USING ENGINEERING SURVEY TECHNIQUES FOR THE TONKOLILI RAILWAYS PROJECT

Prof. Maricel PALAMARIU, Ph.D. Eng.

Marrakech, Morocco, 18-22 May 2011

Contents

1. Introduction

2. Phase One – Path Finder

3. Phase Two – Design And Stake Out

4. Conclusions and suggestions

Marrakech, Morocco, 18-22 May 2011
1. Introduction

- African Minerals Limited (AML) is a mineral exploration company with significant interest in Sierra Leone, West Africa
- Sierra Leone is a mineral rich country which has been largely unexplored and has recovered from a period of instability
- Tonkolili Railways Project is the biggest development project in Sierra Leone since the end of the civil war 10 years ago

1. Introduction

- Dawnus Construction is an international civil engineering and building company, based in Wales, UK
- Dawnus Sierra Leone was formed in 2010 to work with Africa Minerals on the Tonkolili Iron Ore Project
- The engineers are all British and the surveyors are from Romania, who work closely together with Sierra Leone’s engineers
1. Introduction

Due to the size of the project the earth work has been divided into three work packages as follows:

- **Work Package A**: Construction of the earth works from km 0 to the bridge at km 50
- **Work Package B**: Construction of the earth works from the bridge at km 50 to km 85
- **Work Package C**: Construction of the earth works from km 85 to the Tonkolili mine.

Also, Africa Minerals is in the process of refurbishing their Iron Ore port at Pepel, Sierra Leone. Pepel Stockyyard is situated on Atlantic seaport located near the mouth of the Sierra Leone River.

In this paper we will only refer to the topographic operations conducted for the construction of the railway between km 0 and km 50
Geodetic parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>UTM Z28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone Number</td>
<td>28</td>
</tr>
<tr>
<td>Central Meridian</td>
<td>15° 00’ 00.00000° W</td>
</tr>
<tr>
<td>Hemisphere</td>
<td>Northern</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>UTM Z29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone Number</td>
<td>29</td>
</tr>
<tr>
<td>Central Meridian</td>
<td>9° 00’ 00.00000° W</td>
</tr>
<tr>
<td>Hemisphere</td>
<td>Northern</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>WGS84</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-major axis (a)</td>
<td>6378137.0</td>
</tr>
<tr>
<td>Reciprocal Flattening (1/f)</td>
<td>298.257223563</td>
</tr>
</tbody>
</table>

2. Phase One – Path Finder

- The designer provided the coordinates of the railway axis points, 50 meters centres along the alignment.
- The first emergency was to stake out the railway axis and to clear the route from vegetation.
- The stake out method used was the RTK method, using two geodetic receivers with dual frequency, and RTK capability.
2. Phase One – Path Finder

- Many villages have to be passed and everyday the surveyors got involved with local people.
3. Phase Two – Design And Stake Out

At the end of September 2010, the designer provided information about the geometry of the railway axis.

![Table](image.png)

Figure 2 - The horizontal geometric elements of the axis

![Table](image.png)

Figure 3 - The vertical geometric elements of the axis
3. Phase Two – Design And Stake Out

– Control points

- It was necessary to develop a network of control points to ensure homogeneity of the points for the whole project, starting from Pepel, and finishing at Tonkolili.

- The task of developing these networks fell in the beneficiary’s hands and it was done in two campaigns:
  - In the first campaign the primary control points (primary control network) was developed in a major network, covering all perspectives of the beneficiary projects. The distance between the points was of tens of kilometres, and as starting bases, the coordinates of South African and Spanish permanent stations were used. Unfortunately, excepting the coordinates and a placement scheme of the points, no details about the processing method were provided (figure 5).
3. Phase Two – Design And Stake Out – Control points

From the points thus determined, networks have been developed to ensure sufficient covering with control points for all the projects developed by the beneficiary. For the studied project part, new points were determined, at a distance of approximately 5km.
3. Phase Two – Design And Stake Out
– Control points

I have verified the coordinates of these points, in a network developed by the constructor:

