DEBFLOW - The dimensioning tool for flexible ring net barriers against debris flows

Software Manual

Author: Corinna Wendeler, MSc. Civil Eng. TU
PREFACE

Thank you for using DEBFLOW, the dimensioning tool for flexible ring net barriers against debris flows established by the Geobrugg AG, Geohazard Solutions. Every effort is made to give you the best possible support for the dimensioning of our flexible debris flow protection systems.

DEBFLOW offers you the possibility of considering a dynamic impact of a debris flow wave into the ring net and the corresponding static load case of a filled and overtopped barrier. Additionally, a first rough estimation of the retention volume can be carried out. The calculations are based on International Units in English and German.

This manual provides you with the most important references and function descriptions to enable you to use the program correctly. Please read the operating instructions carefully prior using the program for the first time. Keep this reference book close at hand at all times.

Numerous parameters need to be entered for the dimensioning operations. It is the responsibility of the user of this program to select and enter these parameters correctly.

Corinna Wendeler
Geobrugg AG

Romanshorn, December 2010
PRODUCT LIABILITY

Rockfall, landslides, debris flows or avalanches are sporadic and unpredictable. Causes can be e.g. human (construction, etc.) or environmental (weather, earthquakes, etc.). Due to the multiplicity of factors affecting such events it is not and cannot be an exact science that guarantees the safety of individuals and property.

However, by the application of sound engineering principles to a predictable range of parameters and by the implementation of correctly designed protection measures in identified risk areas the risks of injury and loss of property can be reduced substantially.

Inspection and maintenance of such systems are an absolute requirement to ensure the desired protection level. The system safety can also be impaired by events such as natural disasters, inadequate dimensioning parameters or failure to use the prescribed standard components, systems and original parts; and/or corrosion (caused by pollution of the environment or other man-made factors as well as other external influences).

DISCLAIMER

1. The programs are only approved for preliminary designs and preliminary projects. Both the input parameters and output values must always be checked and confirmed by a specialist. All values are average values; they have to be checked and confirmed on project base before any application of a Geobrugg system.

Geobrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur by using wrong assumptions or input parameters.

2. All information and data included in the programs are based on the principles, equations and safety concepts according to the technical documents, dimensioning concepts, product manuals, installation instructions, etc. of Geobrugg which have to be strictly followed.

Geobrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur due to incorrect application of the programs.

3. It cannot totally be excluded that there are errors in the programs.

Geobrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur due to application of faulty programs.

4. Changes in the data of the programs by the user can lead to results which do not comply with the safety regulations given by the law and Geobrugg.

Geobrugg cannot be held liable for damages of all kind which result from changes made by the user. Geobrugg is indemnified and hold harmless by the user from any claims of third parties.
TABLE OF CONTENTS

1. Introduction ............................................................................................................................................... 6
2. The Geobrugg VX/UX debris flow protection systems ............................................................................. 7
3. Testing of the components in 1:1 field tests and calibration of finite element model ............................... 8
4. Access to the online-tool ........................................................................................................................... 9
5. The software ........................................................................................................................................... 14
6. Conclusions ............................................................................................................................................. 25
References ...................................................................................................................................................... 26
1. INTRODUCTION

The software DEBFLOW serves to dimension flexible debris flow protection systems consisting of the high-tensile steel wire ring net ROCCO®, support ropes with a determined number of brake rings, flexible spiral rope anchors and a specially designed abrasion protection device.

The software DEBFLOW is based on FARO [9] simulations of each standard barrier system for the given debris flow input parameters. The design concept is described in [11]. The DEBFLOW concept analyzes the stability of the chosen barrier system and calculates the appearing dynamic and hydrostatic forces during the filling process and the overtopping.

The dimensioning of the anchors in the slopes has to be carried out carefully and respect the prevailing geological circumstances. Anchor forces up to 350 kN have to be transmittable into the slopes.

Figure 1: Application of ring net barriers as an additional building to a concrete check dam in the Illgraben in Canton Valais in Switzerland (left) and a successfully filled ring net barrier in Italy (right).
2. THE GEOBRUGG VX/UX DEBRIS FLOW PROTECTION SYSTEMS

The VX debris flow protection system has been developed by Geobrugg AG and in essence consists of the following elements: The support ropes with its brake rings to absorb the energy while the debris flow impact, the ROCCO® ring net which is clamped between the support ropes, border ropes at each site of the slope and finally the additional abrasion protection (see figure 2).

