Landslide Hazard Assessment

A Resilient Future: Science and Technology for Disaster Risk Reduction

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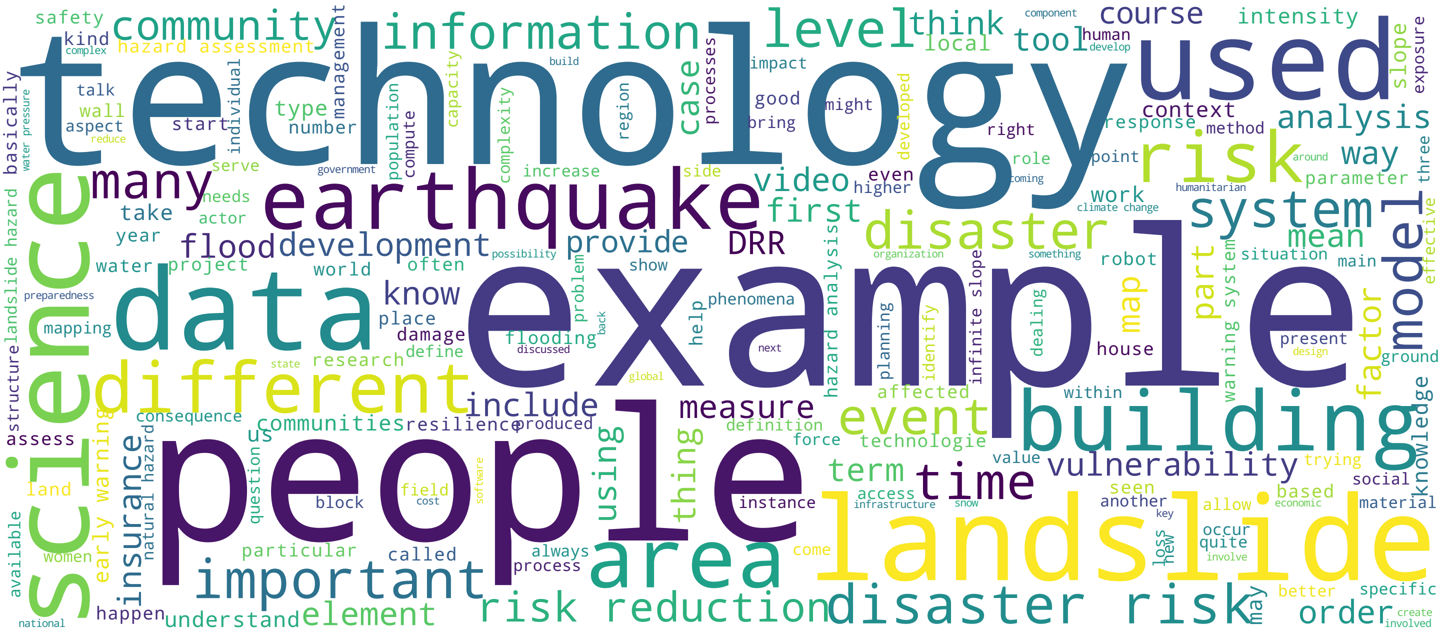