<table>
<thead>
<tr>
<th>Point</th>
<th>DX</th>
<th>DY</th>
<th>DZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTK01</td>
<td>0.014</td>
<td>0.022</td>
<td>-0.040</td>
</tr>
<tr>
<td>DTK02</td>
<td>0.013</td>
<td>0.017</td>
<td>-0.019</td>
</tr>
<tr>
<td>DTK03</td>
<td>0.010</td>
<td>0.016</td>
<td>-0.002</td>
</tr>
<tr>
<td>DTK04</td>
<td>0.007</td>
<td>0.016</td>
<td>-0.007</td>
</tr>
<tr>
<td>DTK0</td>
<td>0.003</td>
<td>-0.002</td>
<td>0.020</td>
</tr>
<tr>
<td>DTK05</td>
<td>0.010</td>
<td>-0.005</td>
<td>0.037</td>
</tr>
<tr>
<td>DTK06</td>
<td>-0.002</td>
<td>-0.007</td>
<td>0.052</td>
</tr>
<tr>
<td>G31</td>
<td>-0.002</td>
<td>0.002</td>
<td>0.062</td>
</tr>
<tr>
<td>DTK07</td>
<td>0.001</td>
<td>-0.004</td>
<td>0.059</td>
</tr>
<tr>
<td>G51</td>
<td>-0.008</td>
<td>-0.007</td>
<td>0.013</td>
</tr>
<tr>
<td>DTK08</td>
<td>-0.004</td>
<td>-0.011</td>
<td>0.012</td>
</tr>
<tr>
<td>DTK09</td>
<td>0.003</td>
<td>-0.011</td>
<td>0.025</td>
</tr>
<tr>
<td>DTK10</td>
<td>0.005</td>
<td>-0.013</td>
<td>0.028</td>
</tr>
</tbody>
</table>

The problem of performing a geometric leveling, was the same as for the control points: the absence of any leveling references. In this situation we had two options:

- The geometric leveling should be done between the GPS control points, using EGM96 geoid;
- The geometric leveling should be done starting from the first point (Km 0), until the last point (Km 50), and back;

Personally, we expressed our scepticism in accomplishing a leveling on a distance of 100 km. Besides the great distance, obstacles made this operation impossible:

- Too much time needed to cover this – in the same time, most of the site operations would not benefit of leveling references;
- Rough relief – at the time of land leveling, the terrain did not benefit of major cut – fill work;
- Railway axis was not completely cleaned – there still were swampy areas that would have made a leveling line crossing impossible.
3. Phase Two – Design And Stake Out

– Precision Leveling

- The leveling was done using a level with an accuracy of 0.2 mm, with a double horizon
- The height of the GPS control points were used. The results were surprising

| BM23320 | 0.008 | BM27020 | -0.004 |
| BM23580 | 0.010 | BM27701 | -0.013 |
| BM23880 | 0.000 | BM27000 | -0.005 |
| BM24120 | -0.004 | BM28160 | -0.010 |
| BM24880 | -0.012 | BM28580 | -0.008 |
| BM25000 | -0.005 | BM29040 | -0.003 |
| BM25700 | -0.005 | BM29420 | 0.002 |
| BM25960 | -0.005 | BM29680 | 0.004 |
| BM26460 | 0.007 | BM30550 | 0.001 |
| BM26920 | 0.007 | BM30850 | 0.001 |

Between the control points, new points were placed (bench marks), for which it was intended to determine the planimetric coordinates and the height

A precision leveling was done. The results were surprising
3. Phase Two – Design And Stake Out

Stake out of the geometrical elements was made in two stages:

In the first stage, the railway axis (CL) was staked out
- After staking out the point, the real values of the planimetric coordinates, and heights were recorded. This approach allowed creating a data file, which was named “Preplot – postplot comparison”

| 180 103411.356 965902.748 66.612 103411.349 965902.760 66 .585 0.007 -0.012 0.014 0.027 |
| 180 103425.337 965888.447 66.587 103425.338 965888.462 66 .574 -0.001 -0.015 0.015 0.013 |
| 200 103439.319 965874.146 66.554 103439.289 965874.155 66 .576 0.030 -0.009 0.031 -0.022 |
| 220 103453.300 965859.846 66.513 103453.287 965859.861 66 .550 0.013 -0.015 0.020 -0.037 |
| 240 103467.282 965845.545 66.463 103467.299 965845.569 66 .563 -0.017 -0.024 0.029 -0.100 |
| 260 103481.264 965831.244 66.405 103481.252 965831.216 66 .558 0.012 0.028 0.030 -0.153 |
| 280 103495.245 965816.943 66.339 103495.222 965816.936 66 .432 0.023 0.007 0.026 -0.093 |

The information provided by this file was very useful, and allowed:
- Identifying possible stake out errors,
- Identifying fill routes, respectively cut routes, important aspect in staking out and determination of geometrical elements of the railway.

