.76	-718.21	2144.57	-0.88	0.02	0.70	82810.88	-718.19	2145.27
A024	0.06	Pass	±3	82957.81	-306.81	2252.47	-0.03	0.00	0.05	82957.78	-306.81	2252.52
A027	2.42	Pass	±3	83352.17	-642.10	2483.28	-0.84	0.12	2.27	83351.32	-641.98	2485.54
A032	-2.44	Pass	±3	85166.21	-415.94	-1044.51	-2.42	0.02	0.31	85163.78	-415.92	-1044.20
A033	0.11	Pass	±3	85259.47	-400.15	-858.85	0.09	-0.00	-0.07	85259.56	-400.16	-858.92
A034	-0.77	Pass	±3	84048.68	-312.61	-679.46	-0.00	-0.77	0.04	84048.68	-313.38	-679.42

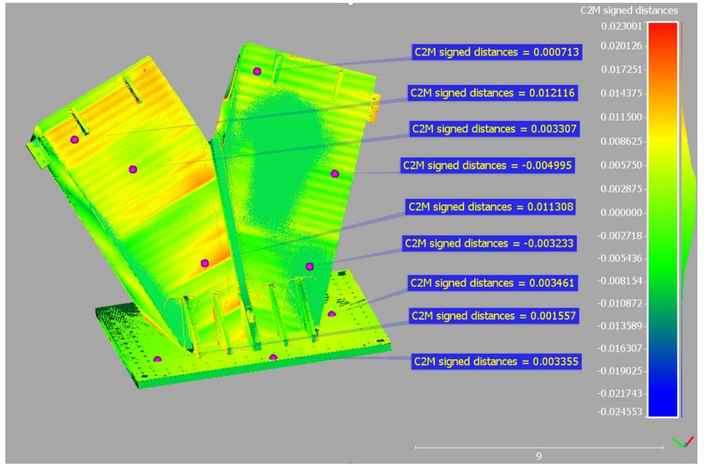
On-site Inspection After Shipping

- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection

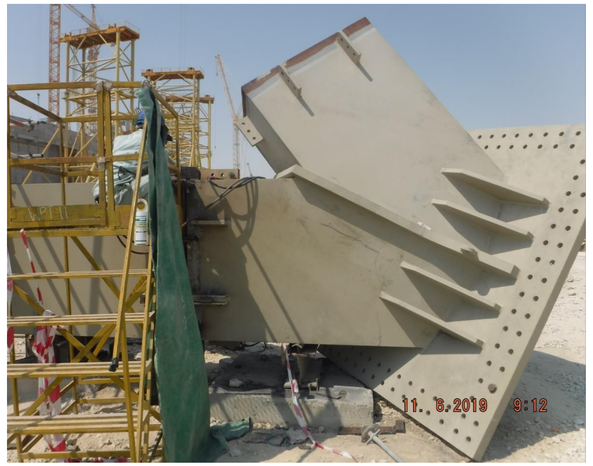
On-Site Scanning of Steel Part

Point Cloud Model of Steel Part

Deviation Analysis of As-Built Vs LOD 400 Model



Actual Fit-up On-Site



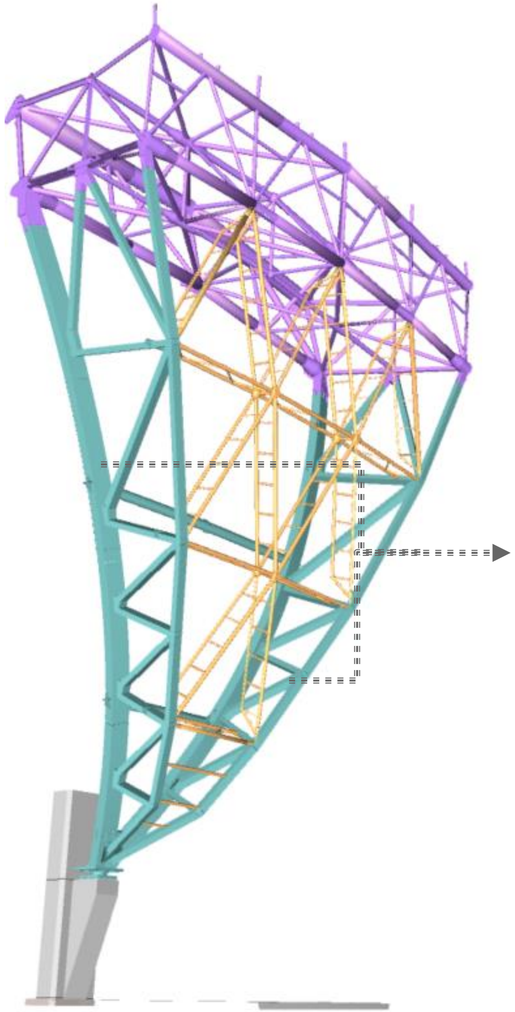
Pinpoint Analysis & Verification of steel elements before assembly & installation using 3D Laser Scanning

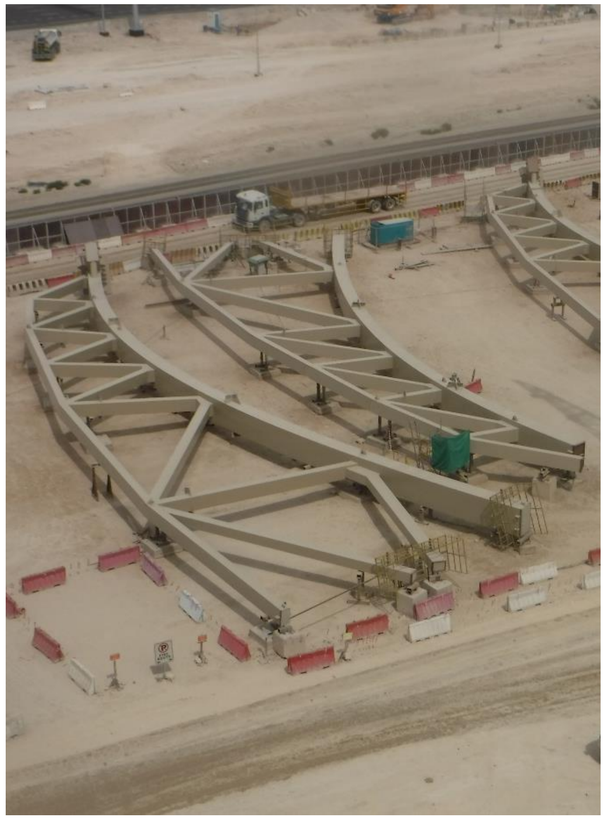
Conclusions – 1. Base plate of steel part is fabricated with 0.5mm accuracy
2. Deviation beyond 30mm from the design location which is taken into account by designer to accept it or rectify before assembly

Deflection Monitoring & Control of Long Span Structures

- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection

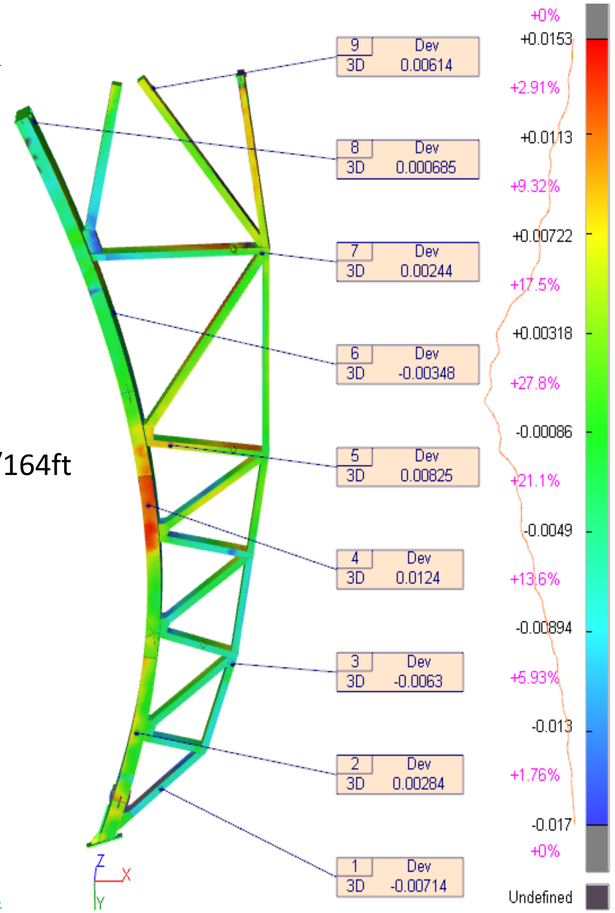
Analysis of Steel Frame





Steel Frame Assembly

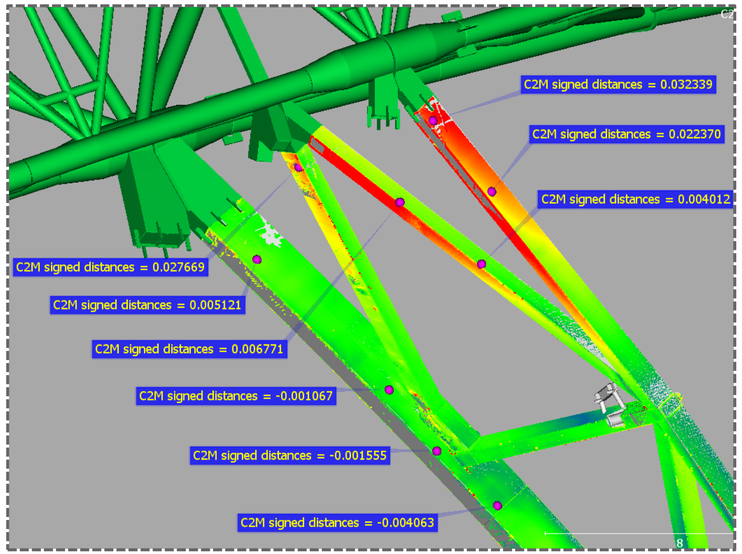
Steel Frame Point Cloud



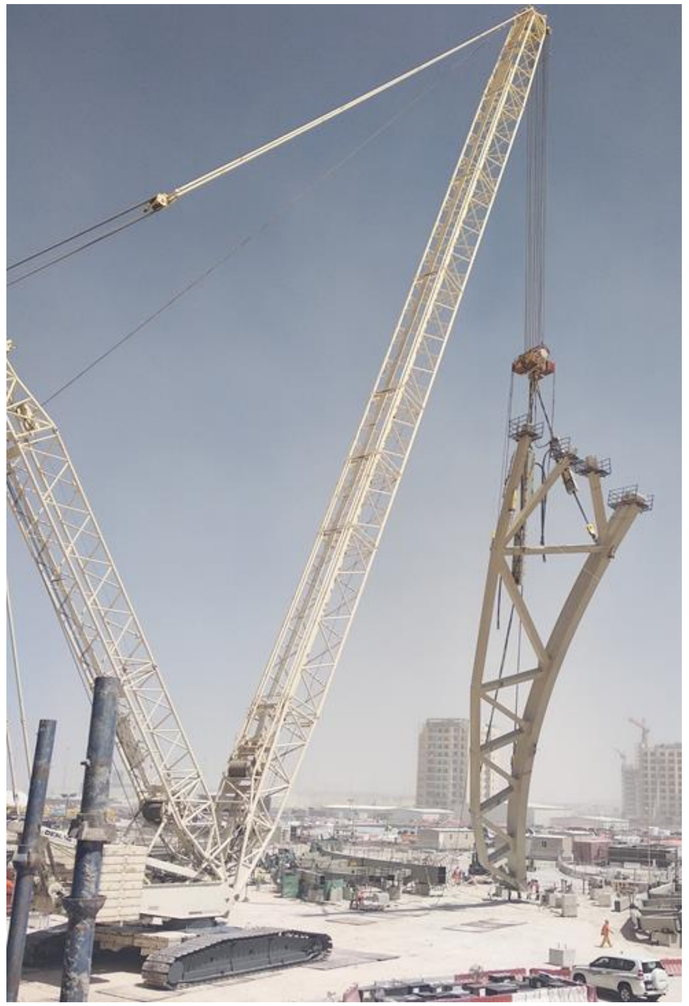
Deviation Analysis of As-Built Vs LOD 400 Model

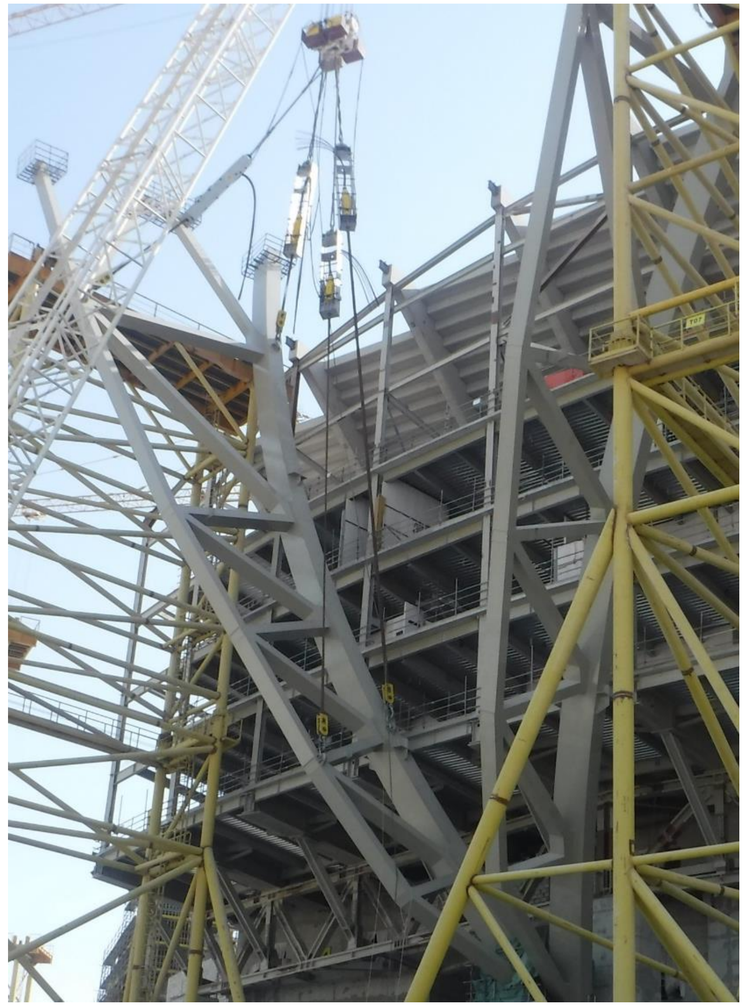
Virtual Erection of Steel Frame

- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection



The point cloud model moved to design location virtually in software to check the errors before lifting



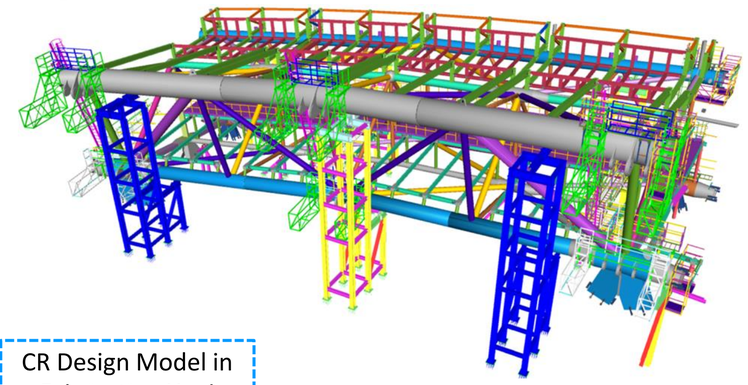


Lifting Sequences

Virtual Erection of Compression Ring(CR)

- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection

1

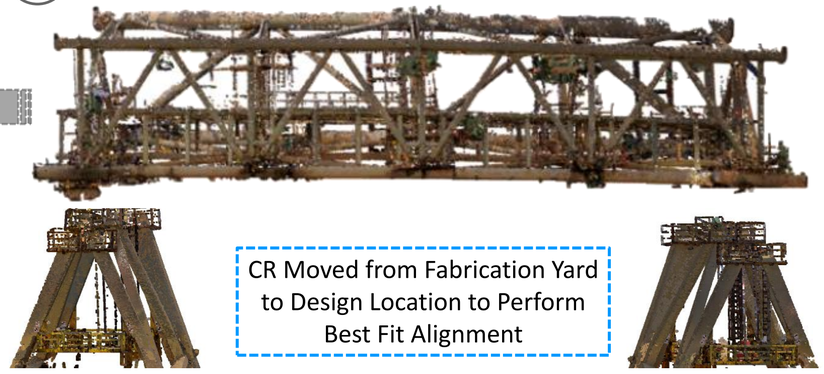


CR Design Model in Fabrication Yard

2

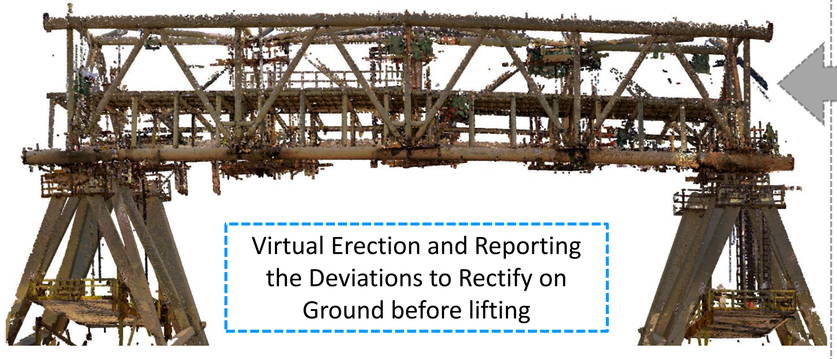
CR Point Cloud in Fabrication Yard

3

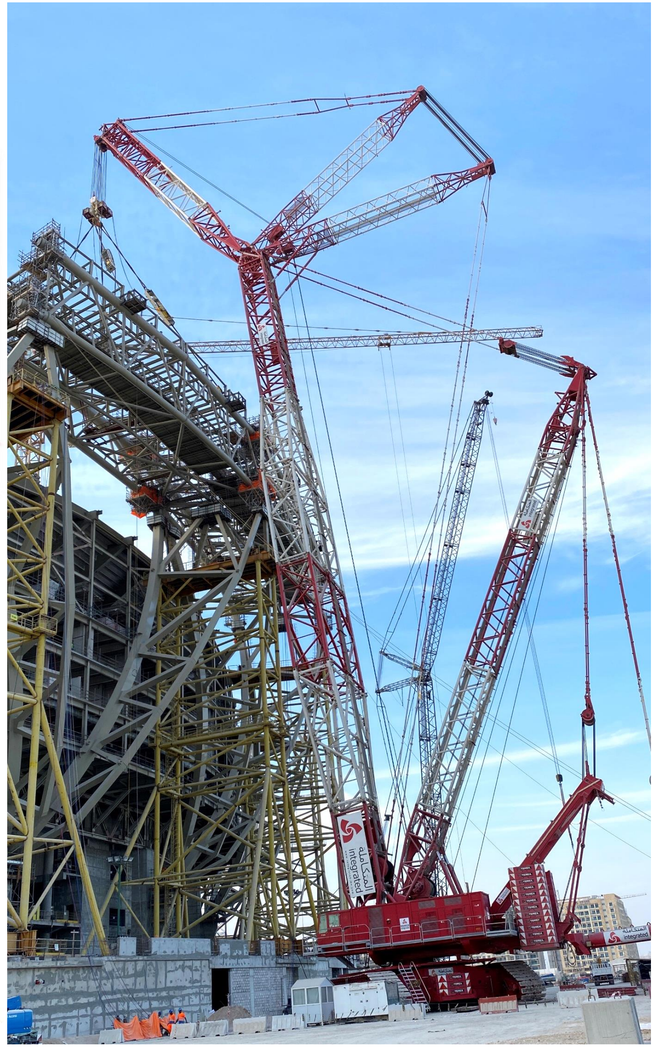


CR Moved from Fabrication Yard to Design Location to Perform Best Fit Alignment

4



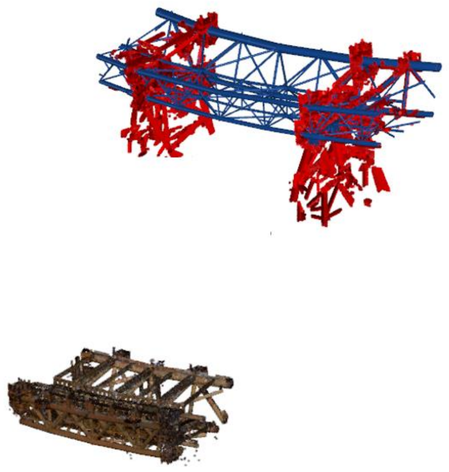
Virtual Erection and Reporting the Deviations to Rectify on Ground before lifting



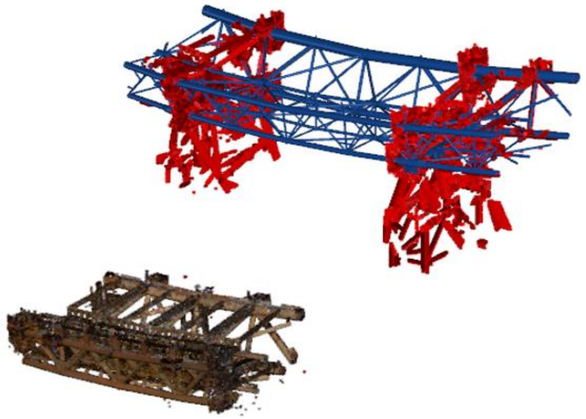
Virtual Erection of Compression Ring – Closer Segment

- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection

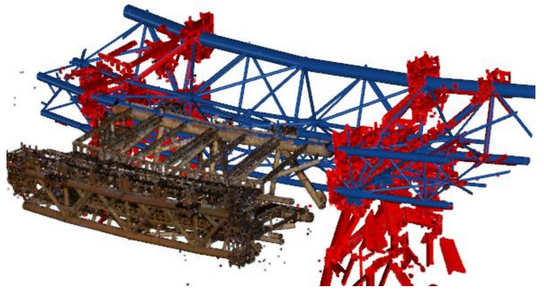
Stage 1
CR Level – +5m



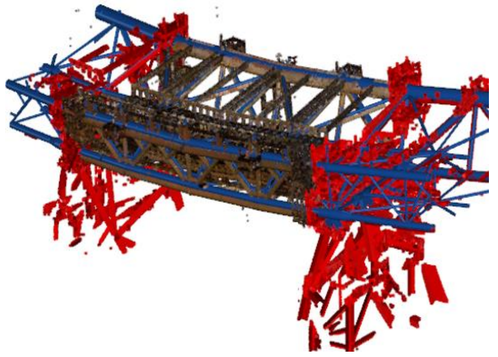
Stage 2
CR Level – +48m



Stage 3
CR Level – +60m



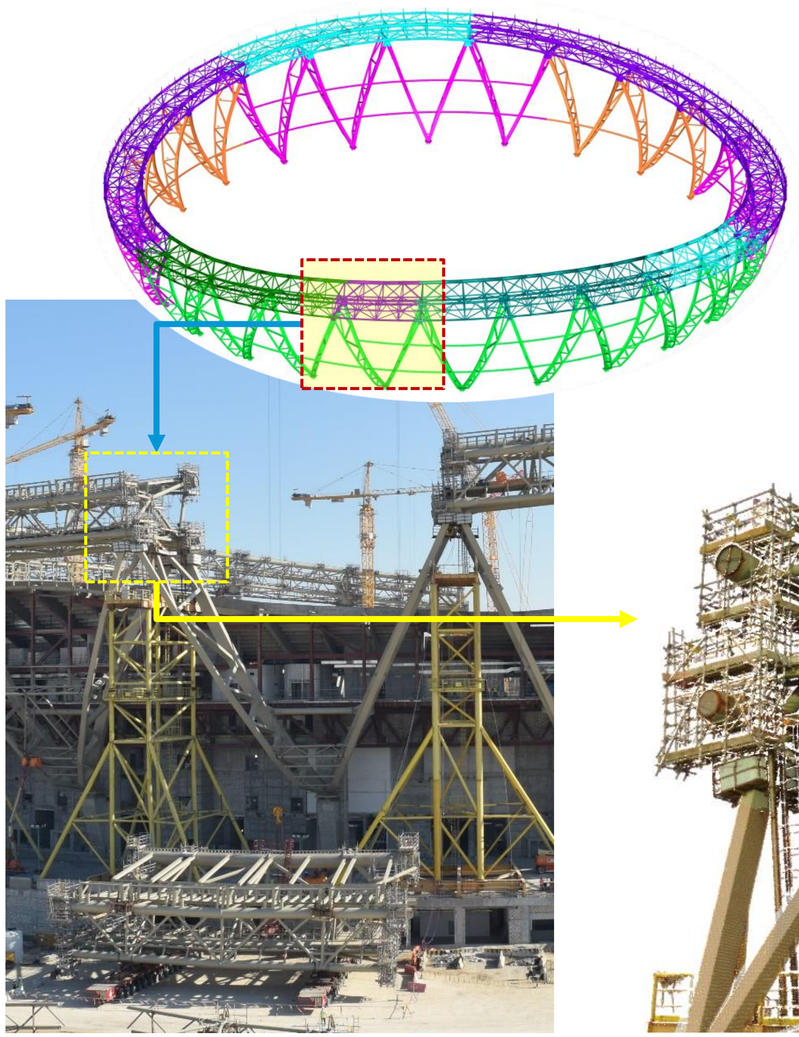
Stage 4
CR Level – +60m



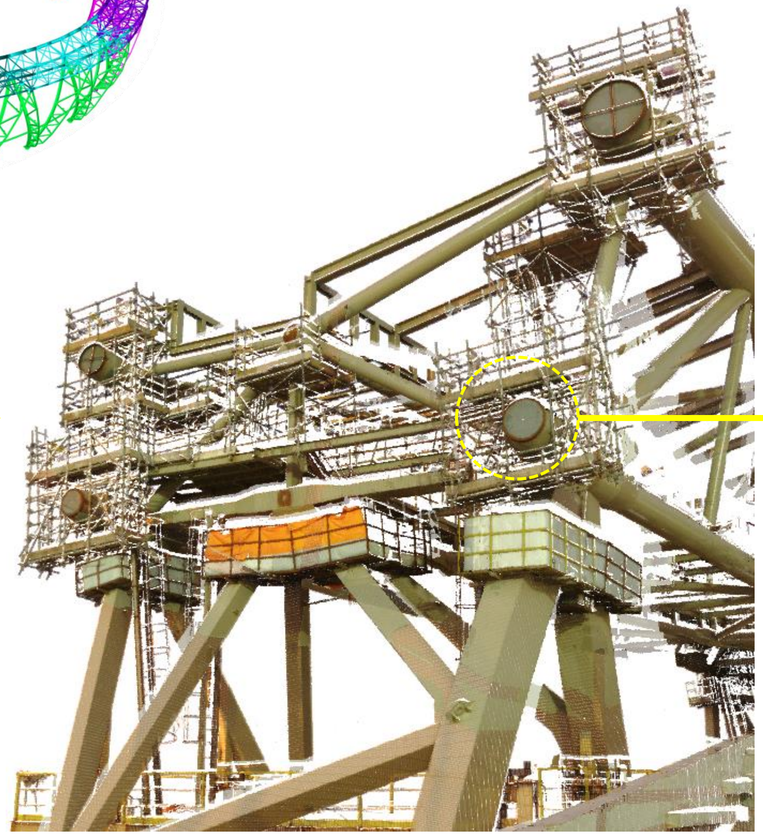
Conclusions – 1. Extraction of lifting path to adjust the segment properly in place
2. Identification of clashes with As-built elements to rectify on ground before lifting
3. Reduction of lifting attempts by one lifting path

Deviation Analysis of Installed Compression Ring

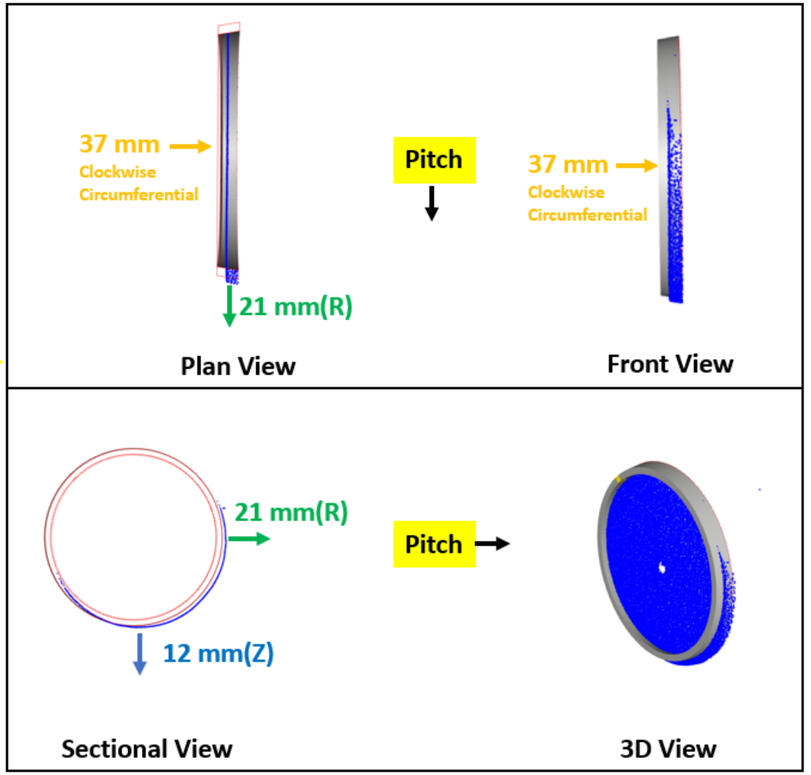
- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection



Closer Section



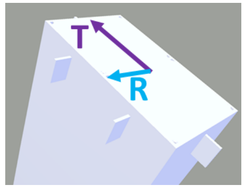
Point Cloud

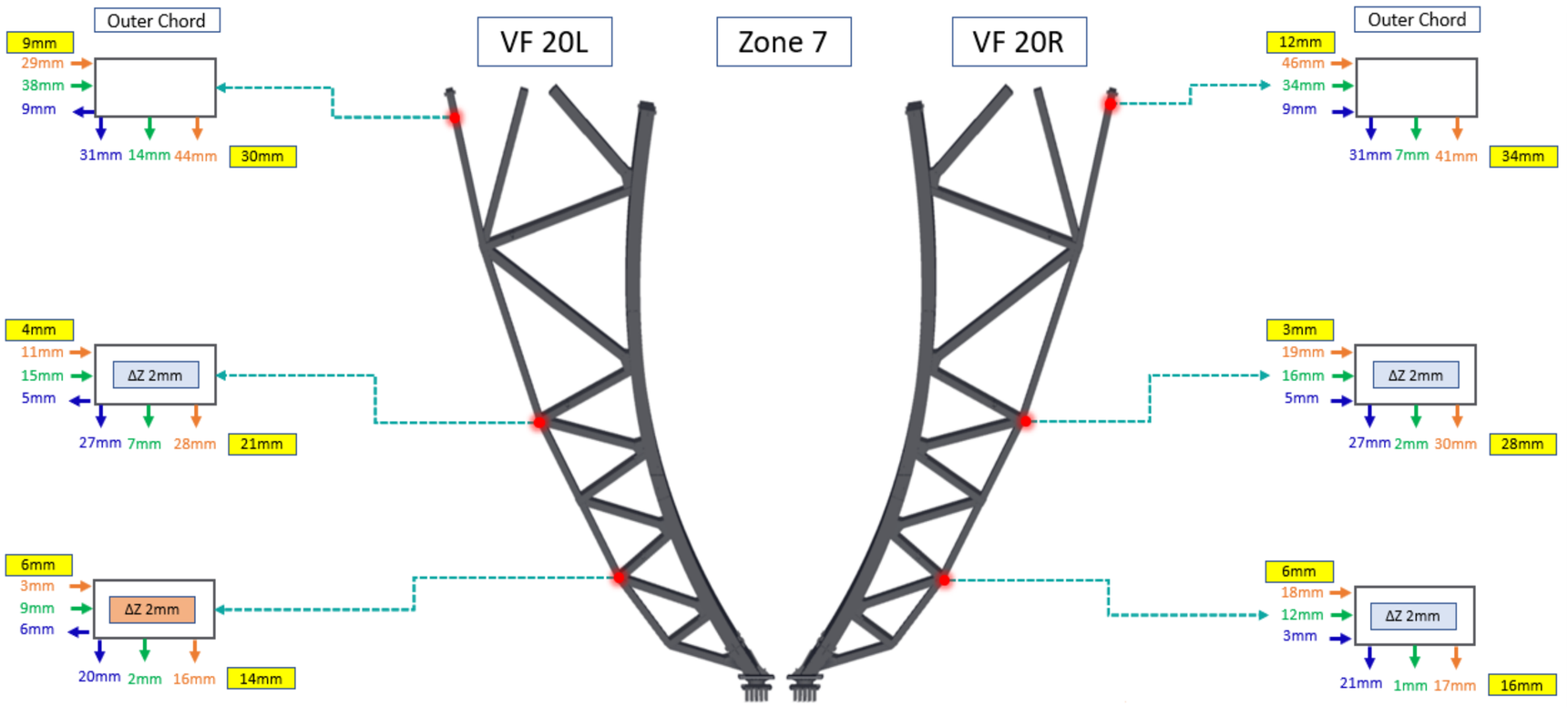


Deviation Analysis

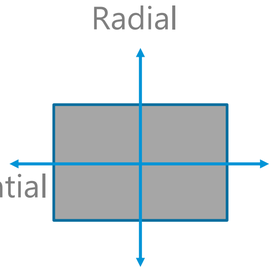
Laser Scanning for Long Span Structures

- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection





Legend:



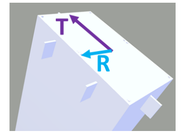
- IFC Vs As-Built Before De-Propping
- IFC Vs As-Built After De-Propping
- Theoretical displacement (IFC Vs Support Unload Model)
- Actual Displacement (Difference b/w As-Built Before & After De-Propping

Conclusions – 1. Difference between theoretical( ) and actual( ) displacement is less than 10mm which helps contractor to validate the de-propping process in allowable tolerance

2. Evaluation and validation of all assumptions made by designers against the de-propping of large steel structure

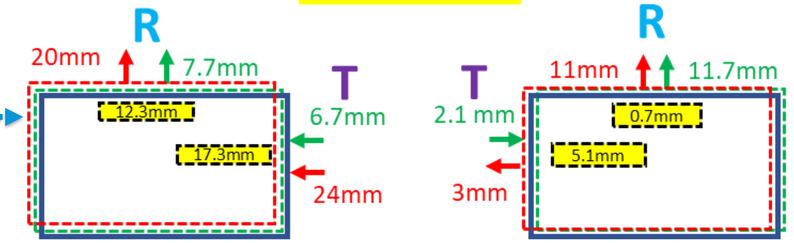
Reality Capture Reporting

- Fabrication
- Trial Assembly
- Fit-up
- Final Assembly
- Virtual Erection
- Final Erection

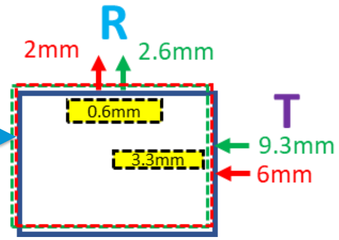


R Radial
T Tangential

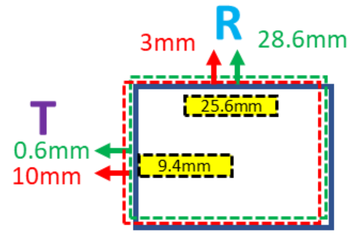
Tower 20



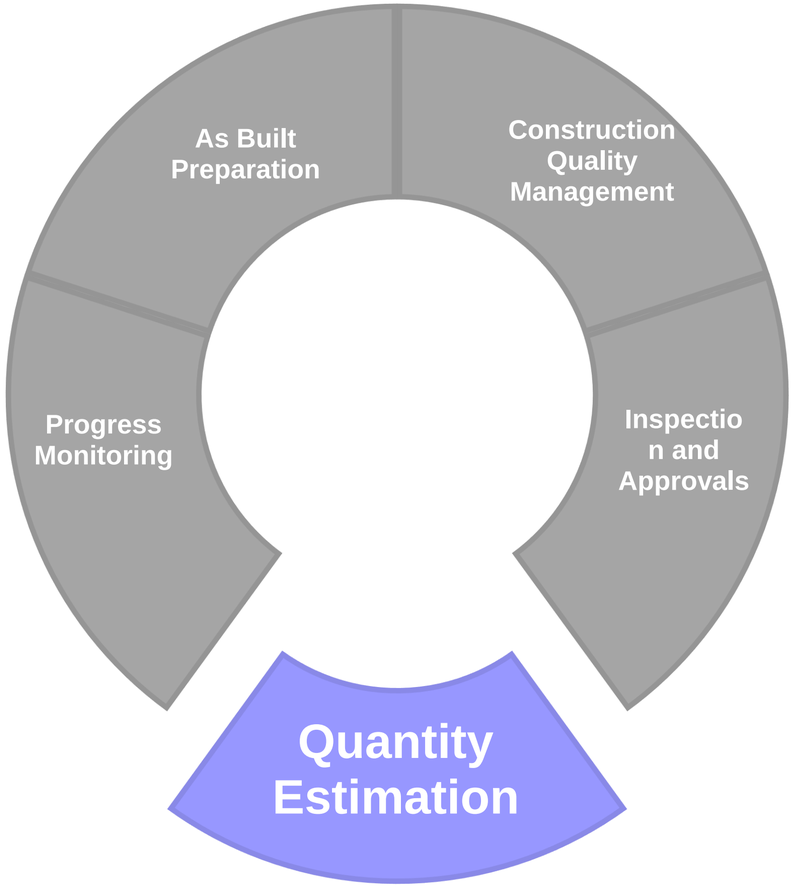
4R



5L



- IFC Position
- V-Frame-As-Built Position
- Compression Ring-As-Built Position
- Difference between As-Built V-Frame Vs As-Built Compression Ring

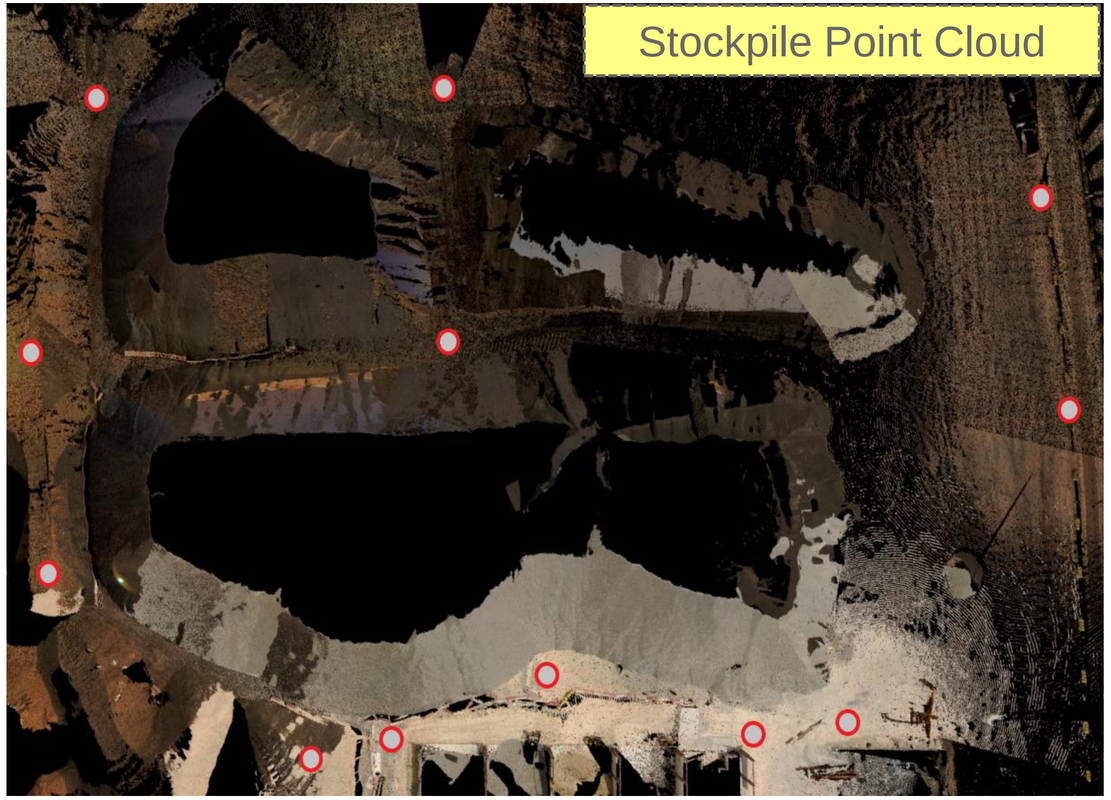


Measuring quantity and maintaining the volume of stockpiles, cut & fill in heavy earthwork industries is difficult. Traditional survey methods are inaccurate and measure up to 80% of original volumes. Measuring a stockpile volume using 3D Laser Scanning is by far the fastest and safest method available.

Earthwork Management

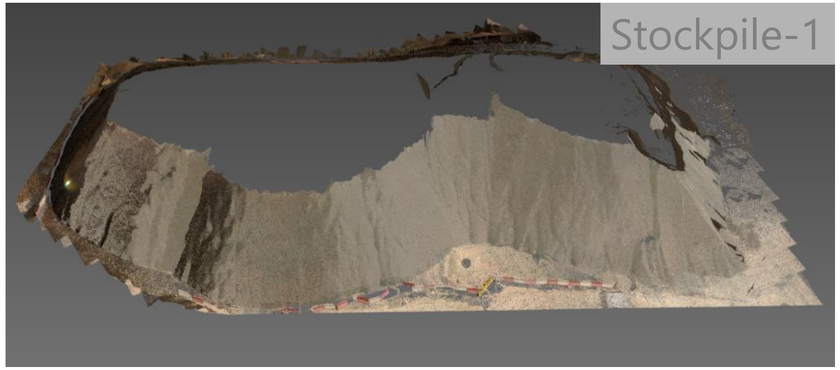
Stockpile Quantification & Management

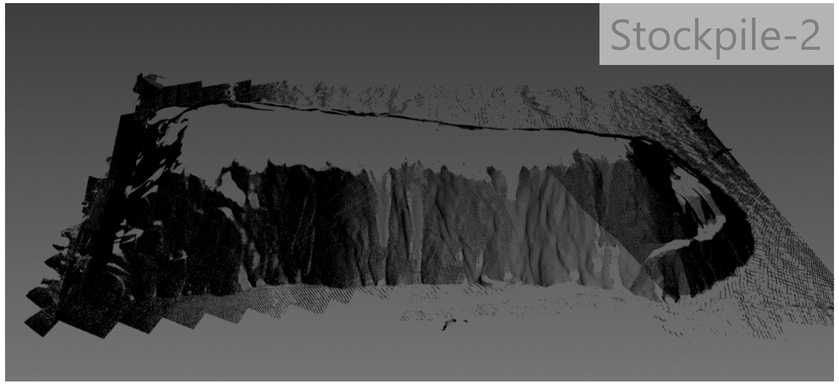
Laser Scanner Location

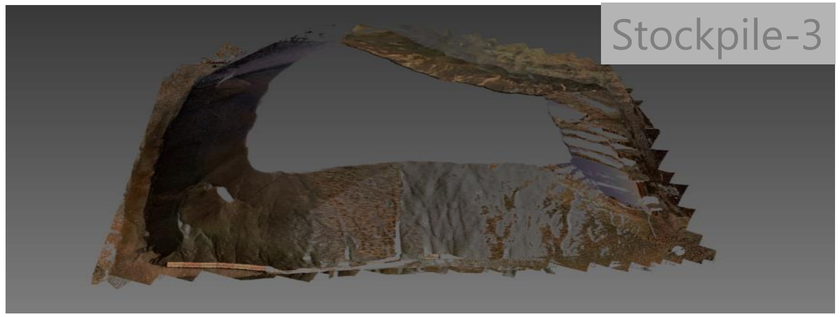


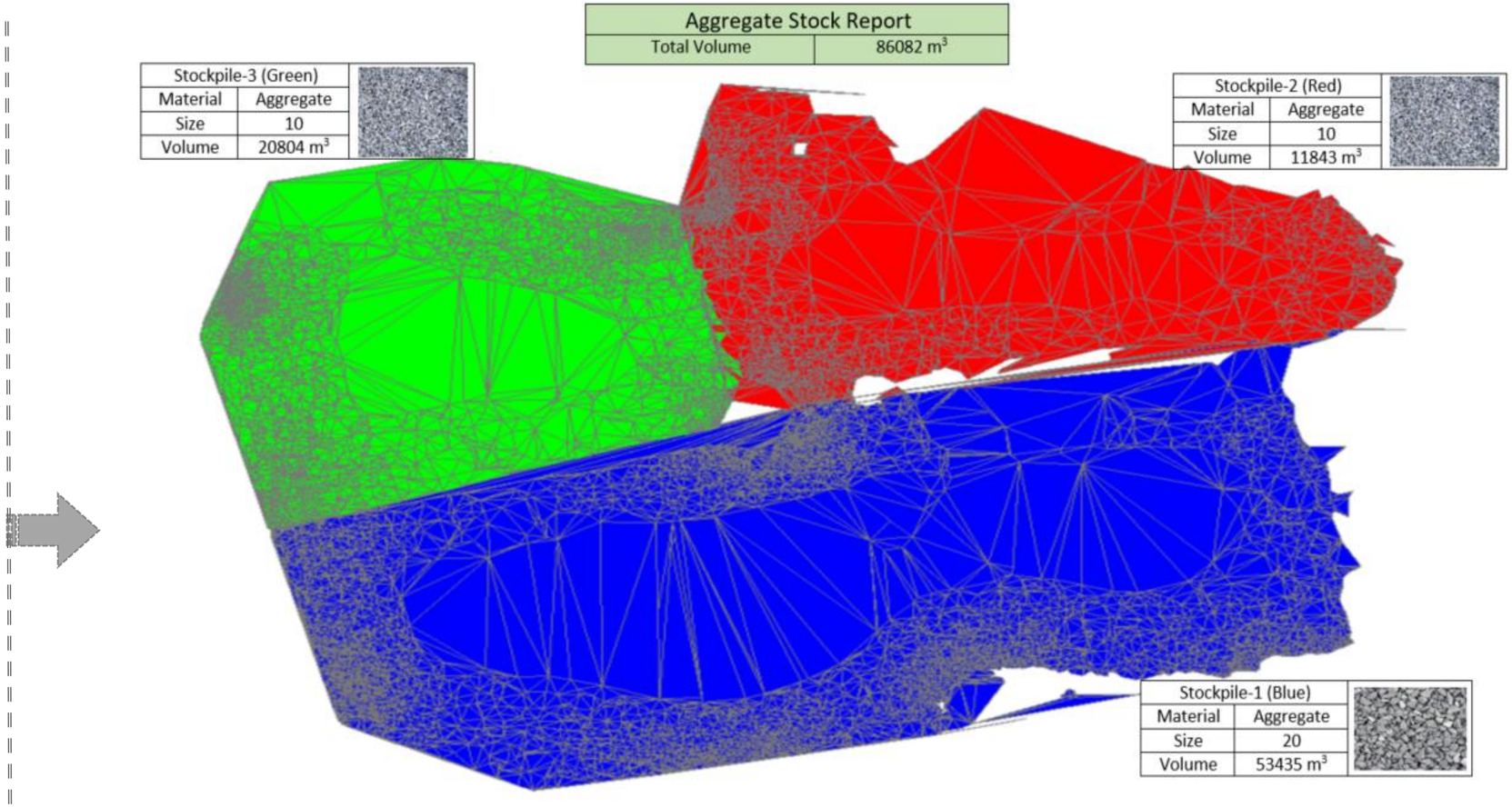
- **General contractors quantify the stockpile material by triangulating point cloud data. Complex mesh elements resulted from the triangulation are used for computation of 3D volume elements of various bulk materials**