![Figure 2: Components of a flexible VX barrier installed in the Illgraben in 2005.](image)

The UX protection system has nearly the same construction design. The important difference is that the UX system is used for larger torrent widths and so posts are necessary keeping the barrier height when the barrier gets filled [10].

The ring net of ROCCO® mesh has openings of 300 mm in size and depending on the standard system a different number of windings. The support ropes used for this application consist of high-tensile steel wire ropes. These support ropes are fixed in the slope with spiral rope anchors or TITAN self-drilling anchors with special flexible heads, which ensure that forces not working directly in the pulling direction can also be transmitted. To protect the upper ropes from abrasion, an angle profile was developed and is fixed with shackles to the upper ropes. So, also overtopping of filled barriers is possible without any damages on the structural system.

To increase the limited retention volume of one barrier, so called “multilevel barriers”, barriers installed in line are possible. With multilevel barriers arbitrary retention volumes can be achieved. One example for multilevel barriers is the installation of 13 barriers at the Haslberg Region in the Bernese Alpes in Switzerland (see figure 3). The total retention volume of several barriers in line can be roughly calculated with the DEBFLOW software tool. But the most accurate method to estimate the retention volume is by laser scanning of the river bed and creating a 3D model.

If there are more or less muddy debris flows expected with small corn sizes, a secondary mesh can be added additionally to the ROCCO® 300 mm mesh size. This secondary mesh is not decisive for the dimensioning concept and is so not taken into account in the DEBFLOW software tool.
3. TESTING OF THE COMPONENTS IN 1:1 FIELD TESTS AND CALIBRATION OF FINITE ELEMENT MODEL

All the barrier components were tested in 1:1 field tests against debris flows. The measured results in the field tests led to a calibrated finite element model with the Software FARO created by Dr. Axel Volkwein at the WSL [9]. All the standard barriers were calculated with this simulation tool. More information about the field tests with debris flow barriers and the development of the finite element model is described in [11].
4. ACCESS TO THE ONLINE-TOOL

The following address offers access to the online software:

http://applications.geobrugg.com

Afterwards the below shown start page appears, which offers the possibilities of the first-time personal registration, the Login and the function of the delivery of the forgotten password per e-mail.

If the program is used the first time one must click on "register here" and the registration form should be filled out once. Afterwards one will get the personal user name and password automatically sent per e-mail.
Anmeldung / Registration

Formular / Form

Haben Sie eine Gebrugg-Schulung "Murgang" / "Spider" / "Ruvolum" zum vollen Verständnis der Anwendung besucht?
Did you join one of our Gebrugg workshops "Debris Flow" / "Spider" / "Ruvolum" for fully understanding the application of the software?
☐ Ja / Yes ☐ Nein / No

Firma / Company *
Abteilung / Division
Beruf / Profession
Vorname / Firstname *
Name / Lastname *
Adresse / Address *
PLZ / ZIP *
Ort / Town *
Land / Country *
Telefon / Phone
Email *

Verifizierung
Verification
Code eingeben
Enter code above
Nachricht / Comment

Weiter oben beachten.
Confirm question above
Senden / Send

With the so get personal login data the program can be opened.

User area for Applications

We changed the login procedure. Please fill out once the registration form.
Wir haben die Anmeldeprozedur geändert. Bitte füllen sie die Registrierung aus.

Login

Benutzer / Username 
Passwort / Password
Login
Then, there is a disclaimer to be accepted.

Haftungsausschluss / Disclaimer

Disclaimer

1. The programs are only approved for preliminary designs and preliminary projects. Both the input parameters and output values must always be checked and confirmed by a specialist. All values are average values; they have to be checked and confirmed on project basis before any application of a Gebrugg system.

Gebrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur by using wrong assumptions or input parameters.

2. All information and data included in the programs are based on the principles, equations and safety concepts according to the technical documents, dimensioning concepts, product manuals, installation instructions, etc. of Gebrugg which have to be strictly followed.

Gebrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur due to incorrect application of the programs.

3. It cannot totally be excluded that there are errors in the programs.

Gebrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur due to application of faulty programs.

4. Changes in the data of the programs by the user can lead to results which do not comply with the safety regulations given by the law and Gebrugg.

Gebrugg cannot be held liable for damages of all kind which result from changes made by the user. Gebrugg is indemnified and held harmless by the user from any claims of third parties.

