DEVELOPMENT OF A SOFTWARE PROGRAM TO GENERATE A WBS FOR EARTHWORK PROJECTS

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*The title and abstract have changed from those originally presented in the EC3 2019 conference proceedings

Abstract

It is very important while creating a schedule plan for any project, to have a suitable work breakdown structure. It is well known that in earthwork projects, there are several criteria that effects the WBS as soil type and level of excavation. The present research shows the steps of the development of a software program using matlab and Microsoft excel. Taking into consideration the topography of the ground and the soil type. The research work aims to create an automated software program that calculates the most economic platform level and creates a WBS for Earthwork projects. The results of the software had been used to be exported to Microsoft Excel in an easy way to be used in the planning stage. In addition, an interface was created in order to make the software program user-friendly and easy to use. The software has been validated by two tests, a theoretical area and a real case study.

Introduction

Background

Early planning is very important in order to create the best combination of price, quality, and time. Earth work can be one of the main activities of most mega projects. One of the early tasks is to choose the best platform levels to begin construction especially in rough terrains. The detailed calculation of the cut and fill volumes are the basics of an effective and economic design. The best way to organize such a big task is to create a Work breakdown structure (WBS) which categorizes the main points of the work. Among different ways to create a WBS, the computerized process can help to reach the most economical solution in short time avoiding the possible manual errors. Therefore, the best approach is always an automated generation that calculates and categorizes all project components in a logical procedure.

In this study, earthworks for large areas (e.g. large industrial areas, compounds, resorts, and huge landscapes) have been considered. This is referred to a mass-haul problem as the project task will be moving materials from one location to another. It would be catastrophic to start such a big task without a detailed earth work plan considering areas and volumes of cut and fill as well as type of cut materials and specifications of the fill materials. Such a study can help the engineer to define the amount of reused cut material and the amount of required imported materials. This procedure can develop an economic and time-saving project.

Software

This study shows the development of a software that calculates the cut and fill quantities with the most economic Platform level of the area. The program is based on only one platform for the whole project area. The program was validated using a real case study.

Literature review

There are different methods for calculating the Volume of a shape. Among many methods, Section method, Simple prisms method, Layer thickness method, Complex prisms method, and cross-sectional method are commonly used.

Different techniques can be explained as follows (Janić et al., 2015):

Section method

For linear objects, the common used method is the cross-sectioning method. This method can be used for surface objects as well, and is used as a control method. The advantage of this method is that visually depicts conducted excavations and embankments, and disadvantage is insufficient accuracy for large profile intervals.

Simple prisms method

This method consists in summing volumes of simple three-sided prisms formed from a network of triangles. TIN triangles are used to form the vertical three-sided prism to some reference elevation, usually zero elevation. In the case of calculating the volume between two terrains surfaces, i.e. upper and lower, their difference is the volume of excavation or embankment. The disadvantage of this method is that both models must have identical external border, and it is not possible to get the information separated for excavation and embankment. If the excavated material is dumped within the common external border, this method will give the volume of zero, which is not correct. This method is applicable only when the excavation is transported outside the

DOI:10.35490/EC3.2019.179

external border.

Layer thickness method

In this method, the points on the first model (vertices of triangles) are projected to the second model and calculated height differences are thicknesses in the points of the first model. Also in the points of the second model similarly are calculated height differences to the first model that also give the thicknesses in these points to the first model. The third set of points consists of the polygon boundary vertices, where the layer thicknesses between two models are also calculated. Thus, obtained thickness now serve as input data for the thickness model formation, where the points of both models and the layer thickness in them as variable Z, forms a model, whose volume should be determined. This method has the advantage over the previous one, because both models do must not necessarily to have identical external border, and which gives information separately for excavation and fill. The disadvantage of this method is that the upper and lower model may not have big changes in elevations. It is recommended to calculate the volume of ore reserves from the exploration boreholes.

Complex prisms method

This method gives the best results, because it takes into account all the inputs from both terrain models: points and break lines. It consists in projecting a network of triangles of the first model to a network of triangles of the second model, resulting in a set of polygons

Cross-sectional method

The cross-sectional method is most commonly used for calculation of site excavation on sites where the grade around the building changes dramatically (Peterson 2012). Like the average-width- length-depth method, the average-end method, and the modified-average-end method, the cross-sectional method produces an approximate volume and is less accurate than the geometric method. The following steps need to be completed to calculate the volume using the cross-sectional method:

Step 1: Divide the site into grids.

Step 2: Calculate the cut or fill at each grid intersection.

Step 3: Separate the cuts and fills with a zero line.

Step 4: Calculate the volume of the cuts and fills.

