EARLY-PHASE MODELLING OF LIME-CEMENT COLUMNS TO REDUCE CARBON FOOTPRINT

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KEYWORDS

Parametric modelling, Early phase planning, Visualization of greenhouse gas emissions, ground improvement

ABSTRACT

With an ever-increasing focus on greenhouse gas emissions within the construction industry, we must try to change the way we work. Or at least rethink the workflow when we plan and design new linear projects.

In this case, geotechnical engineers at Geovita and NGI, together with the Aas-Jakobsen/ViaNova-network, have prepared a workflow that enables a visual representation of greenhouse gas emissions from a geotechnical point of view in early phase planning.

The result is a unique, early quantification and illustration of the greenhouse gas emission for a planned road or railroad. This gives us a helpful tool for early planning of the alignment of linear infrastructure projects.

1. INTRODUCTION

The workflow to perform an early-phase quantification of greenhouse gas emissions from lime-cement columns utilizes a combination of GIS-software and parametric programming in Rhino/Grasshopper, which is explained in more detail in the following sections.

The workflow is demonstrated for a planned road project in Norway showcasing the outcomes of greenhouse gas emissions for three different route options (Alt 1, Alt 2 and Alt 3 shown in Figure 2).

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2. INITIAL DATA ANALYSIS WITH GIS

Step 1 - Compilation of existing data in GIS

In the early phase of a project, we often do not have that much data available, so the first thing we must do is try to collect as much relevant data as possible for the project area. However, in our example there are quite a lot of public data available as WMS services, as shown in Figure 1. In addition to looking at terrain data, historical- and sediment maps, much information regarding existing boreholes and ground investigation reports is available through the national database for ground investigations (NADAG) as well as some defined quick clay areas, all published by the Geological Survey of Norway [1].

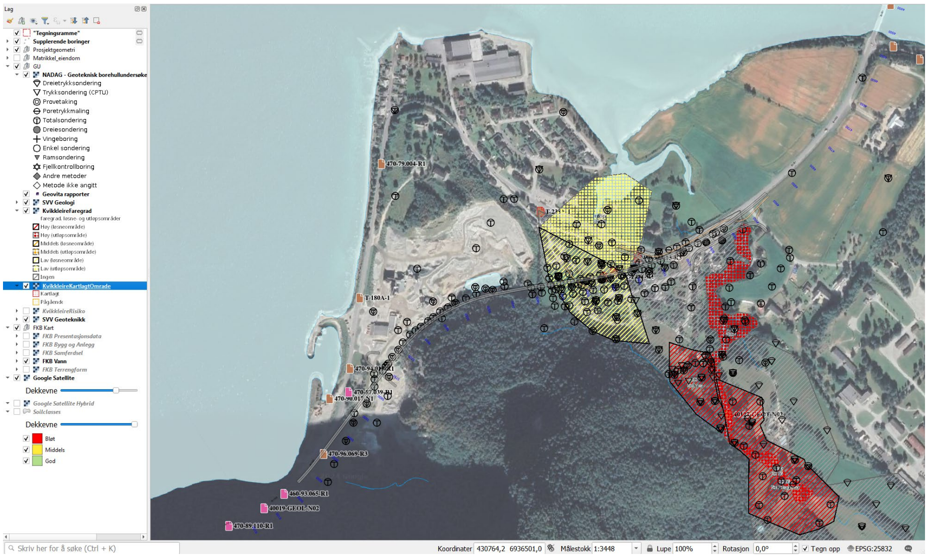

Figure 1 Project area with current WMS-data shown in QGIS.

Step 2- Data analysis and soil classification

Reviewing the available data, the authors decided to divide the alignment into three categories of soil classification, presented in Table 1, to inform the need for soil stabilization along the road alignment.

