Navigating Precision with Network Controls for Construction Continuity

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Key words: Engineering survey; Positioning; Reference systems; network controls; least squares adjustments; iron ore concentrator plant

SUMMARY

This conference paper explores the Control Benchmarks Network Adjustment Project undertaken by Multigeomatics Limited in the ArcelorMittal Iron Ore Mine concession, Liberia, in 2021. Over some months, the project's main goal was to create a solid survey network, connecting separated survey controls with existing structures, with a strong focus on reducing errors, to start off a brownfield plant construction of the Iron Ore Concentrator Plant.

The project began with a significant challenge: most of the reference points were missing due to a long break before resuming the earlier Phase I, leading to the loss of established controls. To address this, the project team identified two essential starting points, GBCT 06 and GBM 07, forming the baseline for their work. Additionally, they carefully placed 22 new control points across the designated construction area.

Another aspect of this project was the need to seamlessly integrate the new controls with existing structures. It turned out that the original construction used different control points, causing an approximate 60 mm misalignment with the new controls. To solve this, a transformation method was developed and executed precisely using Trimble Business Centre, resulting in an impressive minimum error of ±3 mm.

The control network was further refined using the least square adjustment method, widely recognized as the industry's best practice for ensuring the reliability and accuracy of station networks.

The Control Bench Marks Network Adjustment Project at the ArcelorMittal Iron Ore Mine is a remarkable example of precise survey work, innovative problem-solving, and careful planning. The successful execution of this project not only reconnected survey controls but also ensured a seamless transition between existing and new structural installations. This paper provides insights into the project's methodology, challenges, and successful outcomes, offering valuable lessons learnt in the world of surveying.

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1.0 **INTRODUCTION**

Control network system is a system of survey control points established on a site to provide a common reference system for all surveying and construction activities. Survey control network is the starting point of every construction work.
For all engineering works, a network control survey is carried out to fix the position of reference points required for mapping, setting out and other dimensional work. (J. Uren, 2006)

The control network involves the following:

1.1 **Reconnaissance Survey:**

The first step in establishing a control network is to survey the site and identify locations for the control points.
These points must be intervisible and an allowable distance of not more than 200 meters apart. These points were well positioned to avoid destruction in the future.

1.2 **Installations of Control Point**:

Type C beacons of concrete material measuring 15cm square by 45cm depth, flushing with the ground were used for the installation of the control points. An iron peg was used to indicate the center of the beacon.
The Survey equipment used were the Total Station and Automatic level for the control points measurements and establishment.
The control points serve as the reference points for all the subsequent survey and construction activities.

1.3 **Network Adjustment**:

The control network was adjusted to ensure that it provides an accurate and consistent reference system for the entire construction activities.
The surpcac least square adjustment tool was used for the network controls after establishment and traversing. Also, the Trible business center was used for the network transformation after the network adjustment.

2.0 OVERVIEW

ArcelorMittal is a steel manufacturing company which is in the business of mining iron ore from over 15 countries in the world.

ArcelorMittal Liberia phase II project is to build a 15MTPA iron ore concentrator plant at the north east part of Liberia, Nimba county.

The phase II Project was to build a concentrator plant to process iron ore mined from the Gangra mountain and Yuleton mountains in the concession.

The construction of the iron ore concentration plant by ArcelorMittal Liberia started around 2012 and ended in 2013 due to circumstances beyond control and management decision. This was the phase I of the project.

In 2021 the phase II of the construction works started and everything must align to the existing structures for continuity of works.

Hence additional benchmark controls were established around the concession for continuity of the project, since most of the controls were destroyed.

3.0 **METHODOLOGY**

Traversing: From the two main baseline controls GBCT 06 and GBM 07, other benchmarks were established around the site of construction.

The Trimble M3 total station was used for the traversing and was done by observing all the controls benchmarks established around the site in a loop form so we can have a closed traverse with redundant measurements

The Surpac least squares adjustment survey software was used to adjust these new controls established in order to get a very good control network. The standard deviation of the weighted observation was passed and within acceptable tolerance.