In the second stage, the geometrical elements of the railway were calculated and staked out
Further, depending on the GPS equipment capabilities, the two toe points were established:
- Infrastructure basis for fill – distance from axis of 3975 mm,
- Embankment basis for cut – distance from axis of 5475 mm.

Figure 5. The dimensions of the geometry elements of the infrastructure

Figure 6. The dimensions of the geometry elements of the infrastructure
3. Phase Two – Design And Stake Out

AML also started extensive work for redeveloping the port at Pepel. The scope of works at Pepel, was the construction of all Civil Works pertaining to a new Train dump station, conveying and stockpile.

Figure 7. The installation project from Port Pepel.
3. Phase Two – Design And Stake Out

The main problems that occurred in staking out these constructions were:
- Lack of initial control points – the survey has been done more than two years ago. From the initial control points only one was left;
- Two types of survey done – initially the survey was done by GPS, by applying cartographic corrections, and after additions were made with the total station, without cartographic corrections;
- The need of connecting the unloading stations - loading at two fix points imposed by the project;
- High precision stake out imposed.

3. Phase Two – Design And Stake Out

In order to stake out the constructions and the installations, a high precision network had to be made
As starting point of the observations, the only point left from the initial surveying was used, and for orientation a detail point from the field which could be identified was used.

Figure 8. The network made in Pepel
3. Phase Two – Design And Stake Out

Figure 7. The coordinates and the corrections of the new points determined in Port Pepel.

3. Phase Two – Others topographic operations

With a huge volume of construction, every day new problems occurred that required the intervention of the surveyors:
- relocation of control points,
- relocation of beacons,
- stake out and heigh checking,
- weekly production survey,
- calculation of volumes etc.
3. Phase Two – Others topographic operations

Special surveys for the creation of 3D models were done at the two stone quarries – Rofayne and Mackeri

Figure 8. 3D model – Mackeri Quarry

Creating these models allowed developing different exploit methods and precise monitoring of the exploited rock quantities

Figure 9. 3D model – Rofayne Quarry
4. Conclusions and Suggestions

- The described work led to the following results:
  - At km 0, the connection precision with the existent section was of 10 mm,
  - At km 50, the connection precision with the next section (on common control points) was of 5 mm.
- The connection precision at the other section (other contractors) was over 200 mm, that imposed compensation operations.
4. Conclusions and Suggestions

- The teams that helped accomplishing this project were composed of engineers from Wales, surveyors from Romania, and engineers from Sierra Leone.
- The experience of Wales engineers, with the technical knowledge of Romanian surveyors, and the help received from local engineers and the interference with the local culture, have led to great enthusiasm in the execution of the project.
4. Conclusions and Suggestions

The main problem identified throughout the project was the lack of control points – both horizontal and vertical. No benchmarks for vertical control in Sierra Leone previously have been done. EGM96 model has been applied successfully. Some minor differences could occur from:
- poor solution in ellipsoid height
- instruments heights mistakes

4. Conclusions and Suggestions

An other problem identified throughout the project was the lack of an adequate cartographic projection. Sierra Leone is crossed by two UTM zones, Zone 28 and zone 29. All the work was done on zone 29, which led to quite big cartographic deformations.
4. Conclusions and Suggestions

I would like to give my sincere thanks to the following people, with whose help I would not have been able to complete this paper:

Mr. Andy Peters – Project Director
Mr. Mike Condon – Project Manager
A special mention also to my Welsh colleagues for their help and assistance:

Mr. Andrew Pope,
Mr. Ian St. John,
Mr. Gerrant Eduard,
Mr. Richard Samuel

My thanks and appreciation to my staff from Sierra Leone for all their hard work:

Mr. Prince Tucker,
Mr. Ibrahim Sano,
Mr. Vidal Kay,
Mr. Musa Koroma
And, not on the last sincere thanks to my Romanian colleagues for all their help:

Mr. Sergiu Vaida,
Mr. Alex Pop,
Mr. Paul Cristea
THANK YOU FOR YOUR ATTENTION!