Table 1: Soil classification

Name	Colour in model	Description
Good	Green	Friction soils, stiff clays
Medium	Yellow	Soft clay
Poor	Red	Quick/sensitive clay

The soil classification is defined as 2D surfaces in a GIS-software, as shown in Figure 2. We export the polygons as shape-files (*.shp) for further use in Grasshopper.

It must be mentioned that the division of these areas obviously will be a very general assessment and such classification should always be performed by someone with geotechnical expertise.

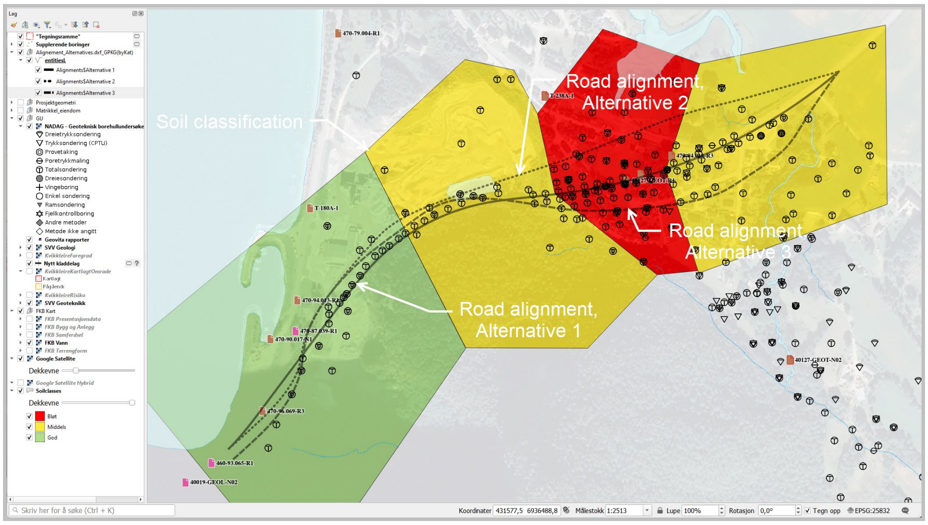

Figure 2 Areas defined by different soil classes together with road alignment alternatives in QGIS.

3. PARAMETRIC ANALYSIS IN GRASSHOPPER

Step 3 - Analysis of road alignment in Grasshopper

With the defined soil class areas in place these areas are imported into a script in Grasshopper, see Figure 3.

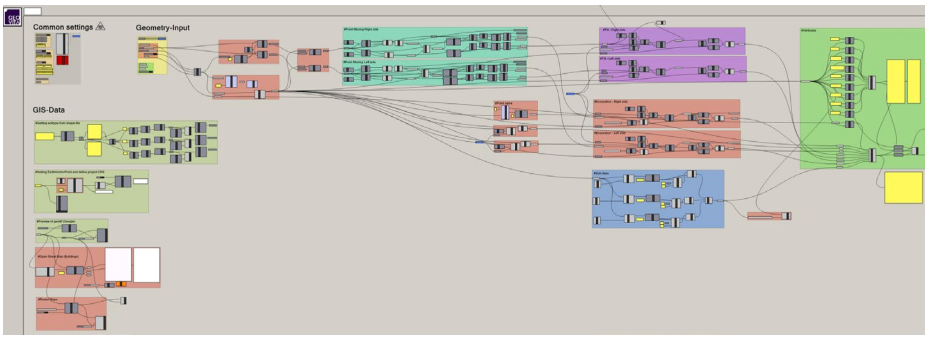

Figure 3 Grasshopper script for alignment analysis.

Further on we need to define the existing terrain, an alignment as geometry with the desired width as well as slope for filling and excavation.