In order to let these new controls also sync with the existing structures on the site which from earlier checks has been established that they were not connecting to each other very well because of the inherited controls used for the previous construction, we employ further survey techniques.

The existing structures were surveyed with the inherited controls. The as-built data was grouped with the least squares adjusted controls established and further transformed them onto the design using Trimble business center thus transformation by least squares.

The Nikon automatic level was used to achieve the elevations of the controls by a close traversing on the various controls we established. The rise and fall method was used for the adjustment to achieved our reduced levels.

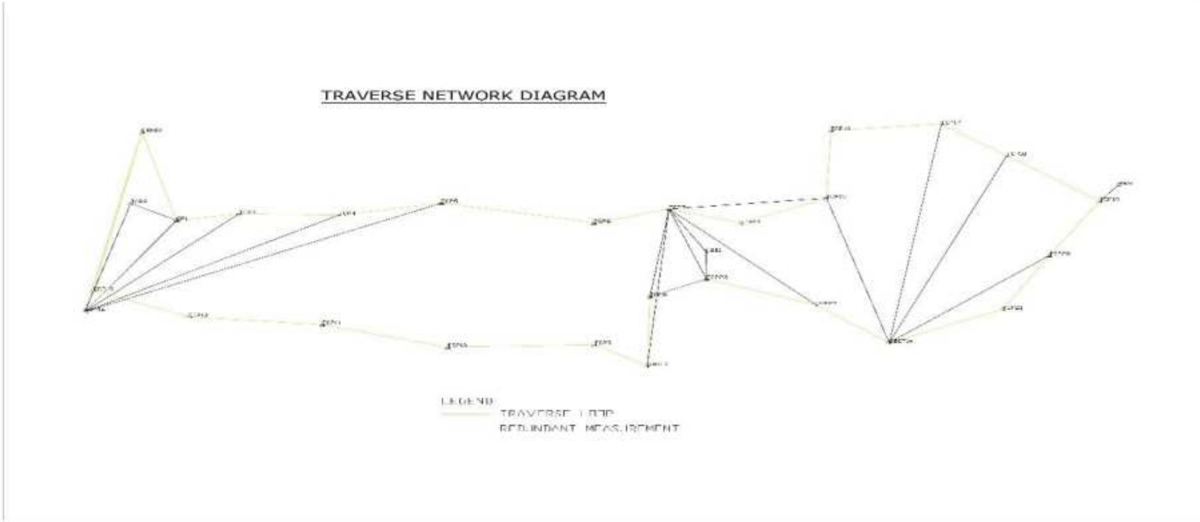
4.0 **RESULTS**

TOKADEH TRAVERSE

	NORTH (Y)	EAST (X)	ELEV (Z)
GBCT06	243.295	289.151	490.076
GMB07	546.798	355.895	494.459

INSTRUMENT STATION		BACKSIGHT SATION									FORESIGHT SATION									REMARKS
				HORIZONTAL ANGLE		VERTICAL ANGLE		SLOPE DISTANCE		H.D			HORIZONTAL ANGLE		VERTICAL ANGLE		SLOPE DISTANCE		H.D	
ID	HEIGHT	ID	HEIGHT	LL	RR	LL	RR	LL	RR	Δ in H.D	ID	HEIGHT	LL	RR	LL	RR	LL	RR	(m)	
GMB07	1.417	**GBCT06**	1.263	192°24'09"	12°24'12"	90°49'37"	269°09'04"	310.814	310.814	0.002	**CP1**	1.465	164°55'24"	344°55'32"	94°21'20"	265°37'19"	154.809	154.808	154.33	
											TCP13	1.549	191°54'58"	11°55'03"	92°26'25"	267°32'19"	273.909	273.909		REDUNDANT MEAS
CP1	1.439	**GMB07**	1.445	344°55'27"	164°55'51"	85°36'27"	274°22'28"	154.812	154.811	0.002	**TCP 2**	1.525	298°21'11"	118°21'28"	91°20'44"	268°38'14"	60.717	60.718		REDUNDANT MEAS
											TCP3	1.615	81°14'08"	261°14'18"	89°25'54"	270°32'57"	73.695	73.696	73.662	
TCP 3	1.595	**CP1**	1.465	261°14'01"	81°14'10"	90°30'56"	269°27'42"	73.695	73.695	0	**TCP4**	1.474	90°55'07"	270°55'07"	89°16'27"	270°42'18"	116.465	116.465	116.427	