Ich akzeptiere / I accept
One can choose between the dimensioning software packages:

**DEBFLOW D** for the design of debris flow barriers in German
**DEBFLOW E** for the design of debris flow barriers in English

**SPIDER Online Tool D** for the design of the SPIDER® rock protection system in German
**SPIDER Online Tool E** for the design of the SPIDER® rock protection system in English

**RU VOLUM Online Tool D** for the design of the TECCO® slope stabilization system in German
**RU VOLUM Online Tool E** for the design of the TECCO® slope stabilization system in English

http://applications.geobrugg.com/

*Figure 6: After given the right password you will enter this page to choose the appropriate program.*

There is no installation of the software on the user’s computer neither necessary nor possible. The software can be used online only.

Every calculation can be stored and printed as a pdf-file with all information about input quantities, decisive loading cases, achieved retention volume and chosen standard systems.
If problems with entering of applications exist, please check if the Flash Player 9 has to be installed at first. Please keep to the given information of the software installation adviser of the Flash Player.

**Figure 7:** If you only have a blank application screen, you have to install the Adobe Flash Player 9.

After installation of the Adobe Flash Player you will arrive at the starting page of DEBFLOW software tool as shown in Figure 8.

**Figure 8:** Starting page of the DEBFLOW software tool.

Now you can start with your calculation!
5. THE SOFTWARE

The software is structured in a one-page-format as follows:

Title

Print preview and pdf

Input Parameters (the debris flow parameters)
- Choice of three different load cases possible
- Type and density of the expected debris flow
- Total volume
- Expected number of waves
- Expected peak discharge or empirically calculated peak discharge
- Global safety factor

Summary of results concerning the retention volume
- Checking of retention volume compared to required retention volume

Barrier specific input parameter for each selected barrier
- Height of selected barrier
- Span width of the upper support ropes
- Span width of the lower support ropes
- Distance to previous barrier (in case of multilevel barriers)
- River bed inclination
- Inclination angle of the deposition (to calculate the retention volume)
- Calculated or expected front velocity
- Calculation of the flow height
- Recommended maximum basal opening height

Choice of the standard barrier system
- Proof of geometric barrier design data compared to geometry of standard systems

Proofs of maximum dynamic loading (stopping process)
- Proof of dynamic loading compared to resistance of barrier
- Resistance depends on the chosen standard system and the global safety factor
- Dynamic loading depends on the debris flow input parameters and the flow parameters

Proofs of static loading (overtopping)
- Calculation of the static loading depending on the chosen system
- Checking the resistance of the barrier against the hydrostatic debris pressure

Proof of the chosen standard system
- Checking of dynamic load case
- Checking of static load case
- Checking of all given load cases (Loadcase 1, 2 and 3)
- Checking of geometrical parameter

Activation of the next projected barrier in case of a multilevel barrier system

Calculation of the overall retention volume of all selected barriers
5.1 Print preview and pdf

Activating the button “Print preview” another window in the preview window appears offering the possibility to introduce further information in the headline or in the footer of the output, respectively. This might be for instance an appendix number, the project name, project number, name of the user or date, etc.

**Figure 9: Creation of the pdf file after the calculation.**

**Figure 10: Window with the possibility to input information in the header or in the footer of the output.**
After, to finally create a pdf, the “Generate PDF” button has to be activated. This may take a minute.

![Figure 11: Creation of a pdf.](image)

What could be the problem, if no pdf can be created and stored after pressing the „Export“ button?

In this case, a popup may be blocked. Using the right mouse button, the settings can be changed for accepting popups temporarily at least. The print preview window disappears after. Thus, to create a pdf, the instructions above have to be followed again.
Figure 12: Temporarily acceptance of popups has to be activated.

If popups are allowed and the pdf window does not open (see figure 13) press the “refresh” button F5. Close the window and try it again. Normally it should work afterwards.

Figure 13: Print error message and possibility to solve the problem.
5.2 Input Parameters

5.2.1 Debris flow parameters

Debris flows behave different all over the world and may not even act in the same manner in one torrent. Therefore a range of input parameters can be specified for the software tool DEBFLOW which seem to be common. These ranges of input parameters are shown in the following Table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Short sign</th>
<th>Default value</th>
<th>Minimum value</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density granular flow</td>
<td>$\rho_{\text{granular}}$ [kg/m$^3$]</td>
<td>2200</td>
<td>1900</td>
<td>2300</td>
</tr>
<tr>
<td>Density muddy flow</td>
<td>$\rho_{\text{mudflow}}$ [kg/m$^3$]</td>
<td>1800</td>
<td>1600</td>
<td>2000</td>
</tr>
<tr>
<td>Debris flow volume</td>
<td>$V_{\text{total}}$ [m$^3$]</td>
<td>1000</td>
<td>100</td>
<td>10000</td>
</tr>
<tr>
<td>Number of surges</td>
<td>$N$</td>
<td>3</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Volume of first surge</td>
<td>$V_{N,1}$ [m$^3$]</td>
<td>3000</td>
<td>10</td>
<td>10000</td>
</tr>
<tr>
<td>Peak discharge</td>
<td>$Q_p$ [m$^3$/s]</td>
<td>50</td>
<td>1</td>
<td>100</td>
</tr>
</tbody>
</table>