Stockpile Quantification & Management



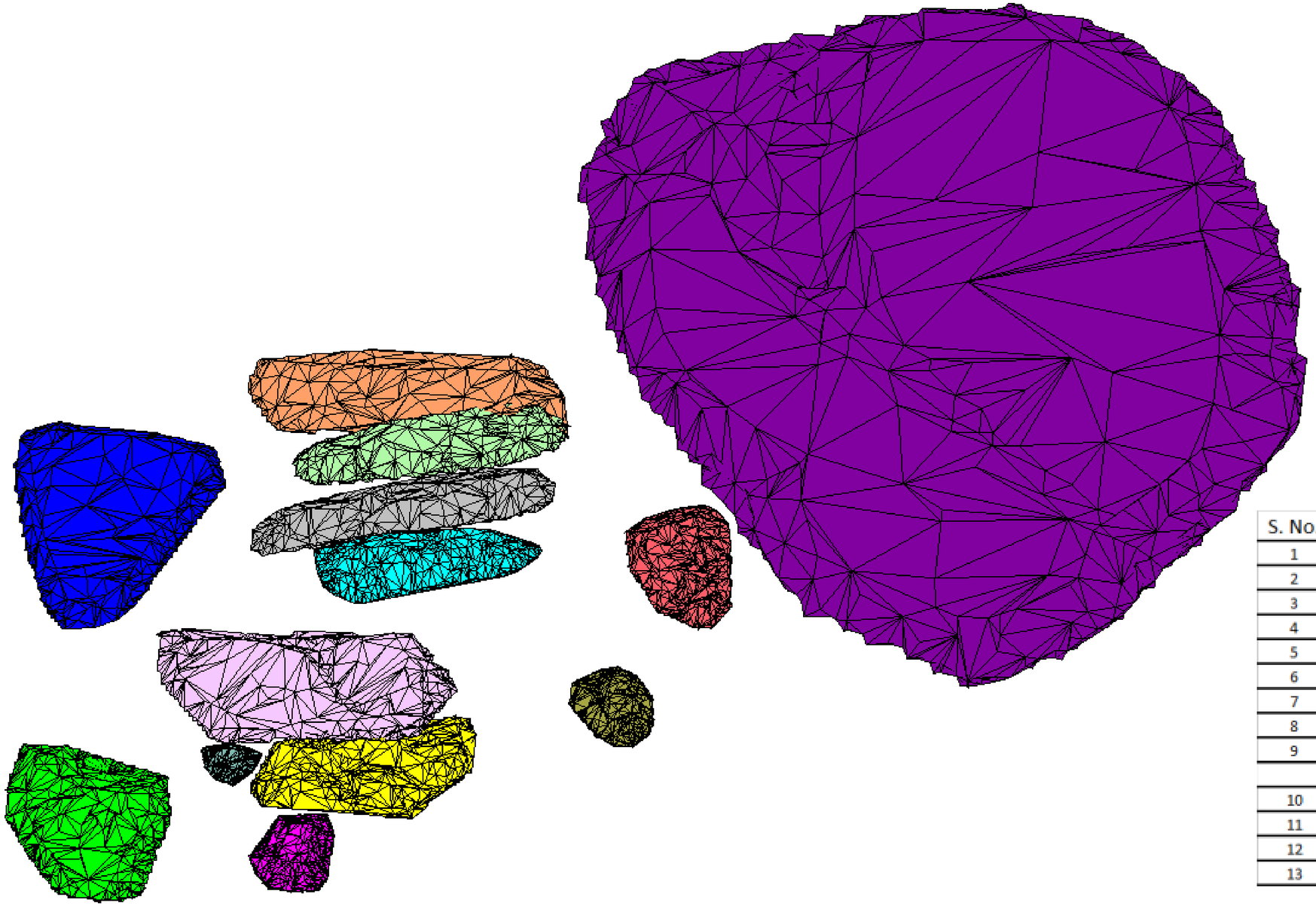






	Actual	Total Station	Laser Scanning
Total Volume	86700 m^3	93500 m^3	86082 m^3
Percentage Error	-	8%	0.07%

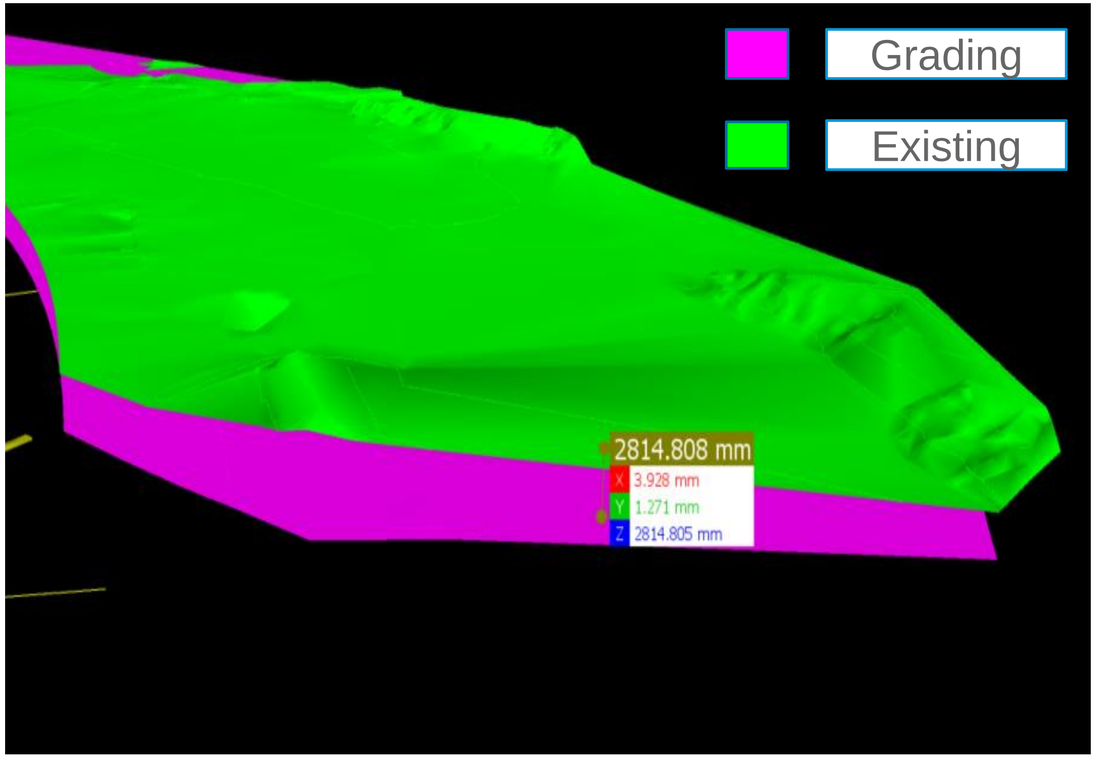
Stockpile Quantification & Management



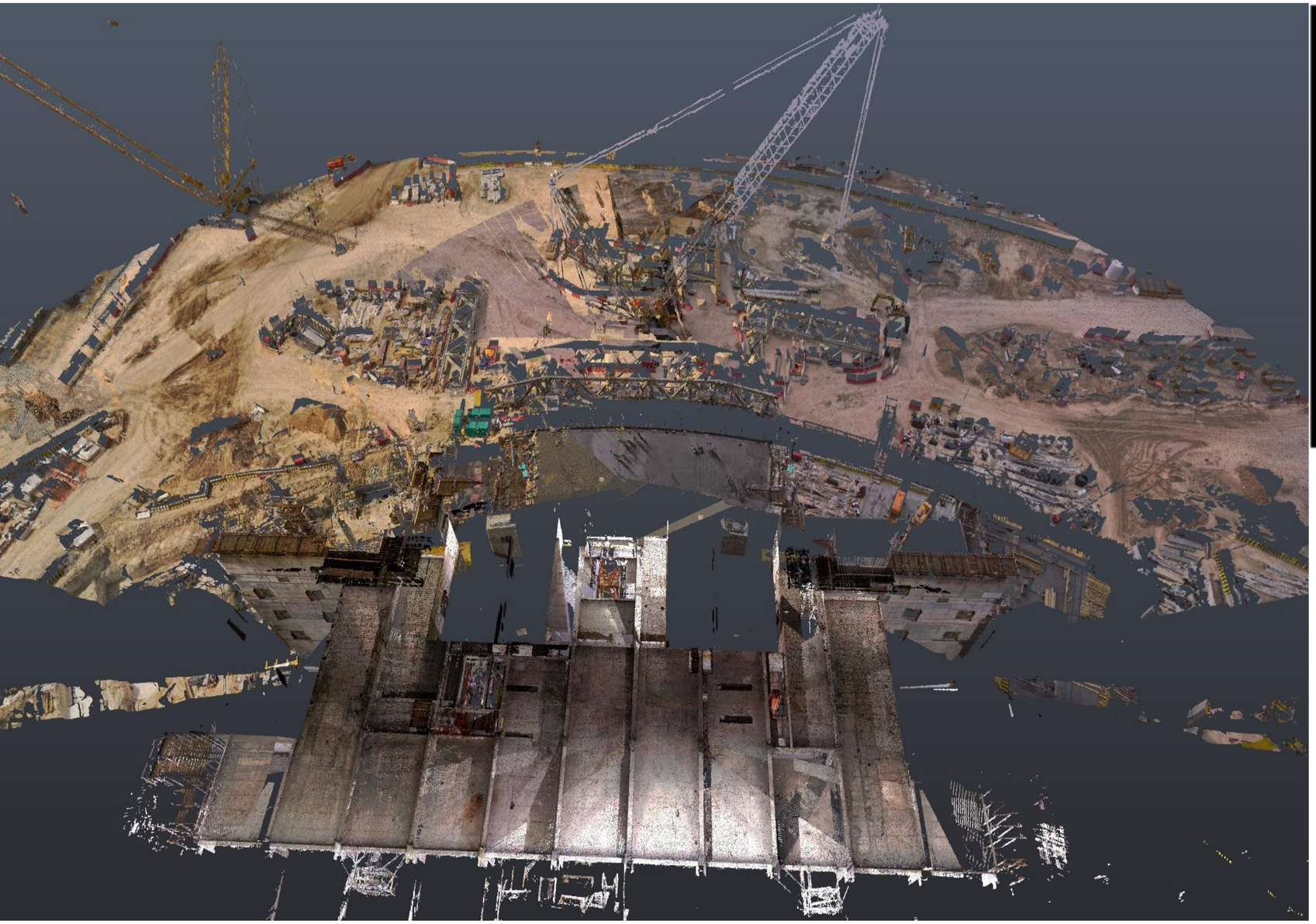
S. No.	Stockpile Name	Volume(Cubic Meter)	Colour Code
1	Dune sand	2835.00	
2	Screen matls1	6101.00	
3	Screen matls2	1058.00	
4	Stone1	2365.00	
5	Stone2	2512.00	
6	Stone3	6100.00	
7	Stone4	1118.00	
8	Unscreen matls(Excavation Mate1	221155.00	
9	Unscreen matls(Excavation Mate2	4984.00	
10	B.fill matl.1	2061.00	
11	B.fill matl.2	810.00	
12	Stone5	2011.00	
13	Stone6	136.00	

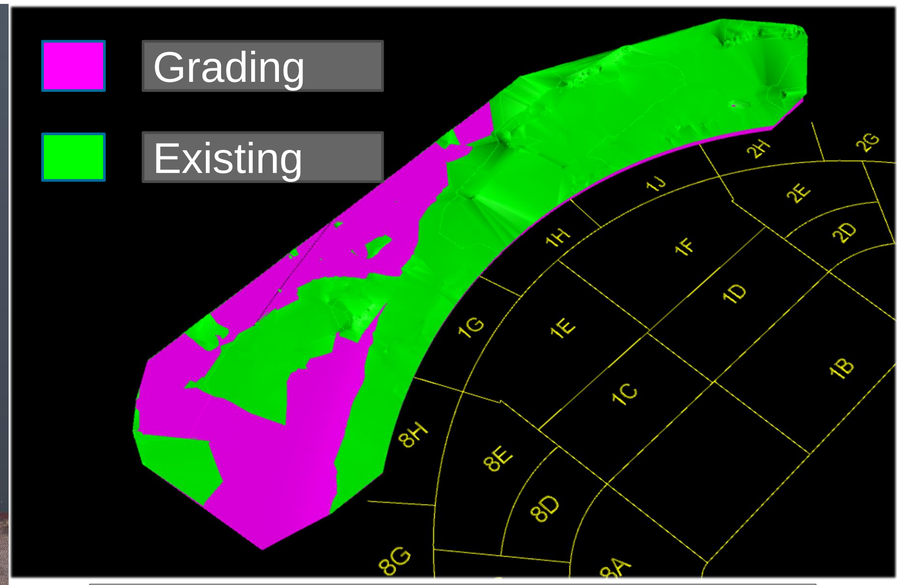
Cut & Fill Quantification

- The projection of topo surfaces of Grading vs. Existing gives variable height factor between these two surfaces. This variable height helps software to calculate net cut and fill quantities between existing and grading surfaces.