TCP4	1.452	**TCP3**	1.617	270°55'02"	90°55'16"	90°41'10"	269°17'26"	116.465	116.466	0.001	**TCP5**	1.605	80°26'00"	260°26'12"	86°49'00"	273°09'41"	121.093	121.093	120.878	
TCP5	1.582	**TCP4**	1.472	260°25'59"	80°26'15"	93°08'43"	266°49'51"	121.091	121.091	0.001	**TCP6**	1.53	100°40'22"	280°40'36"	92°11'45"	267°46'47"	181.291	181.291	181.128	
TCP6	1.446	**TCP5**	1.605	280°40'21"	100°40'36"	87°44'58"	272°13'38"	181.296	181.296	0.001	**TCP7**	0.22	74°50'55"	254°51'03"	88°09'22"	271°49'24"	88.894	88.893	88.818	
TCP7	0.197	**TCP6**	1.468	254°50'51"	74°51'03"	91°47'57"	268°10'58"	88.892	88.891	0	**TCP14**	1.595	105°48'28"	285°48'42"	92°51'52"	267°07'01"	87.494	87.495	87.355	
											FBB1	1.534	149°18'17"	329°18'28"	93°14'38"	266°44'14"	84.23	84.23		REDUNDANT MEAS
TCP14	1.571	**TCP7**	0.216	285°48'30"	105°48'43"	87°05'28"	272°53'18"	87.496	87.497	0.001	**TCP15**	1.489	66°57'01"	246°57'15"	89°58'41"	270°00'02"	107.558	107.558	107.529	
TCP15	1.468	**TCP14**	1.594	246°57'01"	66°57'17"	89°58'52"	269°59'59"	107.559	107.559	0.001	**TCP16**	1.484	2°31'54"	182°32'13"	89°52'38"	270°05'59"	114.242	114.242	114.209	
TCP16	1.465	**TCP15**	1.49	182°31'56"	2°32'12"	90°04'46"	269°53'53"	114.236	114.235	0.005	**TCP17**	1.541	85°15'31"	265°15'54"	89°13'32"	270°45'10"	128.782	128.782	128.74	
TCP17	1.52	**TCP16**	1.485	265°15'34"	85°15'58"	90°44'15"	269°14'25"	128.779	128.779	0.002	**TCP18**	1.599	124°48'12"	304°48'28"	91°18'37"	268°40'03"	92.919	92.919	92.864	
TCP18	1.577	**TCP17**	1.55	304°48'08"	124°48'27"	88°38'51"	271°19'50"	92.919	92.919	0.001	**TCP19**	1.437	125°23'26"	305°23'39"	90°45'57"	269°12'43"	132.603	132.602	132.562	
TCP19	1.416	**TCP18**	1.596	305°23'23"	125°23'41"	89°12'00"	270°46'40"	132.604	132.604	0.001	**BRG1**	0.22	38°37'49"	218°38'03"	92°02'12"	267°56'34"	34.92	34.919		REDUNDANT MEAS