Methodology

Method used in the software

Following the literature review, and comparing different methods in terms of the calculations and suitability, the "Cross-section (grid) Method" was found best suited for large open areas because it is not complicated and gives results with high accuracy. This method divides the area into a network of small simple four-sided rectangular. The dimensions of the developed mesh are fixed to a square with fixed side width. The volumes will be calculated from the area of the rectangular multiplied by the difference between the upper and lower surfaces. The upper surface represents the natural ground level and the lower surface is the Platform level that can be defined via an iteration process. The volume calculation is classified into "Volume cut" and "Volume fill" depending on the sign (positive or negative respectively). The start value of the platform level is chosen equal to the average of the z-coordinates of the points (height of the ground surface), and then it will be increased or decreased by a certain value (e.g. in this work 0.15m) in an iteration process till the value of the cut and fill volumes are nearly equal. The details of subsoil conditions are defined through the boreholes conducted as part of the site investigation. As shown in Figure 1, the fill volume is divided into three parts as follows: the distance between the finishing level to the foundation elevation will represent the so-called "foundation depth" and will be assumed 1.5m and consists of silica sand; compaction will be done for every 0.25m lift. 3m under the foundation elevation will be filled with 1:1 sand and crushed stone which will be compacted every 0.3m. And the rest, till the initial natural ground surface, will be filled with well grades material of size from 0 to 15cm and compacted every 0.5m.

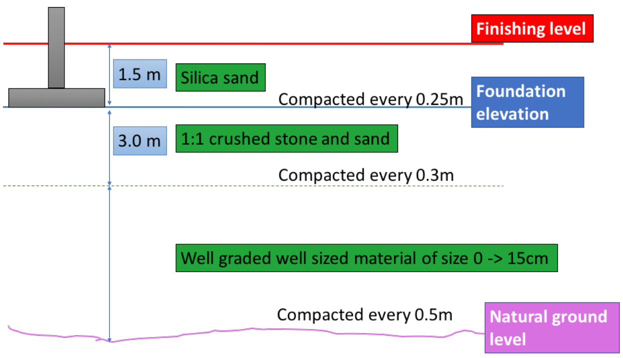

Figure 1: Fill material details

There is also the possibility of getting a volume value of zero, that means that the initial ground surface and the platform elevations are identical at this cell.

Work procedure

Flowchart construction:

After collecting the data and deciding how the calculations will be performed, a flow chart was developed. This flowchart shows the steps and the approach that the program will take.

The software will start with taking following input data:

- Area dimensions
- Spot point coordinates
- Borehole data

Then the calculations are made in the software:

- 1^{st} assumption of the Platform level by taking the average of all spot point heights
- Calculating the Volumes and classify it into 'Volume cut' and 'Volume fill'
- Modification of the platform level depending on the differences between the volumes
- Final calculation of cut and fill Volumes
- Calculation of volume details

The software shows following output data:

- Three 3D-Graphs
- WBS in form of an Excel-document with sheets for 'Platform level', 'cut', 'fill' and 'no work'.

Program development:

There are lots of methods for writing a software-code. It was decided to write a MATLAB-code considering its advanced graphic opportunities. A case study was calculated manually to validate the software and to check its accuracy (see chapter 6 "Case study"). At the end, a graphical user interface was developed to help the user to enter the inputs and understand the calculated results easily in a visible format (see chapter 5 "Graphical User Interface").

Program limitations

The program has some limitations. The following list clarifies the limitations of the software:

- The area that will be calculated should be rectangular with a length and width multiple of 50m.
- Grid dimensions are 50X50m.
- The whole area should have only one platform.

Basic assumptions:

- The origin of the area will be in the lower left corner.
- In every grid, there is a spot point and a Borehole point.
- The unit used in the program are all in SI unit

Software development

Theoretical case:

To create the software and write the code it is always better and easier to have a test with its results to verify step by step everything that will be calculated. This test was assumed as an area with size 350x250m.

Manual test results:

Before writing the code, manual calculations were done to have values for comparison while writing the code step by step. These manual calculations were done with the help of an excel sheet.

Graphical User interface

Definition of "Graphical User interface" (GUI)

The software was developed using MATLAB and a graphical user interface was developed to let the software be user-friendly.

Shape of the GUI

The designed shape of the GUI is shown in Figure 2.