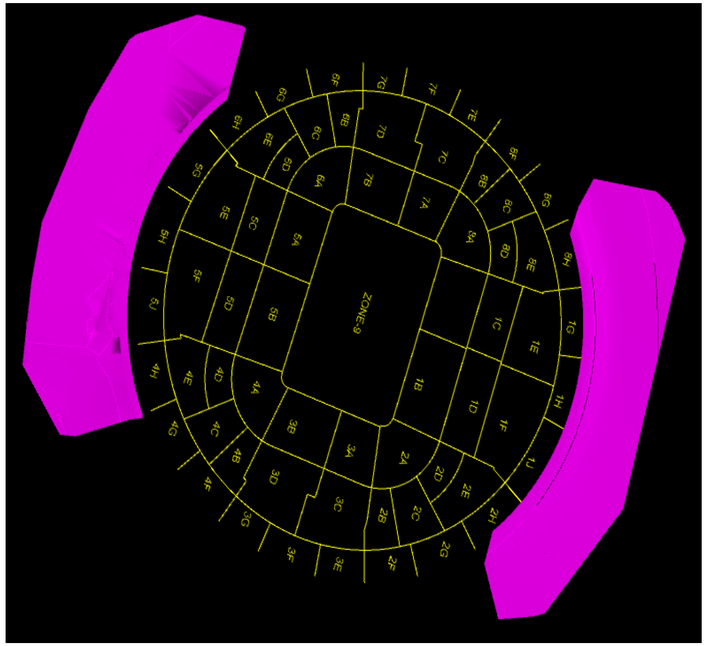
Calculation of Net Cut\Fill





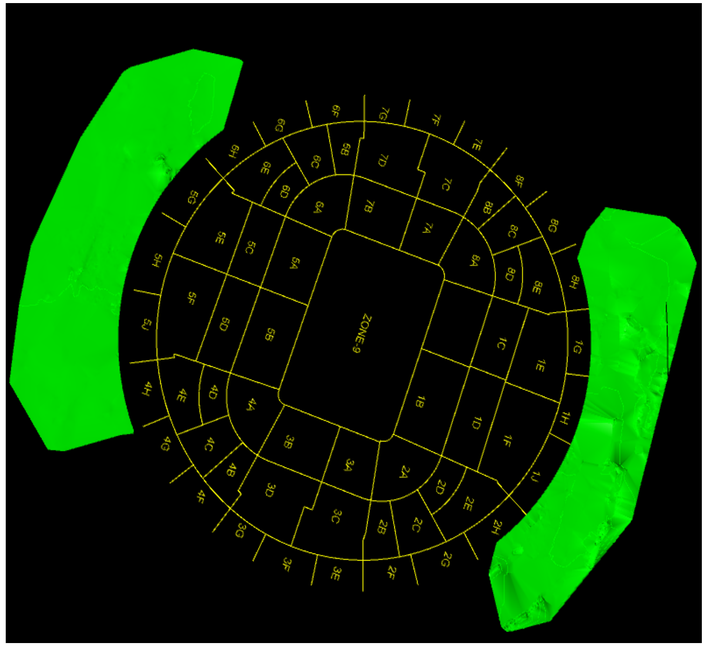
Zone- 1 Projected and Surface Area			
Location	Projected Area	Surface Area	Phase
Z1	8862.05 m²	8972.10 m²	Existing
Z1	8836.13 m²	8839.75 m²	Grading

Zone- 1 Net Cut\Fill			
Location	Cut	Fill	Net Cut
Z1	6820.78 m³	438.74 m³	6382.05 m³



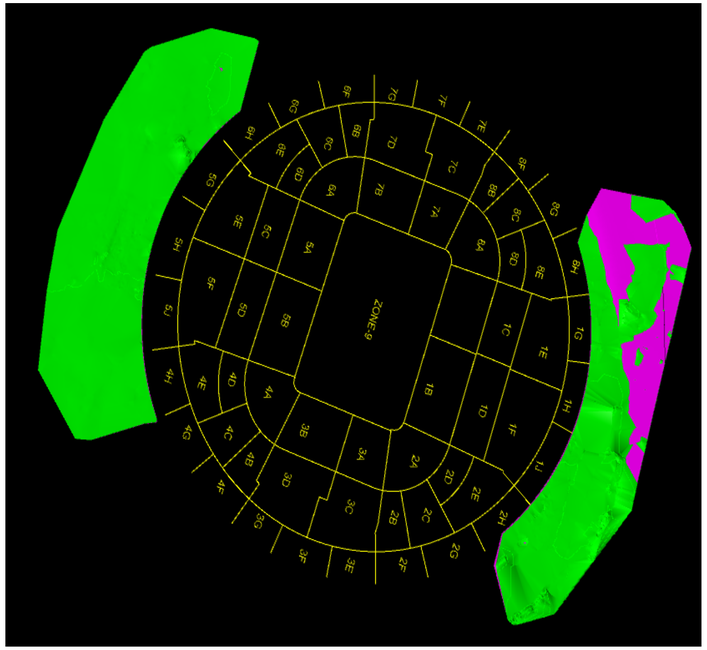
Grading Plan
As Designed

Projected Area	Surface Area
33502.70 m²	33701.60 m²



Existing Plan
3D Laser Scanning

Projected Area	Surface Area
33470.93 m²	33488.25 m²

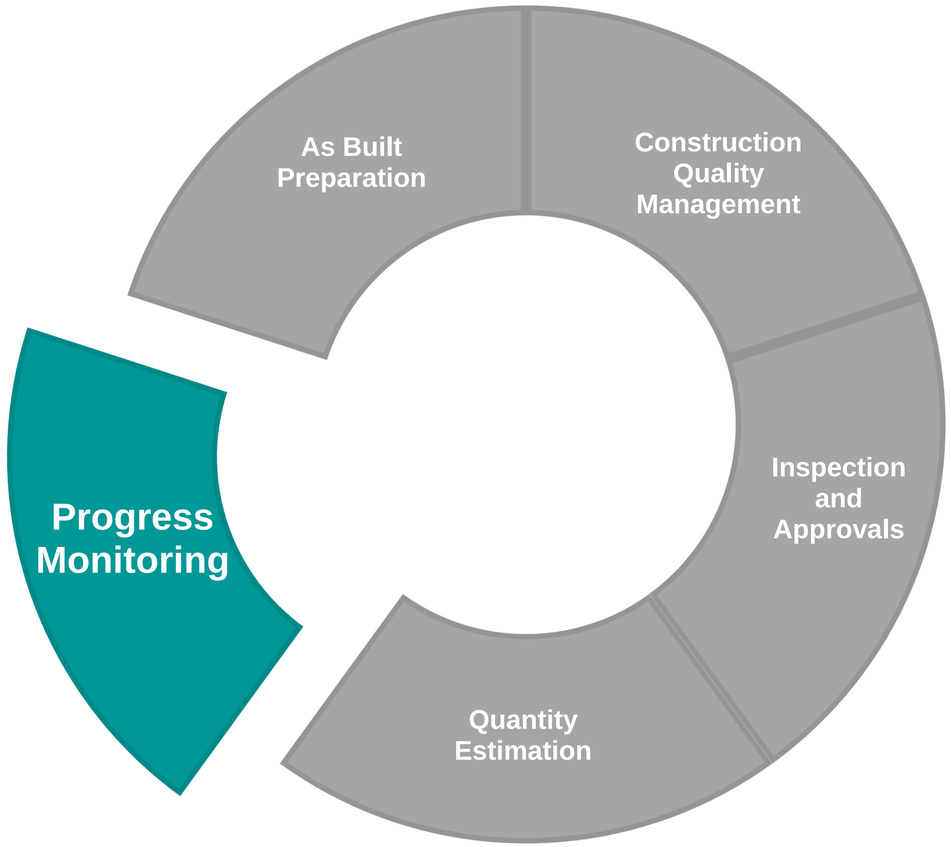


Overlay
Grading VS Existing

Cut	Fill	Net Cut
29878.08 m³	818.05 m³	29060.03 m³

Quantification & Management

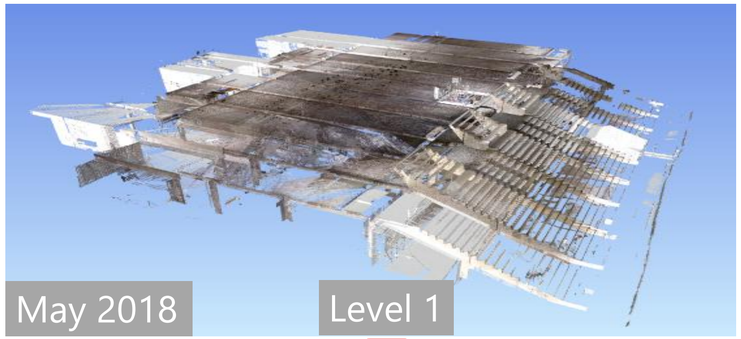
Quantification	Traditional Method(Total Station)	3D Laser Scanning
Data Collection & Processing	Few points creates Less number of triangles	Millions of Points creates an exact surface from numerous triangles
Accuracy	90%	98-99%
Time	More working hours (A person need to hold the prism)	Less Efforts and Time (It’s a non -contact method)
Cost	Due to more working hours the cost increases proportionally	Less cost and efforts due to less working hours
Safety	Need to climb on loose material that can cause safety hazards	Data can easily collected from distance

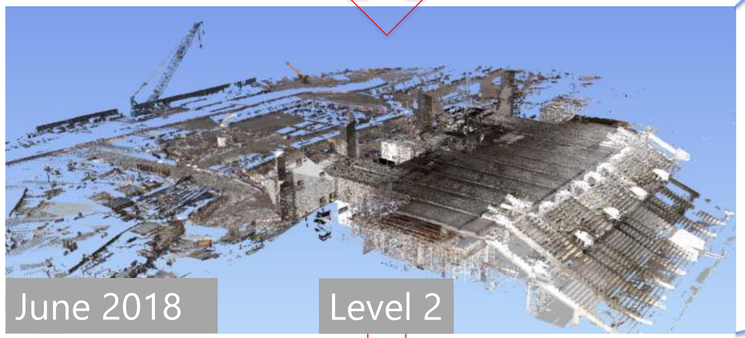


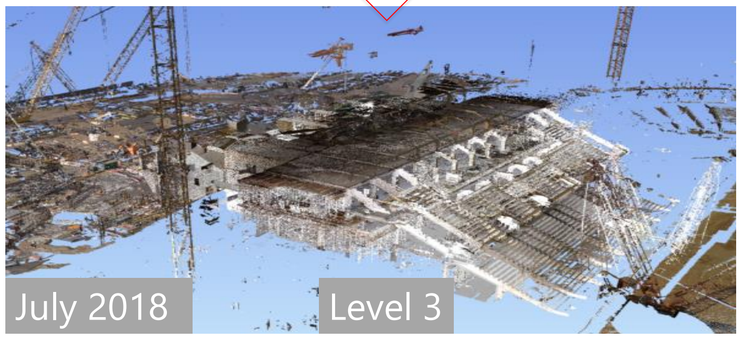
Creation of construction progress model on timely basis is now easier with laser scanning. It creates a point cloud of each element of site. The progress models from every span of time create a clear vision of construction headways.

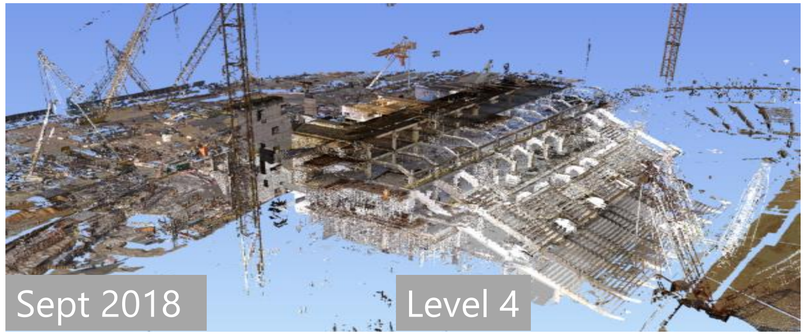
Progress Monitoring

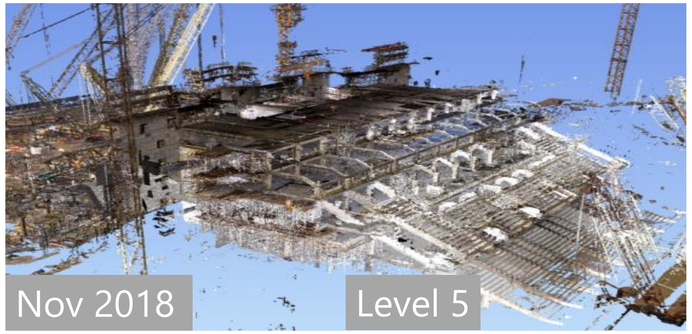
Concrete Structure Monitoring - Planned v/s Actual



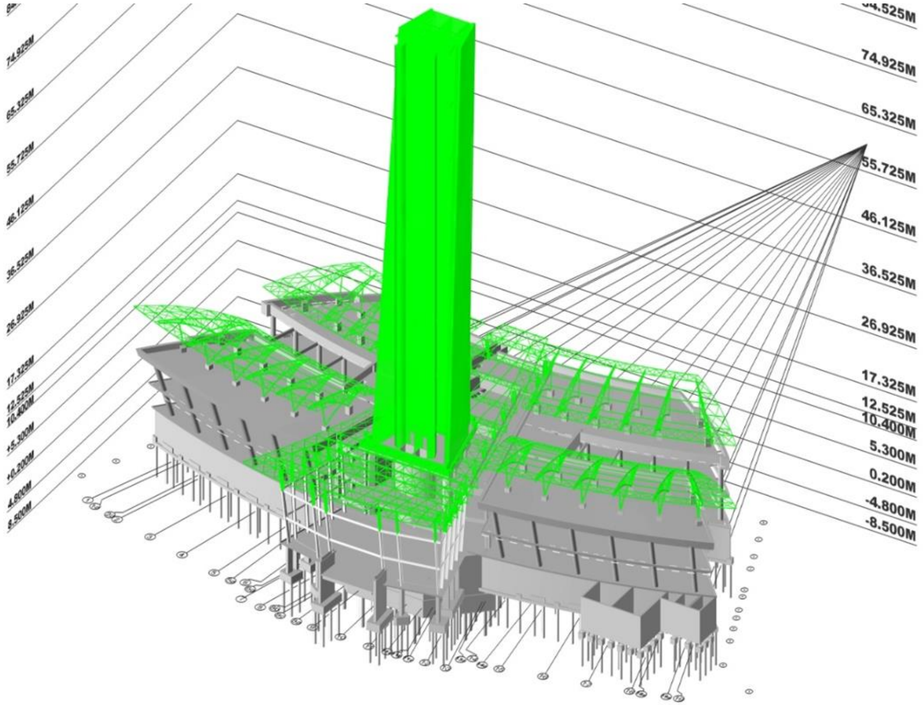




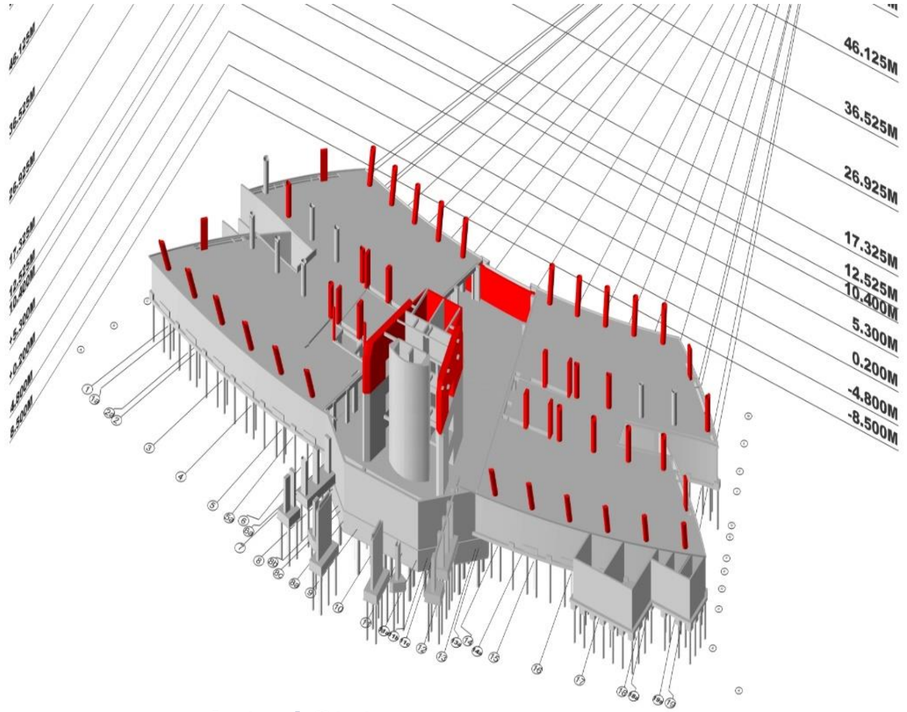




RCC Status – Planned v/s Actual on 12th Oct 2020



CCC Pile 100% Completed
CCC Raft & Pile cap 100% Completed
CCC Column & Retaining Wall 100% Completed
CCC Ground Floor Slab 100% Completed
CCC Ground Floor Lift Wall & Column 100% Completed
CCC Structural Steel Erection 72% Completed
ST Pile & Pile Cap 100% Completed
ST Shear Wall & Slab up-to LVL.106.4m 43% Completed



Actual Status

CCC Pile 100% Completed
CCC Raft & Pile cap 100% Completed
CCC Column & Retaining Wall 90% Completed
CCC Ground Floor Slab 70% Completed
CCC Ground Floor Lift Wall & Column 25% Completed
CCC Structural Steel Erection 0% Completed
ST Pile & Pile Cap 100% Completed
ST Shear Wall & Slab up-to LVL.12.525m Completed

Delay in Construction:38 Days

On Schedule		In progress Activity/Delay	
Ahead of schedule		Completion of concreting	