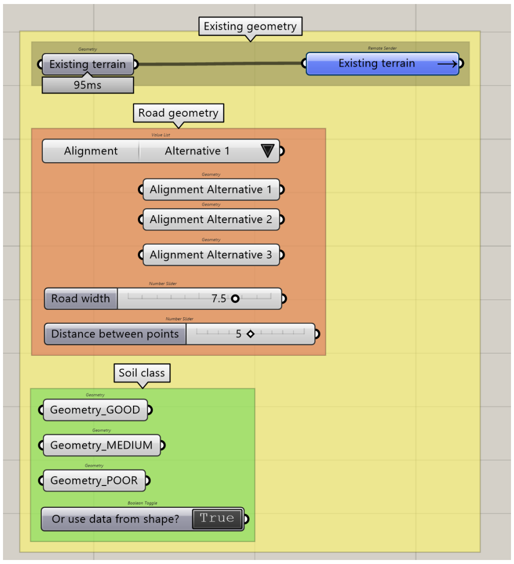

Figure 4 Geometry input in the Grasshopper script.

This script now analyzes the selected alignment and divides this line into points with a user-defined spacing, resulting in "smart points" containing information such as height or depth to terrain, soil class etc. along the alignment. This information is valuable for doing the necessary selection of parameters.

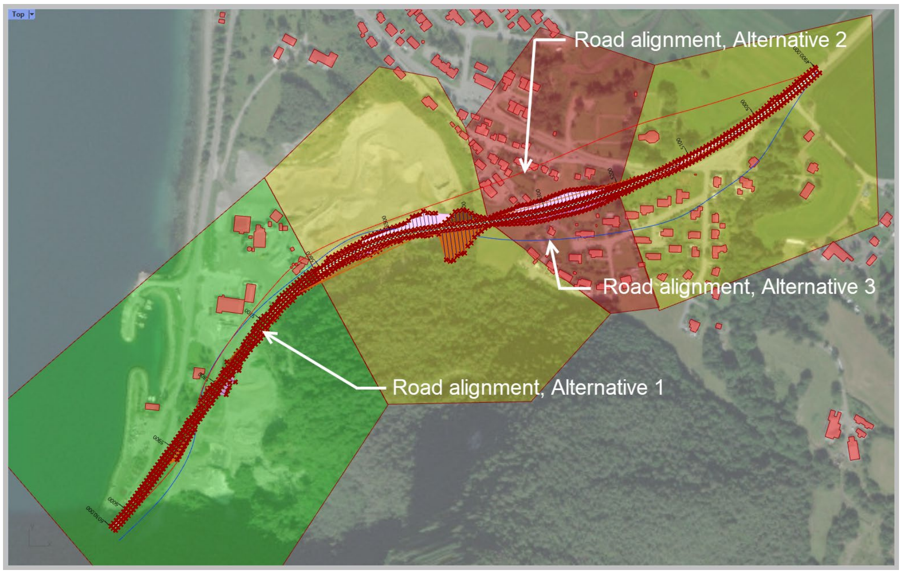

Figure 5 Analyzed points displayed in red in the Rhino 3D viewport.

Step 4 – Evaluating the need for ground improvement

For each "smart point" along the road alignment, we have now extracted details that will enable us to determine if ground improvement by use of lime-cement columns is required or not. For this study, a set of criteria are defined in Grasshopper using the Expression-component to categorize parametrically how much, if required, ground improvement should be installed. The chosen criteria need to be established for each individual project and are in this case selected for demonstrative purposes only.

For points within the poor (red) soil class:

- If depth < 2m (cut) or height < 2m (fill), no lime-cement is required.
- If depth > 2m (cut) or height > 2m (fill), install Ø600mm lime cement columns with 40% area coverage and single-column ribs.

For points within the medium (yellow) soil class:

- If depth < 4m (cut) or height < 4m (fill), no lime-cement is required.
- If depth > 4m (cut) or height > 4m (fill), install Ø600mm lime cement columns with 40% area coverage and single-column ribs.

For points within the good (green) soil class:

- No lime-cement columns are required.

The area coverage and spacing between ribs is calculated in accordance with [3]. For this study, a mixing ratio of 50/50 lime-cement with a binder dosage of 60kg/m^3 is used.