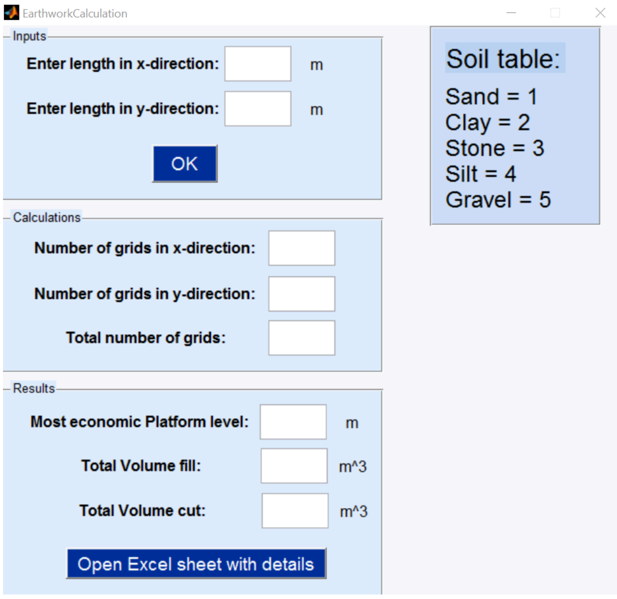

Figure 2: GUI shape

1.1. Inputs:

1. The dimensions of the area
2. The coordinates of the spot-points
3. The borehole data

1.2. Outputs:

1. The three 3D graphs (initial topography, the calculated platform level, and the combination of both).
2. The excel document with all calculated details in 4 different sheets (platform level, cut, fill and no work).

Case study

Any program that is developed has to be tested on a real project with logical values to check that the software is working right and to approve the software.

A real resort project near the beginning of the Alexandria road was chosen as a verification example. The surface topography was given in an AutoCAD file with the x,y,z-coordinates of each point and the borehole-data taken from the site. The area has a highly irregular shape as shown in Figure 3. To simplify the required work, only a part of the project is considered from the test as shown in Figures 4 and 5. The 50x50m grids were drawn inside this area and everything else was deleted from the file to work on the chosen part (see Figure 5). Three boreholes were applied to represent the whole subsoil conditions of the studied area (Figure 6).

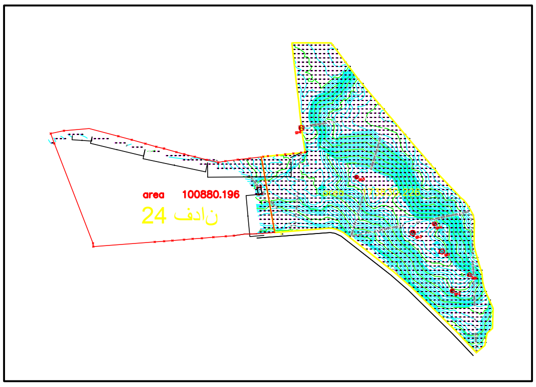

Figure 3: Original area of the real test

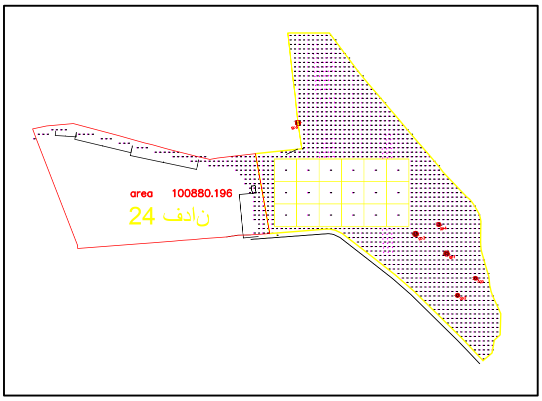

Figure 4: Small area taken from the map

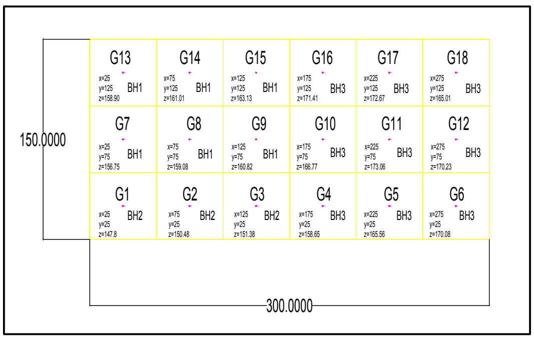

Figure 5: The Grids and data used in the software

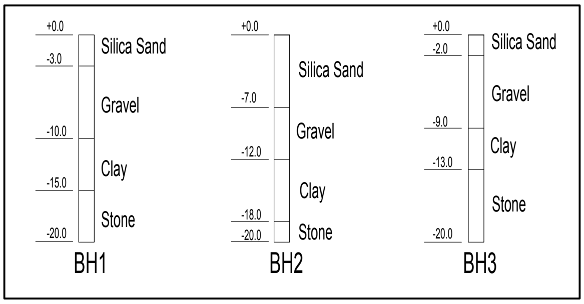

Figure 6: Borehole data of real test

Software results

The software results associated with the case study project are presented below in figure form. In particular, Figure 7 presents the ground level surface graph, Figure 8 the platform level graph while Figure 9 the combined picture of the previous graphs.