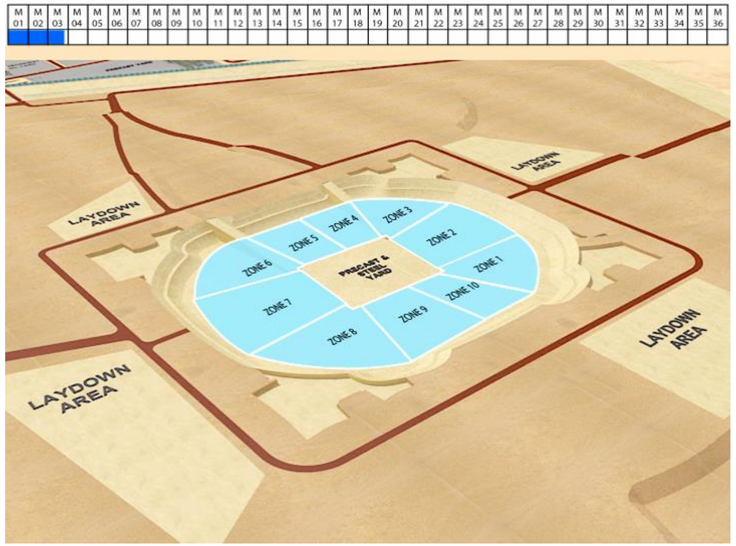
Progress Monitoring

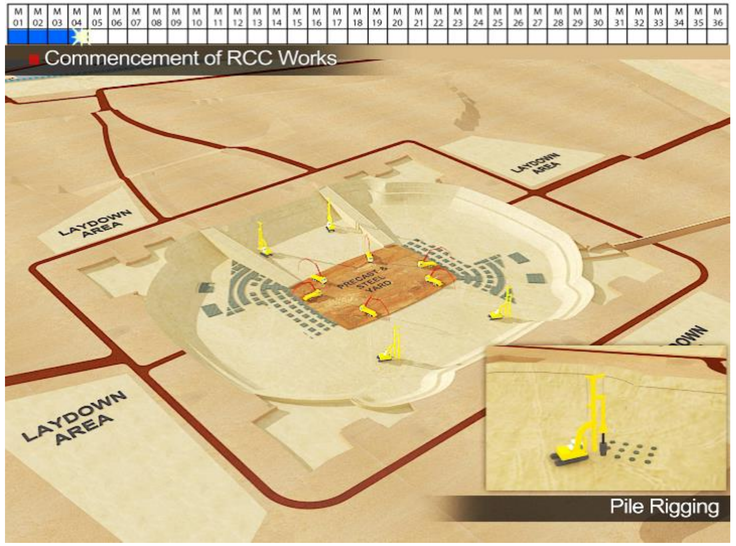
Steel Structure Monitoring - Planned v/s actual

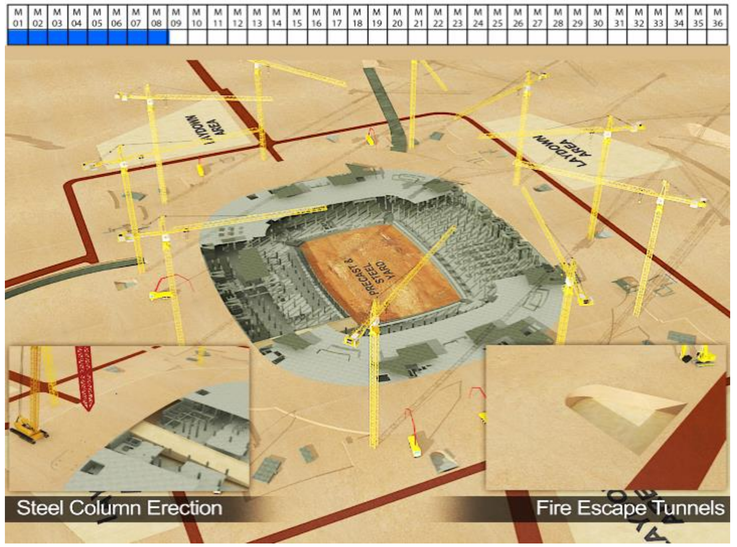
Progress Monitoring

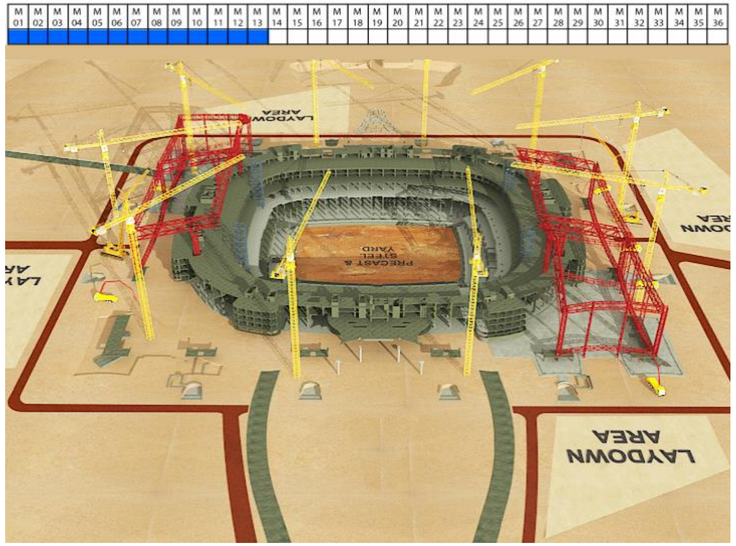
Block Wall Monitoring

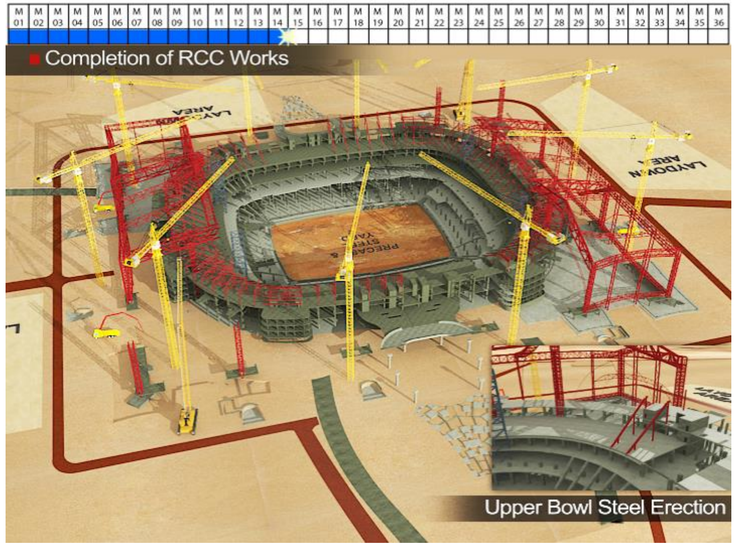
Progress Monitoring

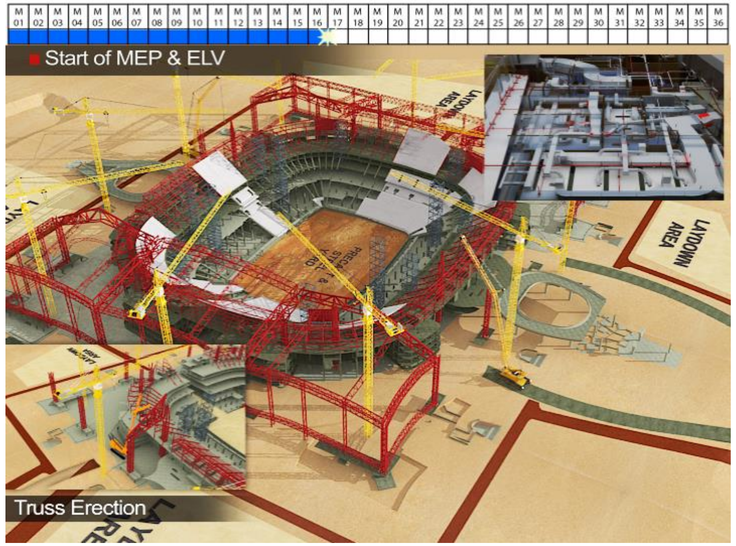












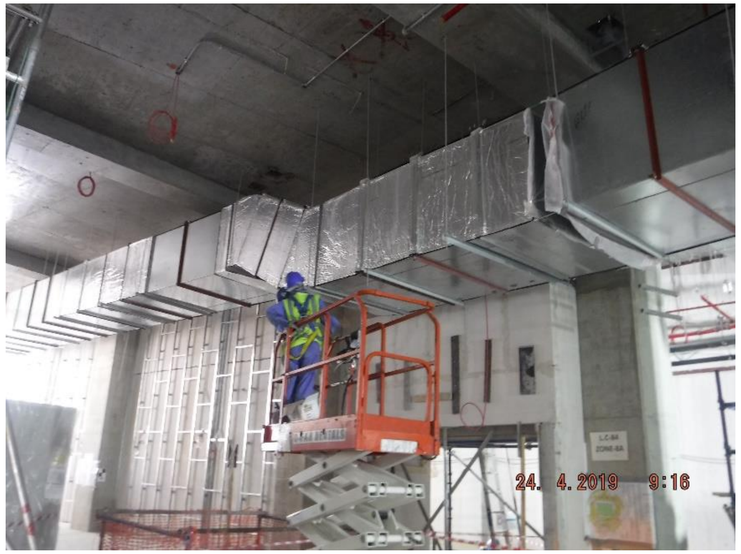
Progress Monitoring

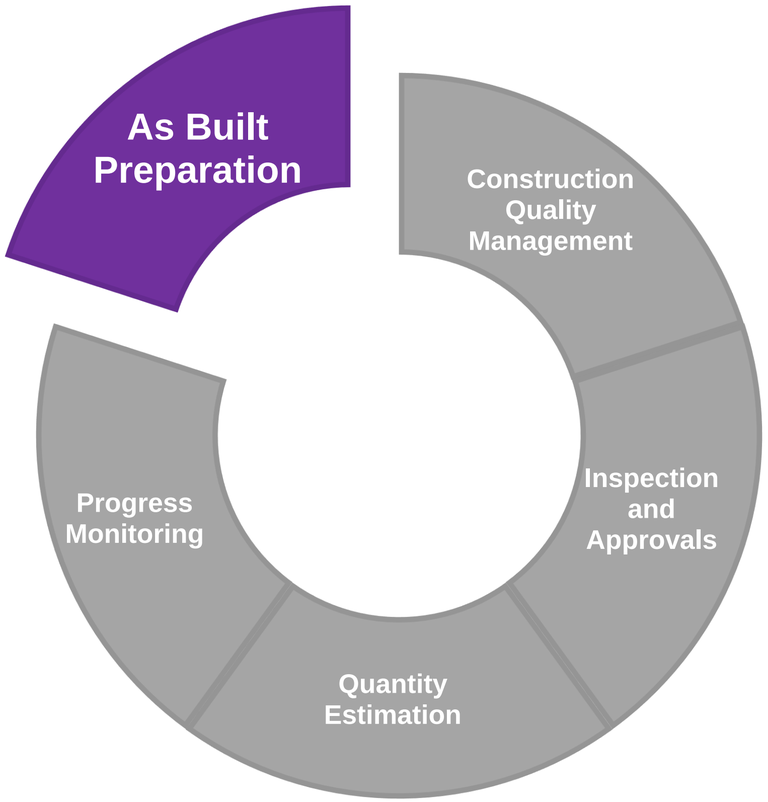
Concrete & Steel Structure Monitoring

12th June 2019

18th August 2019

Site Physical Progress



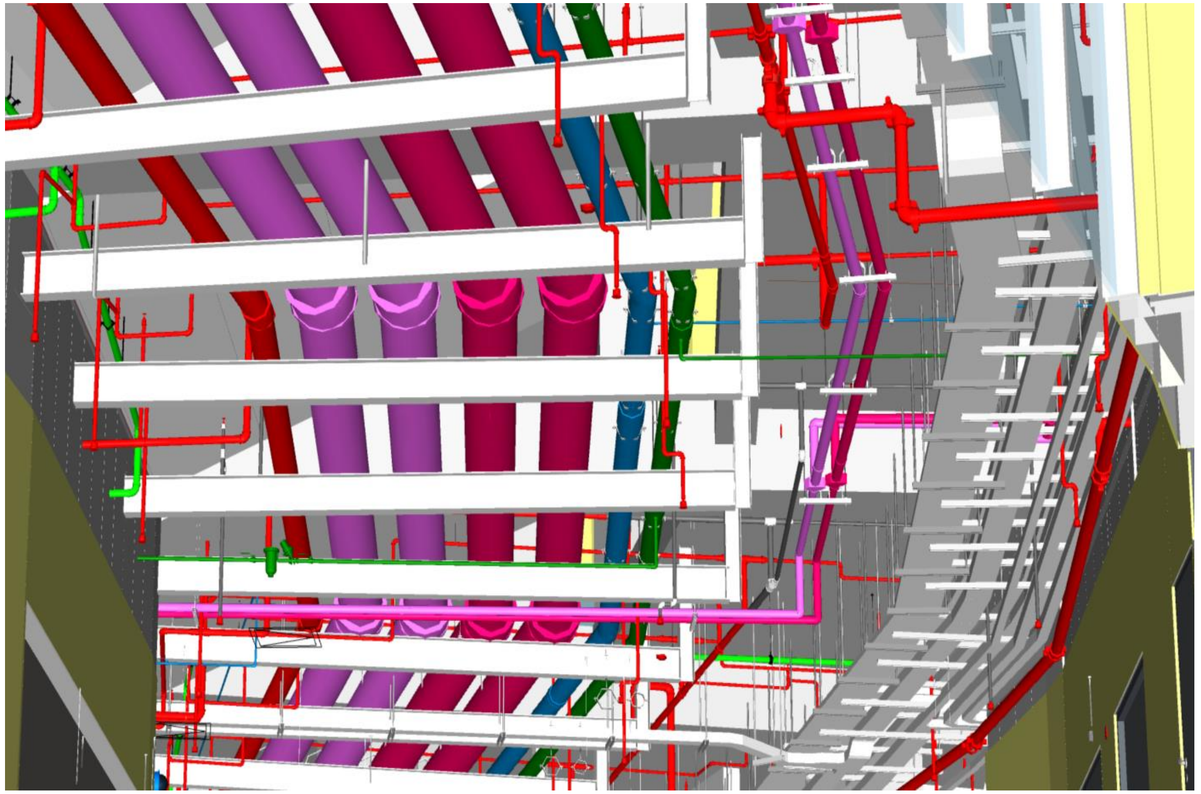


The practice of creating a digital representation of existing conditions of the building with its physical and functional characteristics in BIM.

The point cloud is imported into 3D BIM software (Autodesk’s Revit) in order to create accurate as-built models.