The smart points are split categorized in accordance with the criteria. Next, line objects for the lime-cement ribs are created to enable the creation of column volumes.

Step 5 - Visual representation of greenhouse gas emissions

By changing the alignment, either sideways and/or in height, it will also change the need for geotechnical mitigations, which again will affect the emissions. The modelling in Rhino/Grasshopper is fully dynamic, helping the engineers to easily compare the emissions caused by the different potential alignment choices.

The visual representation is shown as an example in Figure 6 below. For each defined interval of the road/railroad the amount of greenhouse gases is illustrated as columns. In areas with, for example, a large amount of lime/cement columns, the expected calculated emissions will be high. In areas with only some smaller cuts or fillings, the illustration will indicate much lower future emissions. A figure with the emissions for all 3 routes is shown in Figure 7.

Emission factors are based on data from VegLCA [2] which, in Norway, must be used on large road projects (> NOK 51mio.) to calculate greenhouse gas emissions. A summary of the emissions for each route option is given in Table 2.

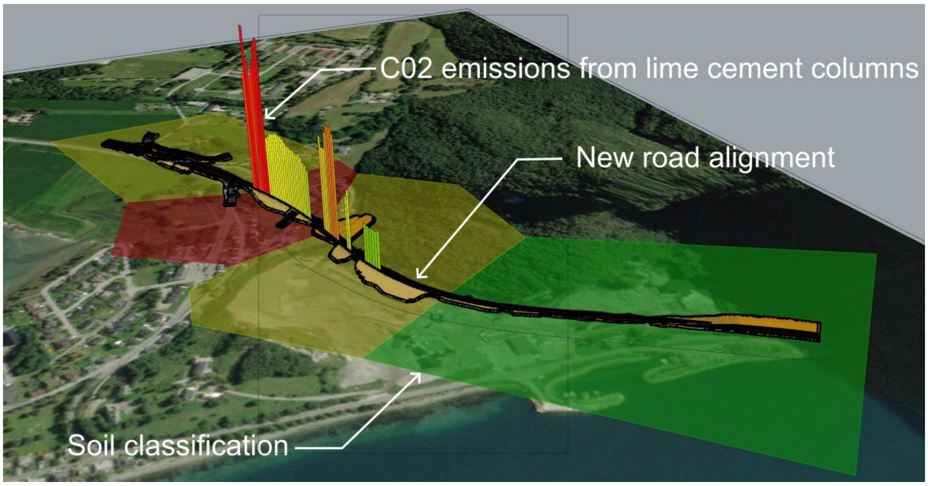

Figure 6 Visual representation of greenhouse gases from ground improvement along route alt 1.

