Application Note - Gabion Wall Analysis

1 Introduction

This note describes the typical steps followed in setting up and analysing a gabion wall stability problem with LimitState:GEO. It also highlights some of the differences in approach to those adopted by commonly used limit equilibrium analysis methods.

All files used in this note are available in a zip file that can be downloaded from http://www.limitstate.com/files/application-notes/LSGAN2/gabion_wall_analysis.zip

Familiarity with the use of LimitState:GEO is assumed. The reader is referred to the user manual for further information on any features discussed in this note.

A movie with all the steps undertaken in setting up and solving the problem is available at http://www.limitstate.com/files/videos/flash/gabionWallApplicationNote.htm

2 Problem definition

The specified problem involves construction of a gabion wall to support the sides of an excavation adjacent to a road. The road is assumed to apply a variable surface load of 20 kN/m^2. The 3m high gabion wall with 6° batter is to be constructed within a stratum of mudstone and backfilled with a granular material as shown in Figure 1. Geotextile between the gabions and backfill is to be used which will reduce the interface shearing resistance.The main problem geometry is available as a dxf file (gabion_wall.dxf) and as a series of co-ordinates.
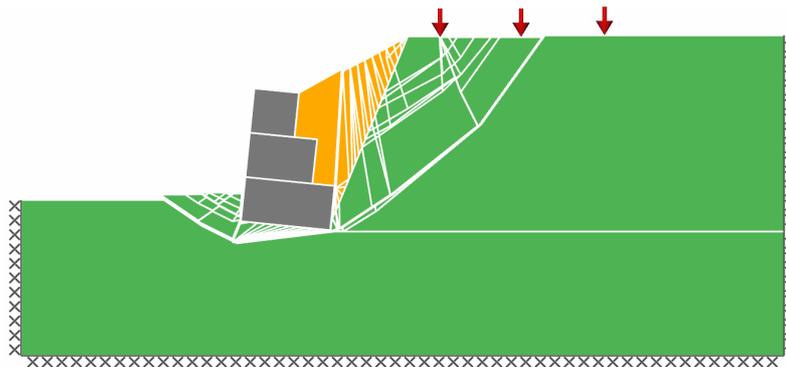

Figure 1: Global failure mechanism for analysed problem

The modelled soils and associated parameters are listed in Table 1. Wall/backfill and wall/mudstone interface properties were assumed to be $0.9\phi'$ and $0c'$, where ϕ' and c' are the relevant backfill or mudstone soil properties.

Soil	c$'$ (kN/m^2)	ϕ'	γ (kN/m^3)
Mudstone	5	25°	20
Granular backfill	0	35°	18
Gabion fill	-	-	18

Table 1: Soil properties

For computational efficiency, the gabion units themselves will be modeled as a **Rigid** material on the assumption that internal wall failure would occur on the gabion unit interfaces. The properties of these interfaces were taken as shear strength: $c'=$ 2 kN/m^2; $\phi'=35°$; and crushing strength $\sigma=500$ kN/m^2. This latter parameter can be considered equivalent to a bearing pressure and allows for a bearing type failure between gabions (typically accompanied by rotation). The problem is to be analysed using Eurocode 7 Design Approach 1, Combination 2 partial factors.

Details of how to set up the problem manually are given in Section 3. To skip direct to the analysis stage, please go to Section 4.

3 Setting up problem geometry, materials and loading

Creation of the LimitState:GEO model was undertaken in the following stages:

1) Import the geometry from gabion_wall.dxf using the **File/Import from Dxf...** function. Remove any residual construction lines using **Draw/Construction Line/Clear All** since these will not be needed.

2) Define material properties using **Tools/Create New Material...** and apply to the geometry (both **Solids** and wall **Boundaries**) by drag and drop. (Further details on this operation are given in the FAQs at the end of this note).

   Alternatively for this example pre-defined materials may be imported from gabion_wall.csv using the **Tools/ Import Materials...** function. Materials are named by the type of **Solid** or wall **Boundary** they should be applied to.

   Key modelling concept: *modelling gabion interfaces to allow for sliding and rotation*

   The properties of the interfaces between gabion units are defined as a **combined material** consisting of a **Mohr-Coulomb** and **Cutoff** material. The **Mohr-Coulomb** material allows for internal sliding failure of the blocks whilst the **Cutoff** material allows relative rotation of blocks to occur through opening up of tension cracks (by setting a zero **Limiting tensile stress**).

   In this example the **Limiting compressive stress** property of the **Cutoff** material is also set to the crushing strength of the gabion unit to allow internal bearing failure.

   To create a **combined material** two materials can be dragged and dropped onto the same object. Whilst dropping the second one, the **combined material** dialog will appear. Select the **Add** option.

   ---

3) Specify the applied traffic load of 20 kN/m^2 by selecting the relevant **Boundary** and by using **Loads - Variable - Normal** via the **Property Editor**. Set the **Loading Type** for this to *Unfavourable*.