The software produces automatically an excel document that is divided into 4 sheets that includes all the calculated volume amounts and their different materials. By comparing those results with the manual calculations done, the software was proven to work accurately.

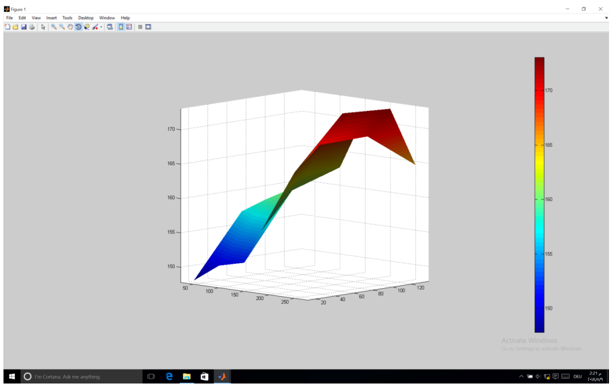

Figure 7: 3D graph of ground level

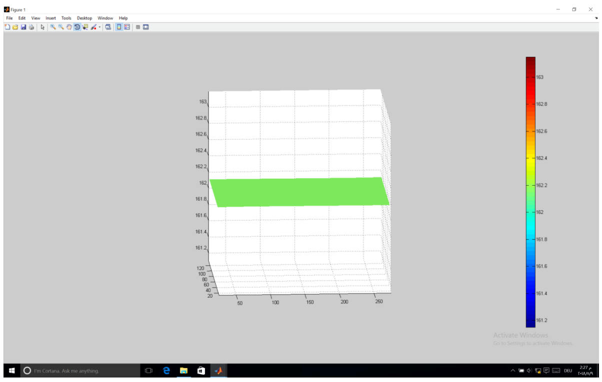

Figure 8:3D graph of the platform level

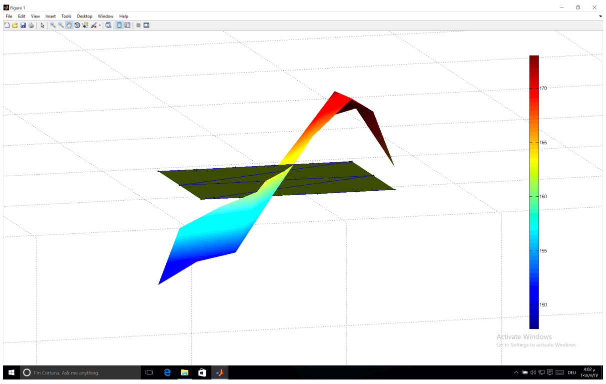

Figure 9: Combined 3D graph with platform level and ground level

Conclusions

Overview

In conclusion, this work shows the development of a software that provides an automated work break down structure. The software uses the dimensions of any rectangular-shaped area, the x,y,z-coordinates of the spot points, and the borehole-data of an area to calculate the most economic platform level with the cut and fill volumes and their details.

Benefits of the developed software

The results of the software are accurate, as the software was tested a lot. The results can help construction managers to plan the earthwork of large open areas. The three graphs that are created by the software helps to understand the process of working on the area, which can be used to present the work. The excel document with all the detailed amounts is very easy to read and shows all the details of the site activities and their locations according to the grid numbering system. The details are very useful for the construction manager to estimate the cost that will be needed to prepare for bids. One of the main objectives is to develop a user-friendly program and to present the results in a simple format.

Recommendations for future studies

This software has some limitations that should be addressed in the future:

The areas calculated by the software has to be rectangular with a length-dimension of multiplies of 50. That could be improved through future studies.

In the developed software only one platform-level is created to fit more site environments, the area could be divided into more platform-levels.

The software works with one borehole in each grid, which means in each spot; this could be changed into a calculation of three-dimensional geotechnical model that can be developed depending on the conducted boreholes.

The software could be linked to an excel sheet that contains all the input data instead of entering them manually.

The software can be further developed to consider both one dimensional (linear) projects such as highways as well as three dimensional projects in one package with all features described in this paper.

Comparison between the developed software and similar work

After searching a lot for similar papers to gain more information and experience regarding the topic, I could not find similar papers that hold the same address or content.

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