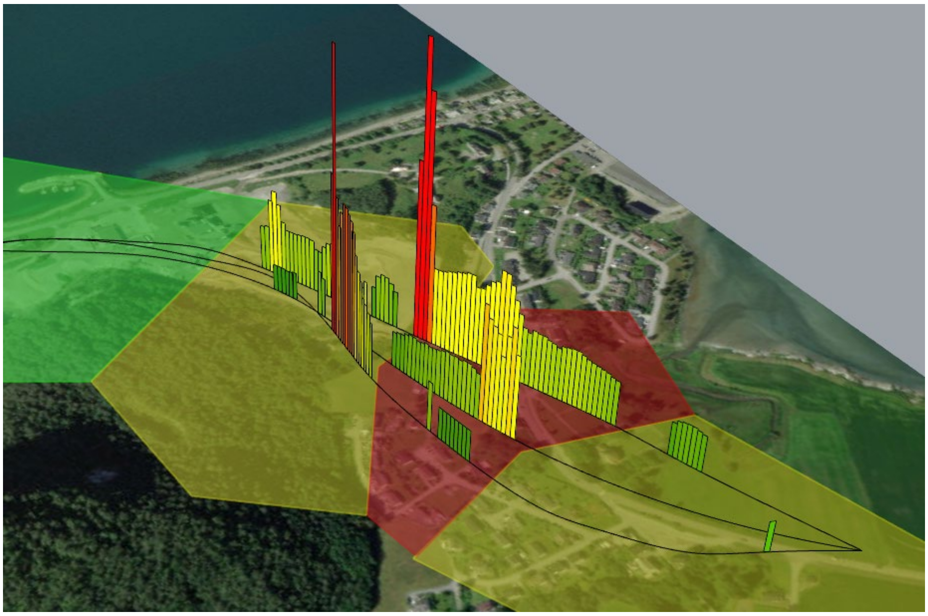

Figure 7 Visual representation of greenhouse gases from ground improvement for all routes.

Table 2: Greenhouse gas emissions from ground improvement for all routes options

Route	Total emissions (kg)
1	953 955
2	2 005 100
3	939 141

4. BIM MODELS

The final product is not only a visualization of the emissions, but you will also get detailed generated BIM models of the assumed necessary measures in the early phase of a project. Using developed property set scripts in Grasshopper, all objects are now assigned with discipline- and project-specific properties such as mixing ratio, binder dosage and Model Maturity Index (MMI) among others. Se Figure 8, which is a part of the model from alternative 3, below as an example.

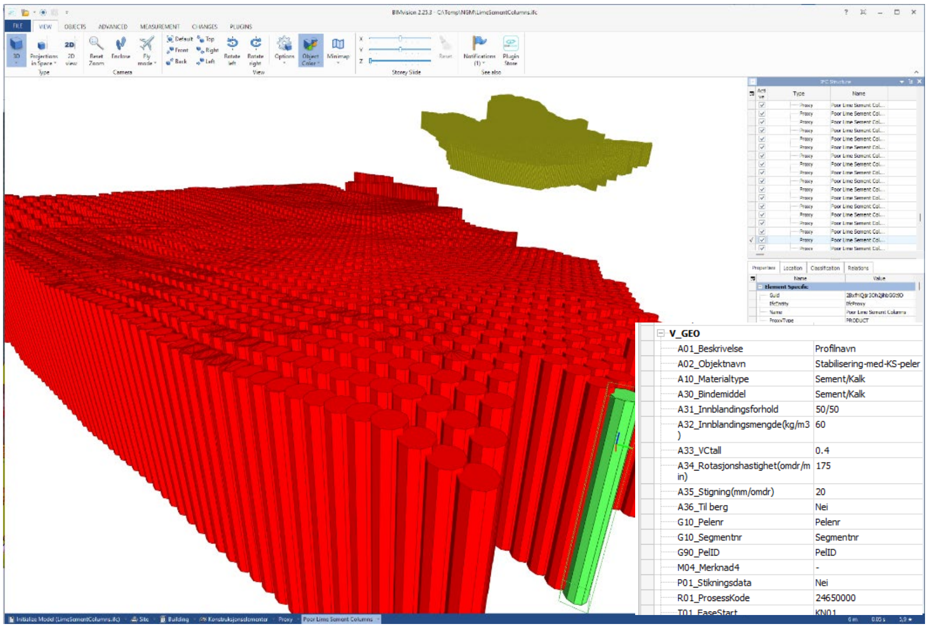

Figure 8 Ifc-model of lime-cement stabilization with specific properties for each Lime Sement Column shown in BIMvision.

5. CONCLUSION

This preliminary study shows that the proposed workflow quickly provides a coarse estimate of the need for ground improvement by use of lime-cement columns along the alignment. The fact that we can quickly change various parameters and see the consequences of this in a few seconds will change the way we plan alignments in the future. We also believe that it will increase the focus on the climate effect from groundwork and its importance during early phase planning of a project.

As ground improvement often is a significant part of the emission factor, these figures can, as showcased, be used as a basis for assessment in the early phase of a project. However, this must of course be seen together with emission figures for all other disciplines as well to get a comprehensive overview of the total greenhouse gas emissions for the entire project.

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