4) Set the boundary conditions on the base and sides of the model as **Fixed**.

5) Apply the **Adequacy factor** to an appropriate surcharge load and/or body force. (Click on the load or body and set **Adequacy** to *True* in the **Property Editor**) In this example it is recommended that the

Adequacy Factor be simultaneously applied to the surcharge load, weight of the backfill and weight of the retained mudstone located behind the wall.

Key modelling concept: *application of the adequacy factor*

Deciding where to apply the **Adequacy factor** is a key stage in setting up any ultimate limit state analysis. Generally it should be applied to a unfavourable load or a combination of unfavourable loads that if increased would lead to the type of collapse being investigated.

In this example it is applied to the surcharge and the weight of the backfill and mudstone retained by the wall (but not including the soil below the wall founding level or in front of the wall). The question being asked of the software is 'by what factor do these parameters need to be multiplied by to cause collapse'. The resulting number can be thought of as a factor of safety on this combined load. This will be over and above any other partial factors applied in the problem.

If an **Adequacy factor** of 1.0 is found then it means the problem as modelled is just on the point of collapse (i.e. the loads do not need to be modified for collapse to occur).

---

6) Choose the required Partial factor set using **Scenario Manager**. In this example the Eurocode 7 Design Approach 1, Combination 2 (DA1/2) scenario will be investigated. Select DA1/2 from the drop down box. Also tick the **Long term analysis** box to specify a drained analysis. (N.B. since all materials have been defined as *Always drained* this is not strictly necessary but is good practice).

7) Set the **Nodal Density** to **Fine**.

4   Analysis

The LimitState:GEO model may be set up manually as described in Section 3. Alternatively the complete model may be loaded by opening the file gabion_wall.geo.

Click **Analysis/Solve** or ▶ to obtain an **Adequacy factor** of 1.31 and the failure mechanism depicted in Figure 1. A value above 1.0 means that in Eurocode 7 terms the structure is safe. The achieved additional margin of safety (or overdesign factor) of 1.31 is given in terms of the load to which the **Adequacy Factor** was assigned (see box above).

An alternative factor of safety (F.O.S.) commonly required in geotechnical analysis is the factor on soil strength required to cause collapse. In LimitState:GEO the F.O.S. on strength is found by setting partial factors on the soil strength parameters using the **Scenario Manager** and adjusting these until the **Adequacy Factor** is equal to 1.0 (i.e. the loads do not need to be modified for collapse to occur).

To do this, select the *User* parameter set in the **Scenario Manager** and modify the factor on all material properties. In the analysed example, the required factor is 1.42. This exceeds the Eurocode 7 DA1/2 factor of 1.25. This is equivalent to an additional margin of safety (or overdesign factor) of 1.14 in terms of soil strength (1.42/1.25=1.14). However note that in this case the comparison is not exact as the Eurocode 7 DA1/2 factors on actions were not applied. This modified model may be found in gabion_wall_factor_on_strength.geo.

Frequently Asked Questions

1) *How are materials created for the gabion wall problem?*

   Use the standard **Tools/Create New Material...** function. The type of materials which should be used for the specific **Solids** and **Boundaries** are listed in Table 2. Specify the **Drainage Behaviour** of all Mohr-Coulomb materials as *Always drained*.

Solid or Boundary	Material type
Soil and backfill	Mohr-Coulomb
Wall/backfill and wall/soil interfaces	Mohr-Coulomb(Derived)
Gabion unit	Rigid
Interface between gabion units	Combined: Mohr-Coulomb and Cutoff

Table 2: Recommended model materials for gabion walls

2) *Where do the interface properties of the boundaries between gabion blocks come from?*

   Properties used for the internal failure checks can normally be obtained from the manufacturer of the gabion system.

3) *How does LimitState:GEO deal with the complex geometry of the gabion wall in the analysis?*

   Unlike the some approaches using a virtual back, LimitState:GEO analyses the problem with its real geometry which allows for a more accurate representation of the mechanics of the problem.

4) *Why does LimitState:GEO provide only one failure mode and an associated* **Adequacy Factor** *whilst conventional limit equilibrium based software performs checks for several different standard failure modes?*

   LimitState:GEO identifies the critical failure mode (which may not be a standard mode) from millions of potential mechanisms instead of checking a few pre-specified collapse modes Thus only the critical solution is returned. Specific modes of failure can be forced e.g. an internal sliding failure can be modelled by changing the base stratum of soil from a mudstone to a **Rigid** material. It will be seen that in this case the **Adequacy factor** and thus margin of safety goes up and therefore the mechanism is not critical.

5) *How accurate will the solution be?*

   The accuracy of the solution depends on the resolution of the nodes at the failure mechanism. The accuracy can be refined either by increasing the **Nodal Density** or by optimizing the nodal distribution. For more information on how to improve solution accuracy see the LimitState:GEO manual Section 8.4.

For more information: www.limitstate.com/geo