As Built Preparation

MEP Point Cloud Model

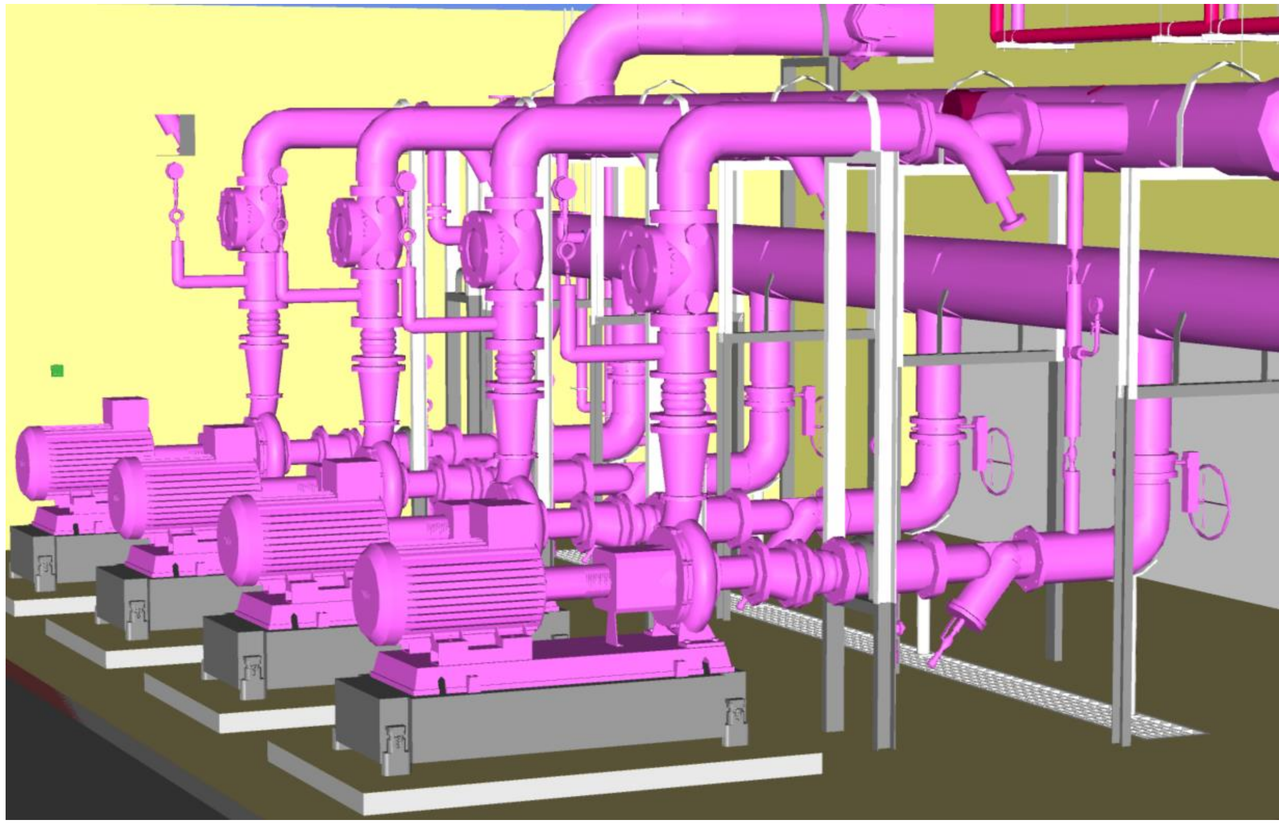


MEP BIM Model

As Built Preparation

Scan ⇨ BIM

Pump Room Point Cloud Model

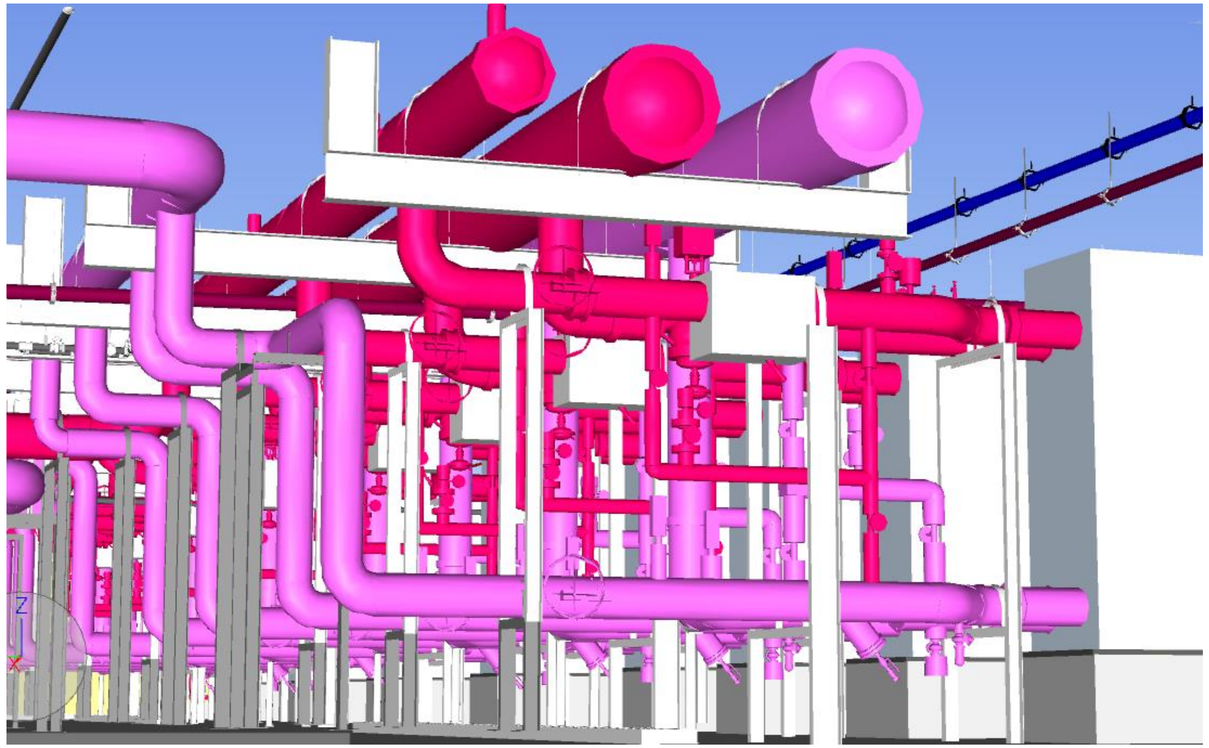


Pump Room BIM Model

As Built Preparation

Scan ⇨ BIM

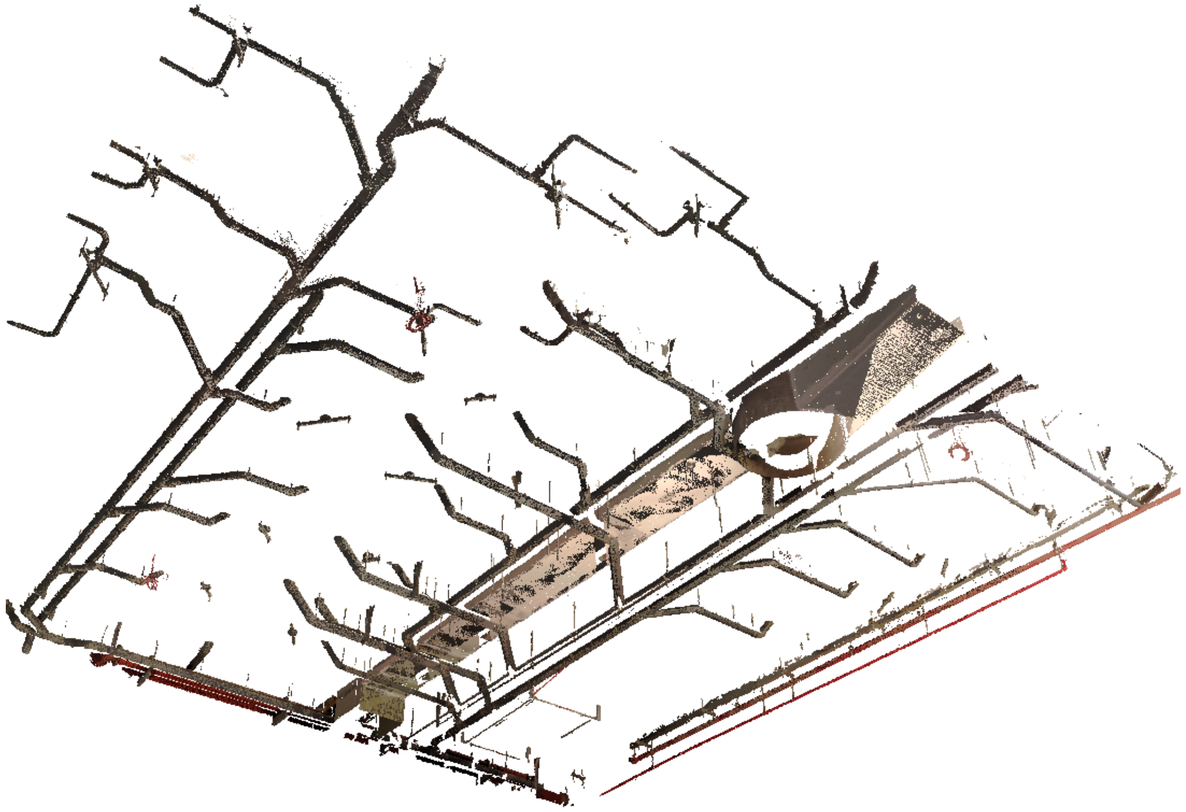
Chilled Water Pipes Point Cloud Model



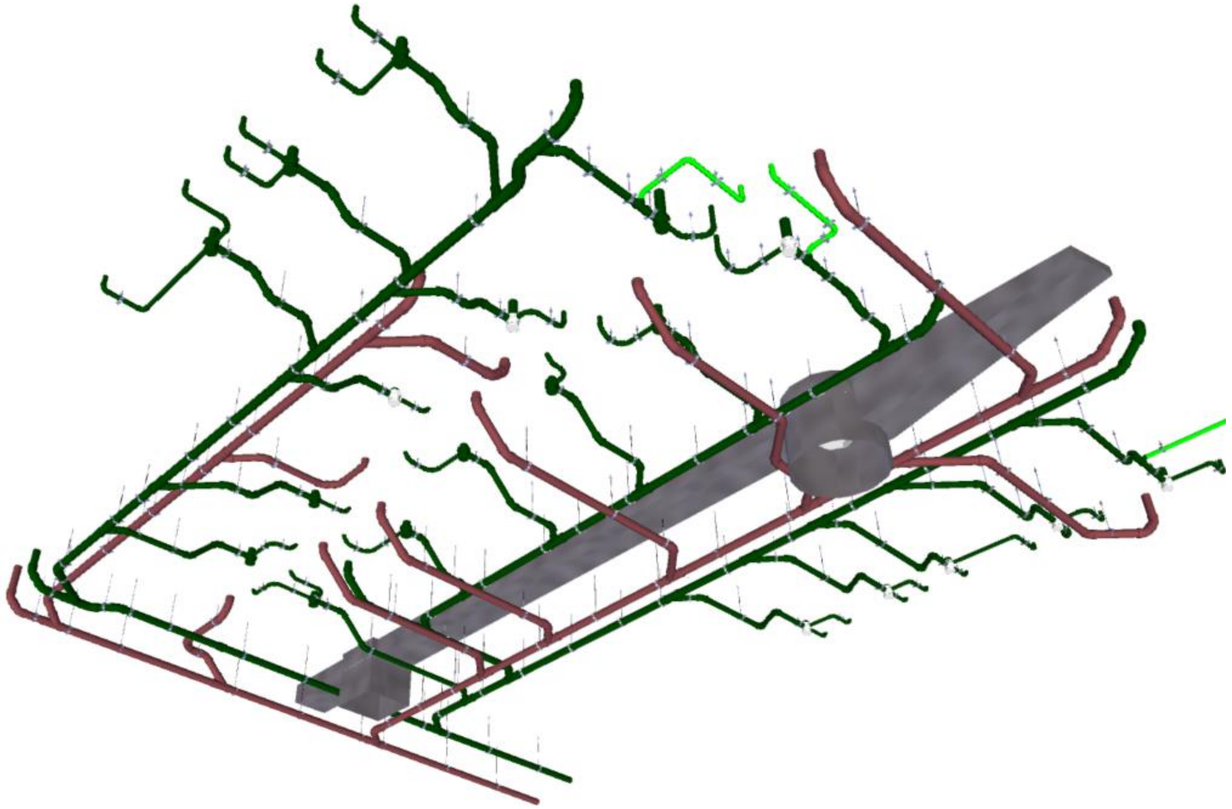
Chilled Water Pipes BIM Model

Scan to BIM of Public Health Services

Scan ⇨ BIM

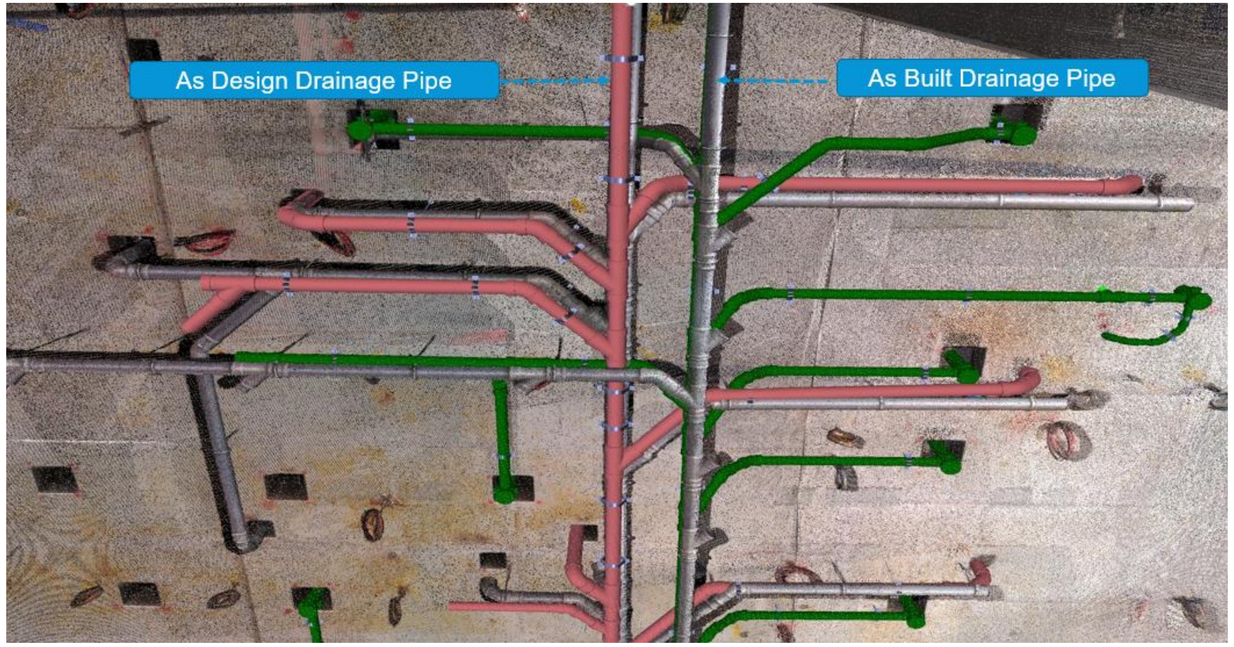


Drainage Pipes Point Cloud Model