A section of field booking of the traversing



Traverse Network Control Diagram

Trimble Business Center Transformation Statistics

Overall Residual

Standard deviation:	0.017 m
Maximum (100):	0.028 m
Mean:	0.000 m

Easting Residual

Standard deviation:	0.011 m
Maximum (100):	0.023 m
Mean:	0.000 m

Northing Residual

Standard deviation:	0.012 m
Maximum (461):	-0.026 m
Mean:	0.000 m

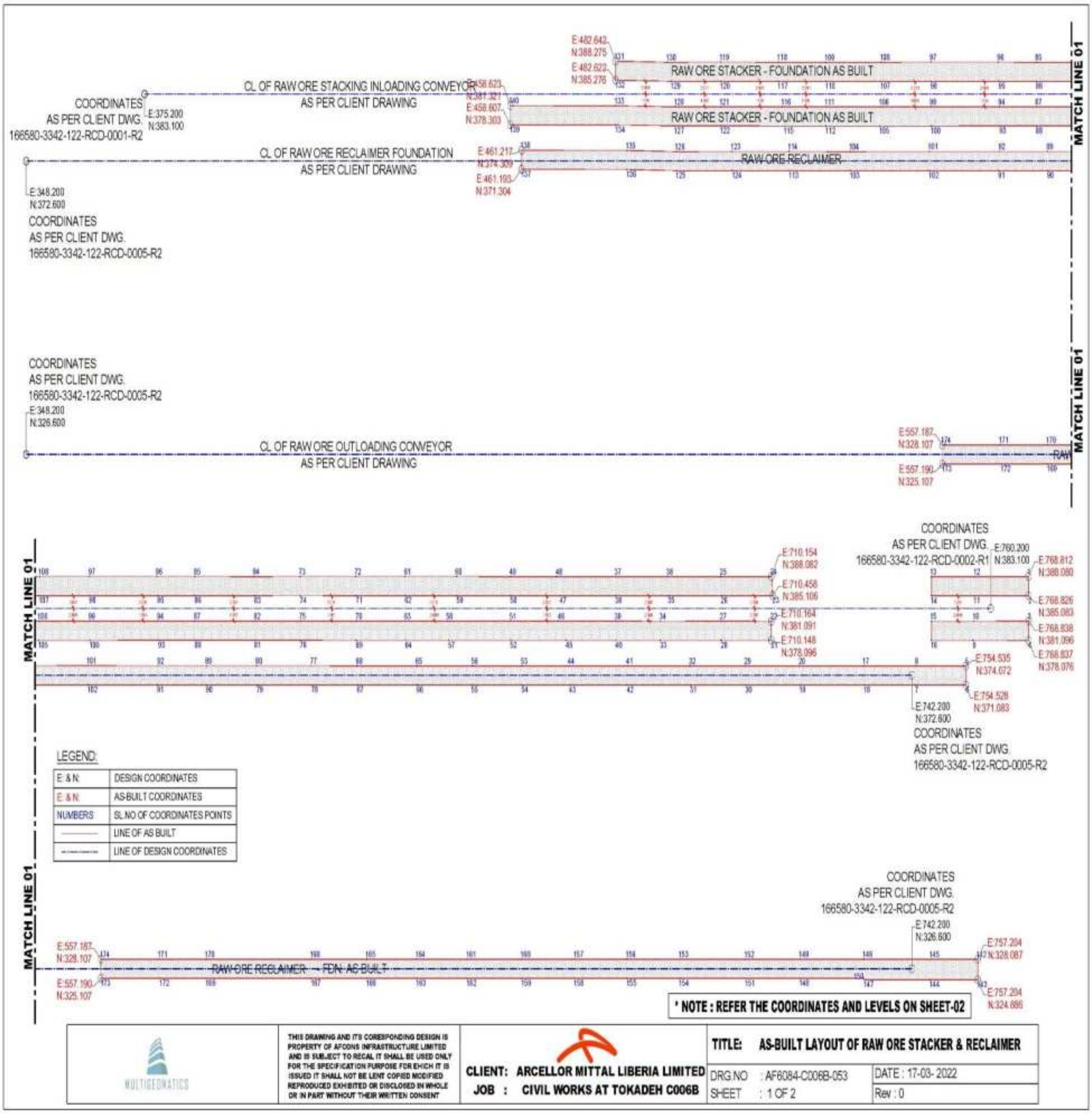
Elevation Residual

Standard deviation:	0.000 m
Maximum (100):	0.000 m
Mean:	0.000 m

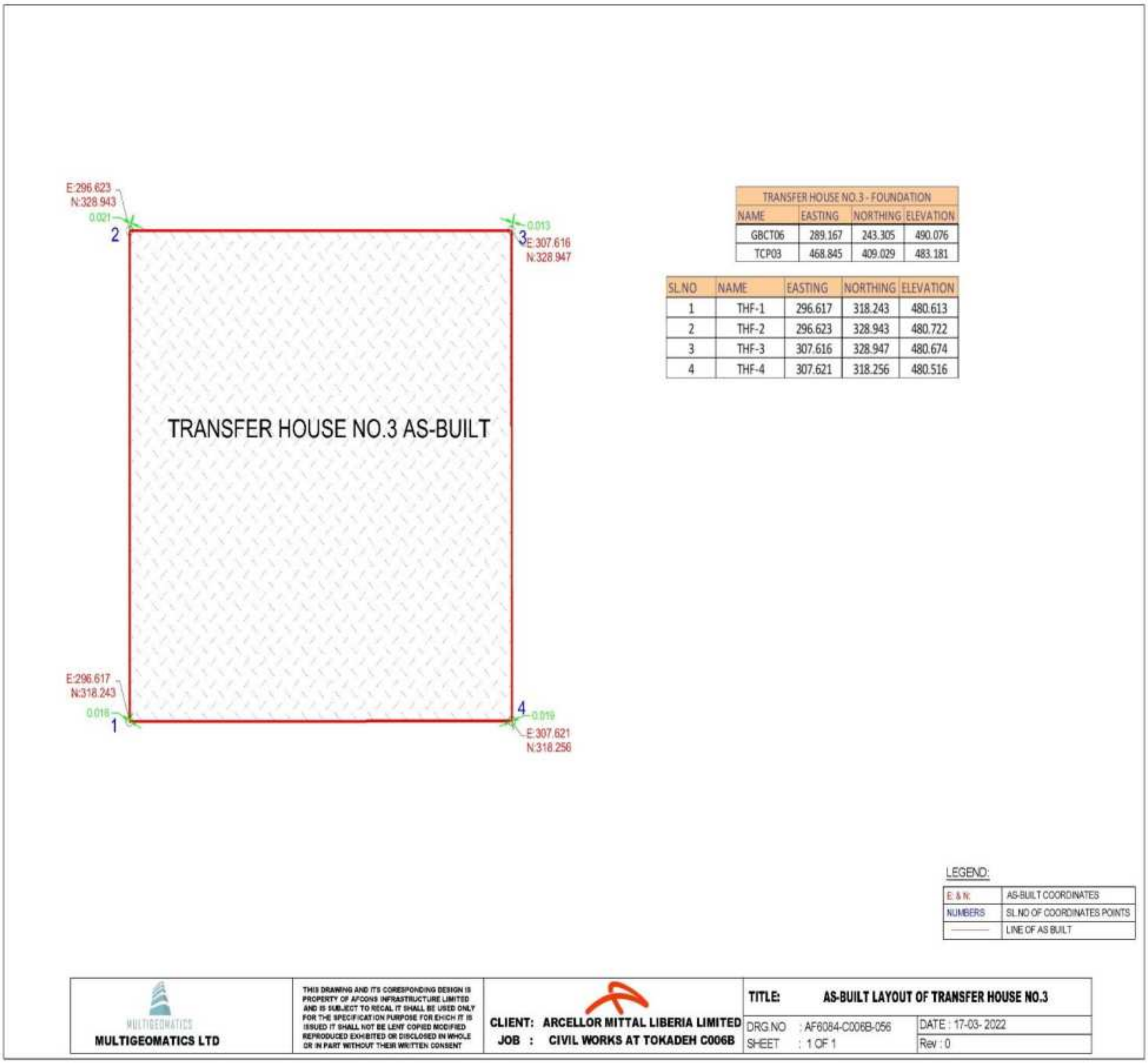
Transformed Points

Point ID	Easting	Northing	Elevation	Code
1	289.167 m	243.305 m	490.076 m	GBCT06

2	355.885 m	546.814 m	494.460 m	GMB07
3	299.419 m	279.069 m	482.626 m	TCP13
4	468.845 m	409.029 m	483.181 m	TCP3
5	585.259 m	407.154 m	484.765 m	TCP4
6	704.461 m	427.222 m	491.308 m	TCP5
7	721.082 m	318.706 m	483.765 m	AFCN8
8	882.457 m	393.679 m	484.369 m	TCP6
9	911.534 m	293.393 m	483.905 m	AFCN10
10	946.030 m	268.956 m	483.779 m	TCP8
11	968.189 m	416.894 m	488.454 m	TCP7
12	1151.186 m	435.184 m	482.787 m	TCP15
13	1156.239 m	549.279 m	483.004 m	TCP16
14	1279.957 m	559.563 m	485.232 m	AFCN15
15	1360.787 m	506.904 m	482.443 m	TCP18
16	1468.849 m	430.127 m	480.794 m	TCP19
17	1410.208 m	338.323 m	482.302 m	TCP20
18	1339.137 m	215.695 m	485.588 m	AFCN19
19	1223.993 m	191.366 m	490.179 m	GBCT14
20	1138.601 m	255.383 m	485.991 m	TCP22
21	942.803 m	152.148 m	485.065 m	GBCT07