*Table 1: Debris flow input parameters*

More about how to choose the input parameter of debris flow can be found in several articles like [12] or [11]. These input parameters can be varied for three different kinds of load cases.

5.2.2 Load cases

In the program three different kinds of load cases can be chosen (see figure 14). This option is necessary, if different load cases appear and have to be considered.

Example:

Two load cases have to be considered

- Mudflow, release volume $\approx 2000$ m$^3$ in three surges, density $\rho \approx 1800$ kg/m$^3$ with high velocity $v = 9$ m/s

- Granular flow, release volume $\approx 1000$ m$^3$ in two surges, density $\rho \approx 2200$ kg/m$^3$ with slower velocity $v = 3$ m/s

For every load case the discharge will be calculated empirically based on Rickenmann [7]. But if you have better information about peak discharge data you can choose your own decisive value in the program directly after the proposed value. If you don’t have any experiences in evaluate the peak discharge please set $Q_p = Q_{p,rec}$. 
The velocity can also be chosen in a different way for every load case. The decisive load case is determined by the DEBFLOW software afterwards. More about the barrier design input parameters is written in Chapter 5.2.4 and the later necessary decisive barrier design is shown in Chapter 5.2.5.
5.2.3 Global safety factor

The global safety factor SF can be chosen between 1.0 up to 1.5 depending on the risk potential in case of damages [11].

Please choose the safety factor very carefully and in accordance with the respective rules and regulations in your country. If there is no recommendation available and for the risk to death of humans is high, the safety factor has to set to SF=1.5!

5.2.4 Input parameters for the barrier design

5.2.4.1 Geometry of barrier location

Most of these parameters influence the later chosen standard barrier system. The range of application is shown in Table 2.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Short sign</th>
<th>Default value</th>
<th>Minimum value</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System height</td>
<td>H₀</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Width of torrent at the bottom</td>
<td>bᵤ</td>
<td>10</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Width of torrent at the top</td>
<td>bₒ</td>
<td>15</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>Distance to previous barrier upstream</td>
<td>Lₒ</td>
<td>500</td>
<td>5</td>
<td>500</td>
</tr>
<tr>
<td>River bed inclination</td>
<td>Iₛ</td>
<td>18</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>Deposition inclination of filled barrier</td>
<td>Iₛ’</td>
<td>12</td>
<td>0</td>
<td>80</td>
</tr>
</tbody>
</table>

Table 2: Geometric parameters for the projected installation place.

If the minimum value Lₒ = 5.0 m is selected, the impact velocity of the flow is reduced to \( v_{\text{red}} = 0.4 \cdot \max(v_{\text{base}}, v_{\text{str}}) \) (see figure 18) according to the performed laboratory tests [13]. Because of the overflowing process the impact velocity to next barrier is reduced.

5.2.4.2 Calculation of retention capacity

With values of table 2 and the fixed barrier inclination \( \xi \) (barrier always 5 ° inclined in forward) the approximately retention capacity of each barrier is calculated. If the length of the retained material \( L₁, L₂, \ldots \) is \( L_{0,1}, L_{0,2}, \ldots \), the retention capacity is influenced by the next barrier upstream and DEBFLOW software is considering this in the retention capacity. The maximum length of the retained material is then \( L₁, L₂, \ldots = L_{0,1}, L_{0,2}, \ldots \).

Figure 16: Calculation of retention capacity of entered barrier.
5.2.4.3 Impact flow parameters

The flow parameters are important to calculate the impact force of the debris flow surge impacting the barrier. Caused by resistance of flexible barriers and very high impact forces there are the following limitations for the design of impact velocity:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Short sign [ ]</th>
<th>Default value</th>
<th>Minimum value</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chosen front velocity v</td>
<td>v [m/s]</td>
<td>3</td>
<td>1</td>
<td>10</td>
</tr>
</tbody>
</table>

*Table 3: Flow specific input parameters for every barrier location*

Debris flow front velocities can be determined out of curve deposit, river bed inclination and deposit behavior in general. But therefore an explicit reconstruction of a past event is necessary. If you don’t have any information about front velocities, please take the empirical calculated values the DEBFLOW program advices you! The first velocity value is based on empirical values published by Rickenmann [7] and the second check of flow velocity is done with \( v_{str} \) based on Japanese Guidelines for debris flow [8] (based on a Strickler flow regime).