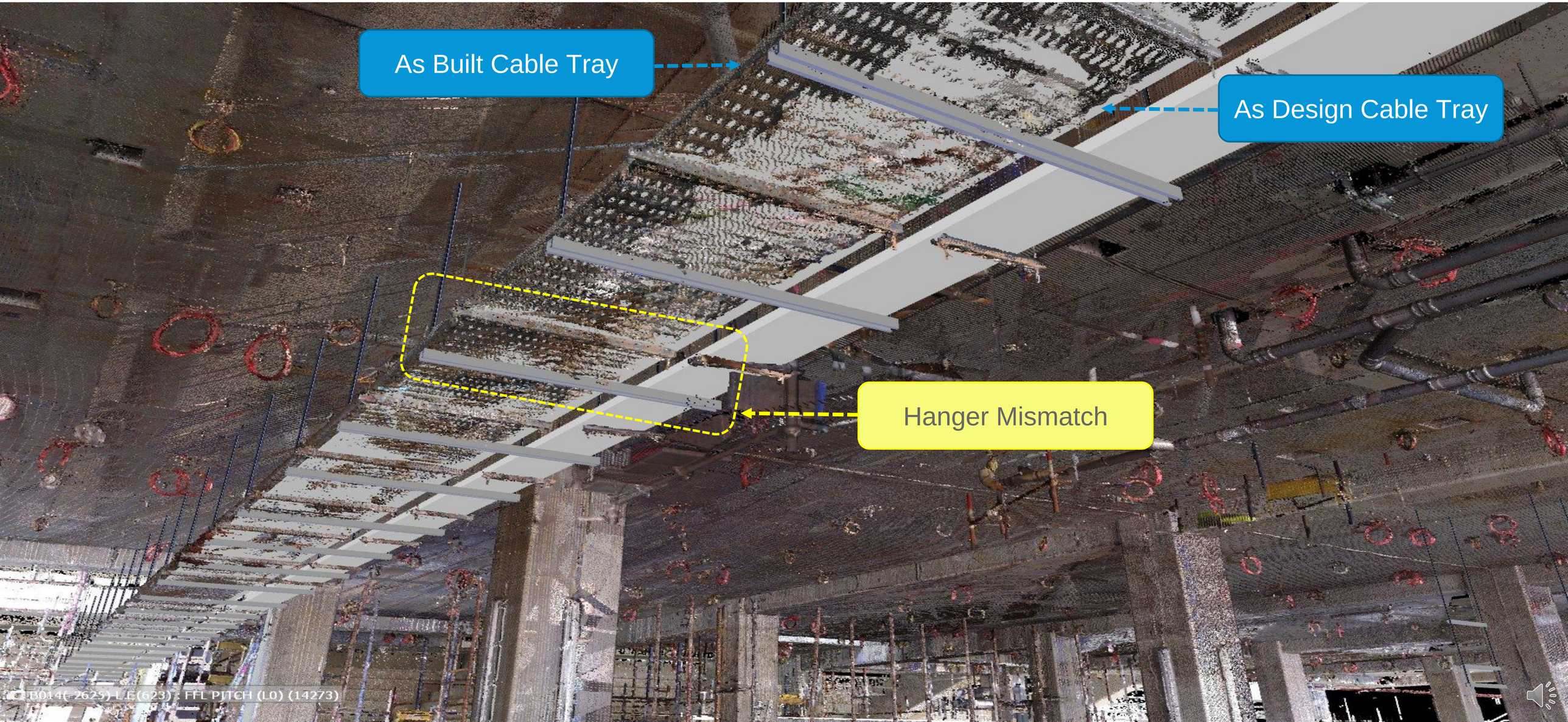


Drainage Pipes BIM Model

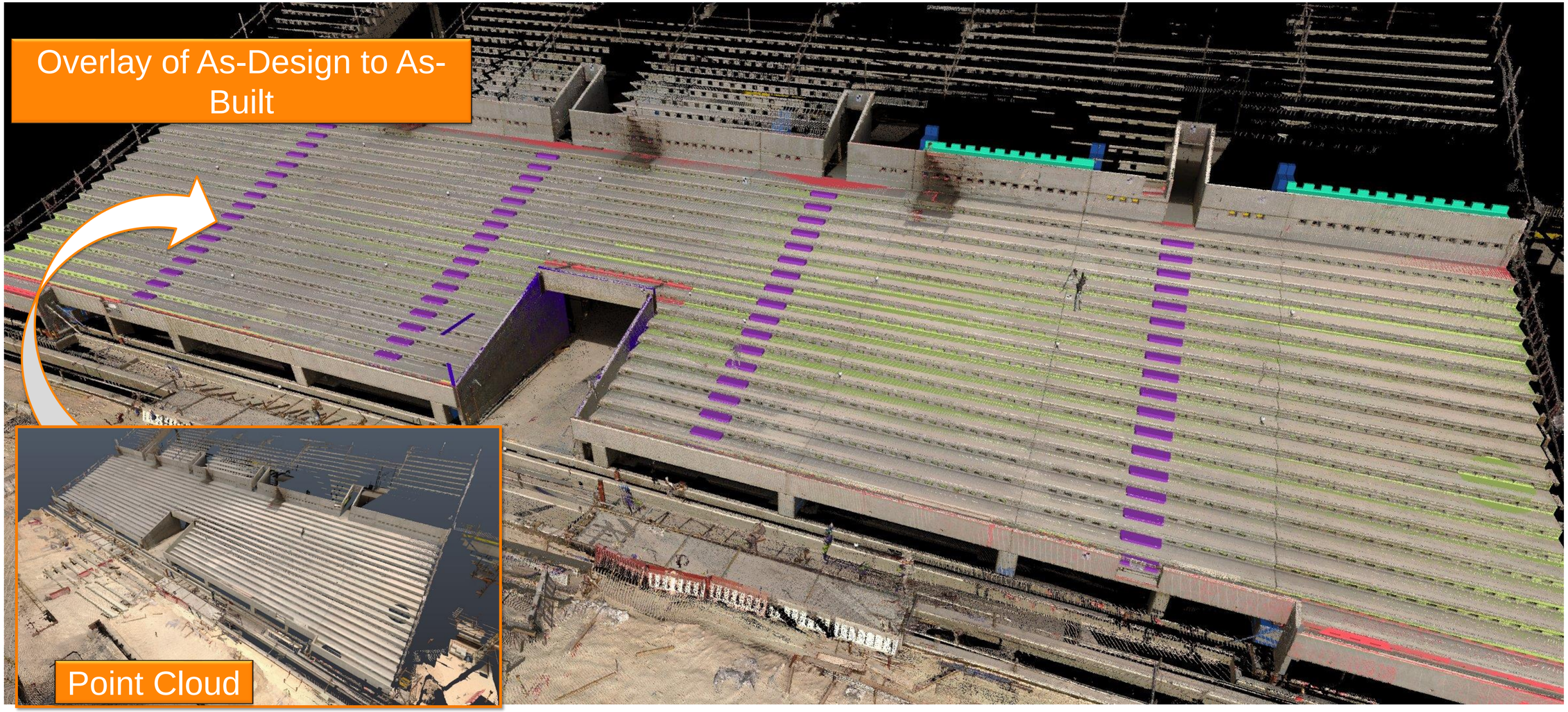
Builder’s Work As-built



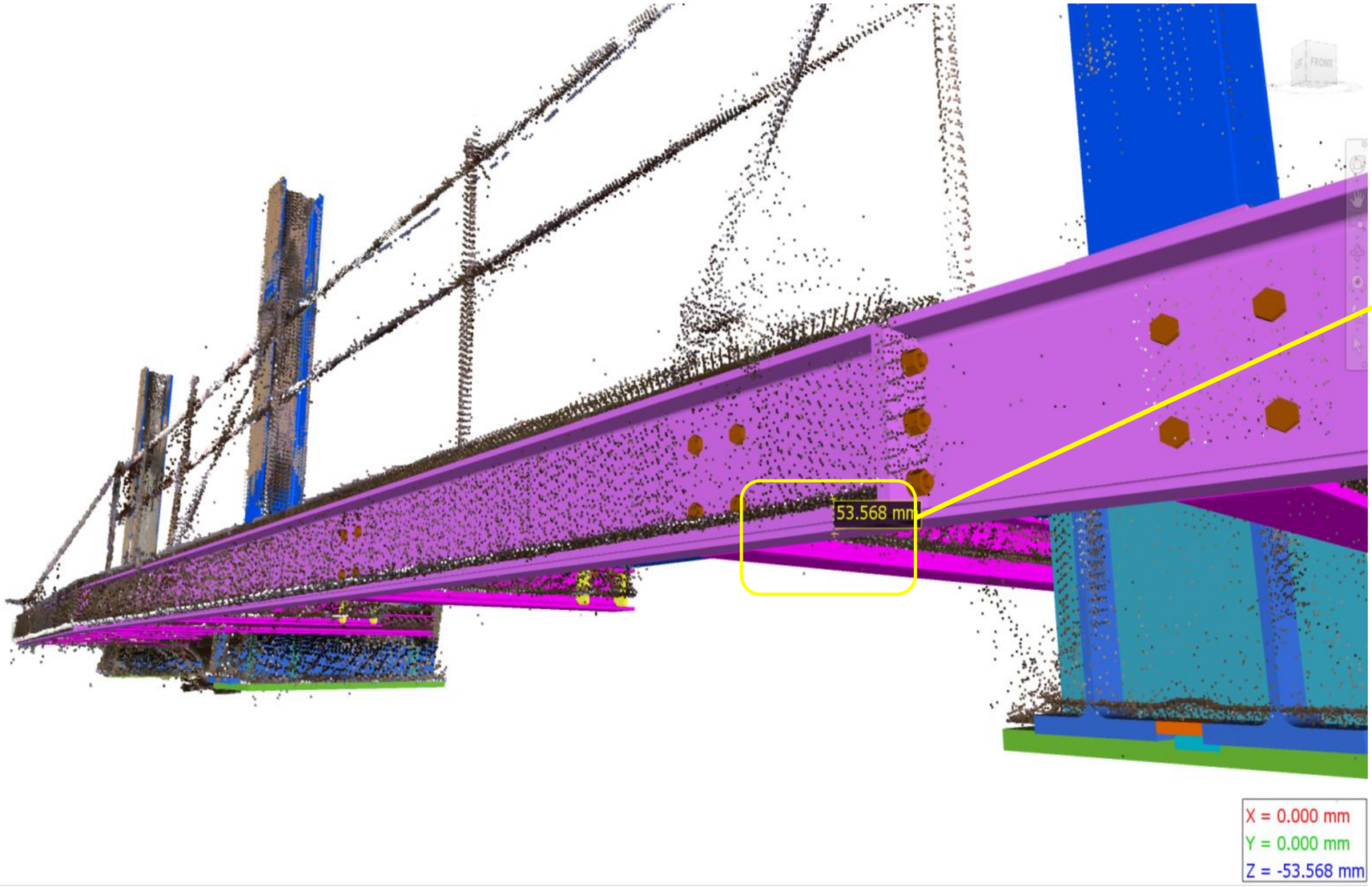
Evaluation of As-Built Conditions

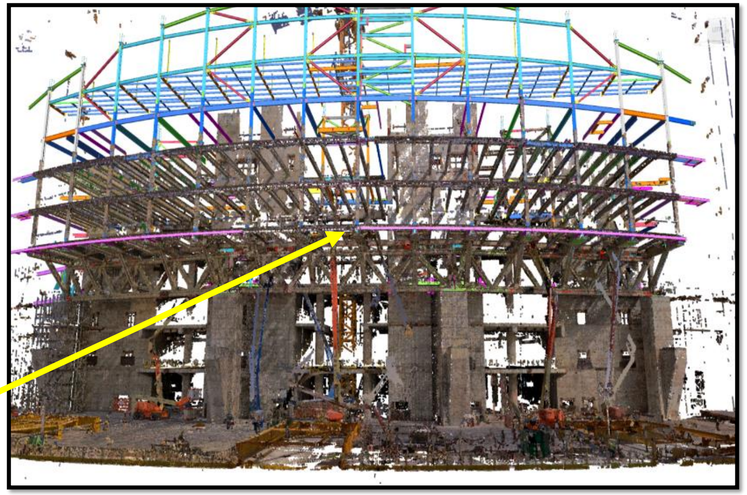


Updating of As-Design to As-Built



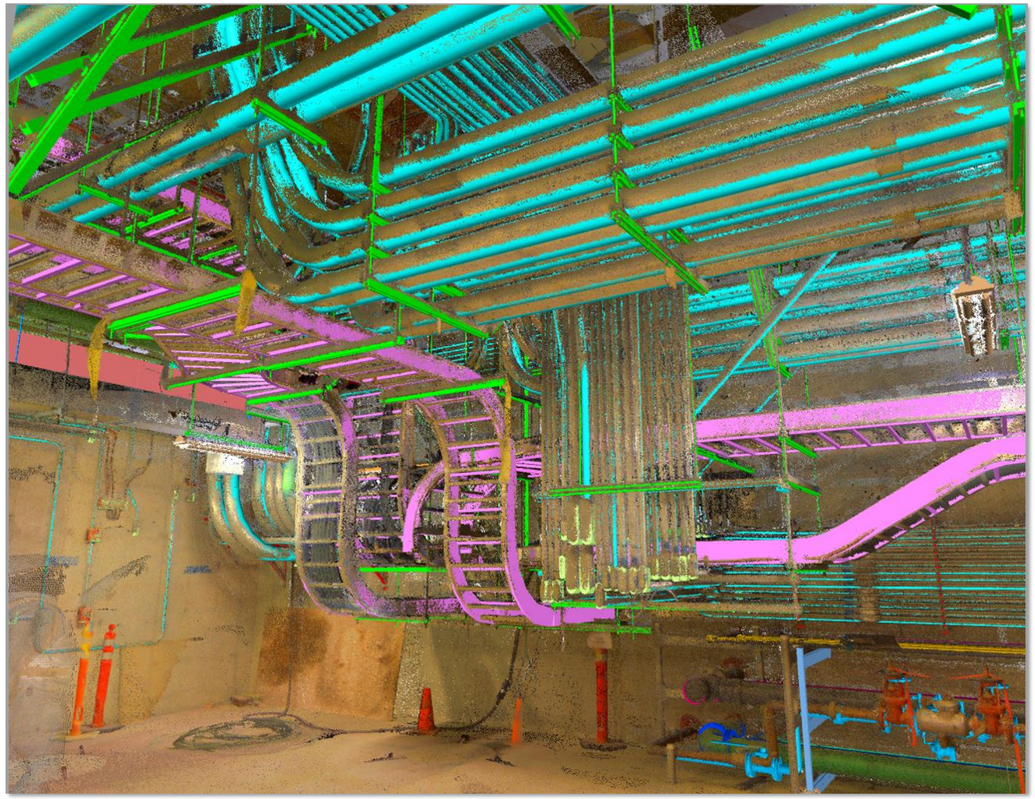
As-built to As-Design Deviation in Steel Structure

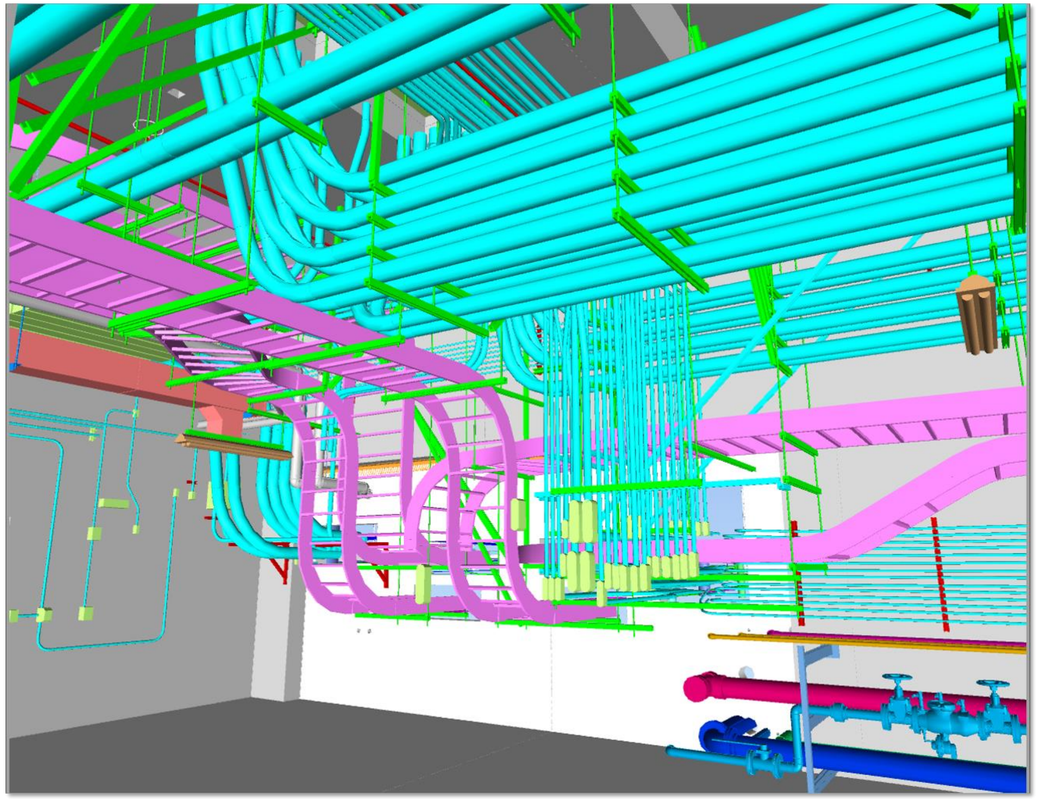




ΔH= -53.57mm
At the bottom edge of cantilever beam

Updation of As-builts





Thank you

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