22	710.979 m	183.544 m	482.741 m	TCP10
23	565.247 m	221.683 m	482.409 m	TCP11
24	409.818 m	234.513 m	481.713 m	TCP12



As-built data of Raw ore stacker and reclaimer foundation using new transformed controls



		DESIGN			AS BUILT		
SL.NO	NAME	EASTING	NORTHING	ELEVATION	EASTING	NORTHING	ELEVATION
1	THF-1	296.603	318.250	480.750	296.617	318.243	480.742
2	THF-2	296.603	328.950	480.750	296.623	328.943	480.741

3	THF-3	307.603	328.950	480.750	307.616	328.947	480.740
4	THF-4	307.603	318.250	480.750	307.621	318.256	480.742

As-built data sheet of an existing Transfer tower 3 foundation corners using new transformed controls.

5.0 **CHALLENGES**

- ❖ The Absence of survey control benchmarks: The many years of no construction activities caused a lot of the benchmarks used for the construction works at that time got damaged and couldn't be found or traced anywhere. Most of them have been one way or the other demolished or damaged.
- ❖ Most of the structures and their components were also destroyed and others incomplete and under construction: From the old data gathered from the phase I, control benchmarks previously established were not in sync with each other. Testing the few we saw on site shows that they were independent of each other at various places of the site, which doesn't help in connectivity of the structures for construction sense. It appeared every block of the site had a different network control which makes it difficult to link the entire site as one site with the structures in connection.
- ❖ During the traversing of the controls, choice of locations of points and weather conditions contributed to some of the challenges. Heavy rain pours and sunshine inhibited the traversing process for some time, till we had a good and friendly weather conditions to continue.

5.0 **CONCLUSION**

The entire survey control network process and the results showed that after the new control benchmarks were grouped with some of the existing structures and transformed using Trimble business center least square transformation, they seamlessly resulted in a minimal marginal error between the design and asbuilt.

These benchmarks served as the primary controls which offered a rigid framework for the entire construction works which is ongoing with the highest form of construction precision. A lot of other secondary controls have been established from these primary controls and are syncing very well with the structures both old and new.

6.0 **RECOMMENDATION**

Control points at construction site should be well protected by using a visible type of barricading to prevent easy demolishing.
Also control points should not be placed where there will be possible existence of structure.
Careful planning is the key to achieving the right type of control network.

REFERENCES

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