Based on the condition of continuity, the flow height of the debris flow \( h_d \) is determined out of the flow velocity and the channel width at the bottom. A maximal possible value for the basal opening \( h_d \) is proposed by DEBFLOW calculated out of the determined flow height \( h_d \).

![Empirical calculation of v based on Rickenmann](image1.png)
![Proof of v with Japanese Guidelines (based on Strickler)](image2.png)

*Figure 17: Calculation of flow velocity and entry value.*

![Choice of v for the dynamic calculation](image3.png)

*Figure 18: Calculation of flow velocity \( v_{red} \) for very closed barriers.*
5.2.5 Choice of the decisive standard barrier system

An overview of the standard systems and their design and geometrical limitations are shown in Table 4. For the standard drawings of the barriers please contact us per e-mail: info@geobrugg.com

<table>
<thead>
<tr>
<th>Standard barrier system</th>
<th>max Height $H_{\text{max}}$ [m]</th>
<th>max width top $b_{\text{o,,max}}$ [m]</th>
<th>max width bottom $b_{\text{u,,max}}$ [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type VX080-H4</td>
<td>4</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Type VX140-H4</td>
<td>4</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Type VX100-H6</td>
<td>6</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Type VX160-H6</td>
<td>6</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Type UX100-H4</td>
<td>4</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Type UX160-H4</td>
<td>4</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Type UX120-H6</td>
<td>6</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>Type UX180-H6</td>
<td>6</td>
<td>25</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 4: Standard systems based on FARO simulations.

The first number is the intensity of the debris flow surge acting on the width of the barrier and the second number describes the height of the barrier. The VX systems are without posts for smaller sections and the UX with two posts in the middle for wider flow sections. You can only choose the standard system which fits to your geometric input values. If the standard barrier you have chosen is too weak for the debris flow loading, the DEBFLOW software tells you that the proof of the barrier is not fulfilled. In this case you have to choose a stronger standard barrier.

Figure 19: Example for a too weak barrier at the static loading case for load case 1.
5.2.6 Calculation of multilevel barriers

If you want to calculate several barriers in line, you have first to activate the second barrier after the successful input of the first one (see figure 20).

After design of the second barrier you have to continue with barrier 3 until you will achieve your desired retention volume. The overview of the retention volume of each barrier compared to the required retention volume is shown in DEBFLOW. An example for two barriers is shown in Figure 21. Every safety factor of each barrier is checked with the chosen global safety factor. If each safety factor of each barrier is equal or bigger than the chosen global safety factor the complete multilevel barrier is fulfilled. If also the required retention capacity is fulfilled all the calculations are fulfilled (see figure 22).

Figure 20: Activation of barrier 2 after the successful calculation of the barrier at location 1.

Figure 19: Checking of the required retention volume with two barriers.
Figure 20: Checking of the complete entered barrier system (safety factors, retention volume).
6. CONCLUSIONS

- DEBFLOW covers STANDARD TYPE debris flow barriers with flexible ring nets for muddy and granular debris flow within certain limits.
- Proof of barrier resistance is given for stopping of the front, filling of the barrier and overflowing.
- Proof of standard channel retention geometries is given.

The program should be used as a quick and reliable calculation in the earliest planning stage. If some parameters of the barrier do not correspond to standard barrier parameters, a solution may still be possible! Please contact your Geobrugg agent for a design proposal.
REFERENCES


Geobrugg protects people and infrastructures from the forces of nature

It is the task of our engineers and partners to analyze the problem together with you in detail and then, together with local consultants, to present solutions. Painstaking planning is not the only thing you can expect from us, however; since we have our own production plants on four continents, we can offer not only short delivery paths and times, but also local customer service. With a view towards a trouble-free execution, we deliver preassembled and clearly identified system components right to the construction site. There we provide support, if desired, including technical support – from installation right on up until acceptance of the structure.

Rockfall barriers
Rockfall drapes
Slope stabilization systems
Debris flow barriers
Avalanche prevention structures
Open pit rockfall barriers
Special applications