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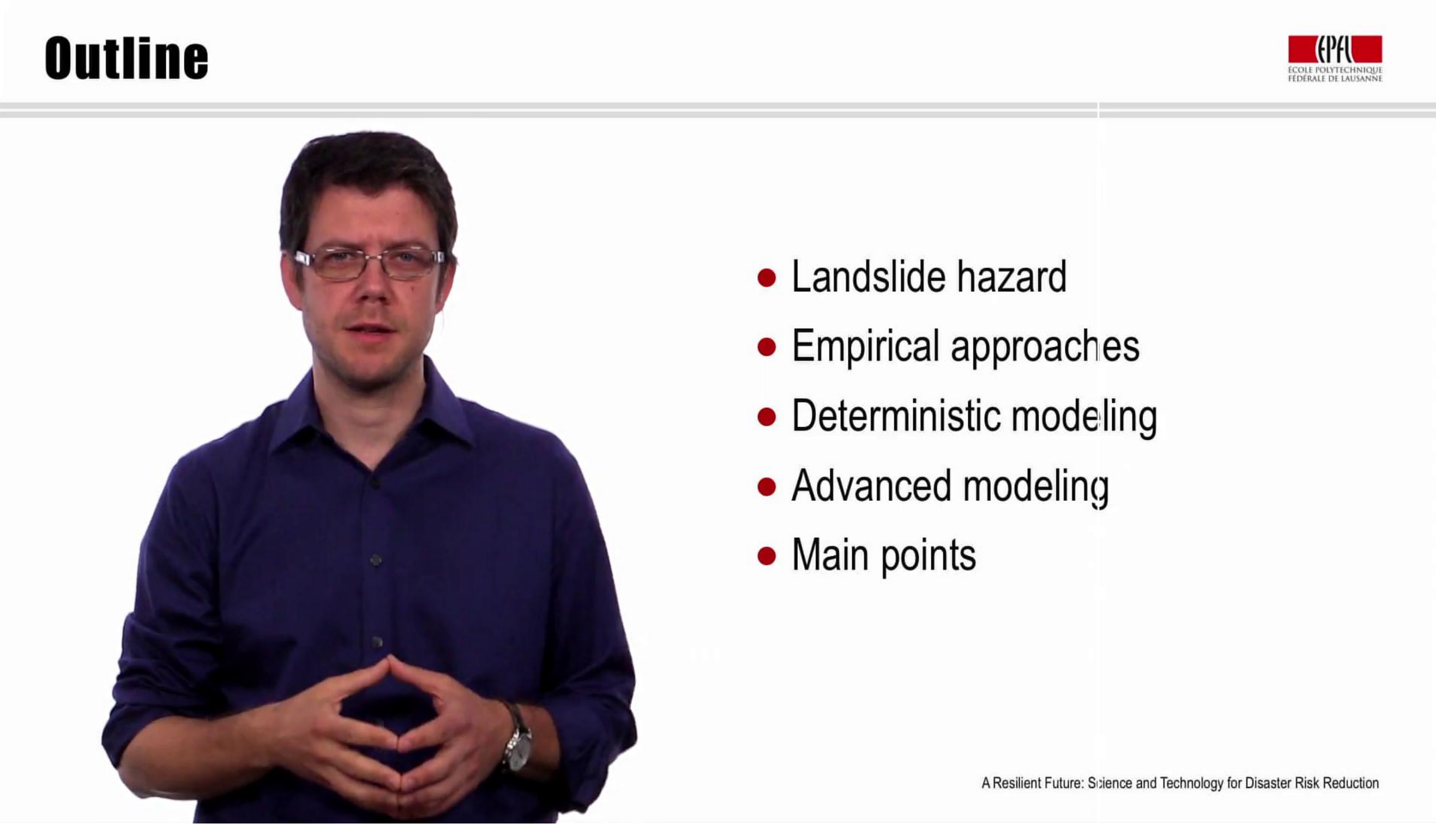


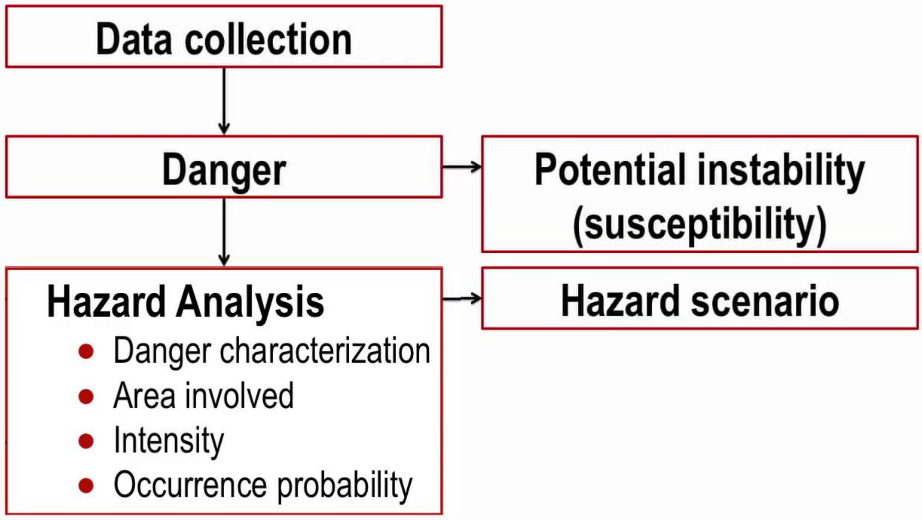
Landslide Hazard Assessment A Resilient Future: Science and Technology for Disaster Risk Reduction Hi. This is Alessio Ferrari again. In the next minutes we will try, mainly using some examples, to state the different approaches that may be used in the context of a landslide hazard assessment.

Notes

Summary

0m 00s

Landslide hazard assessment

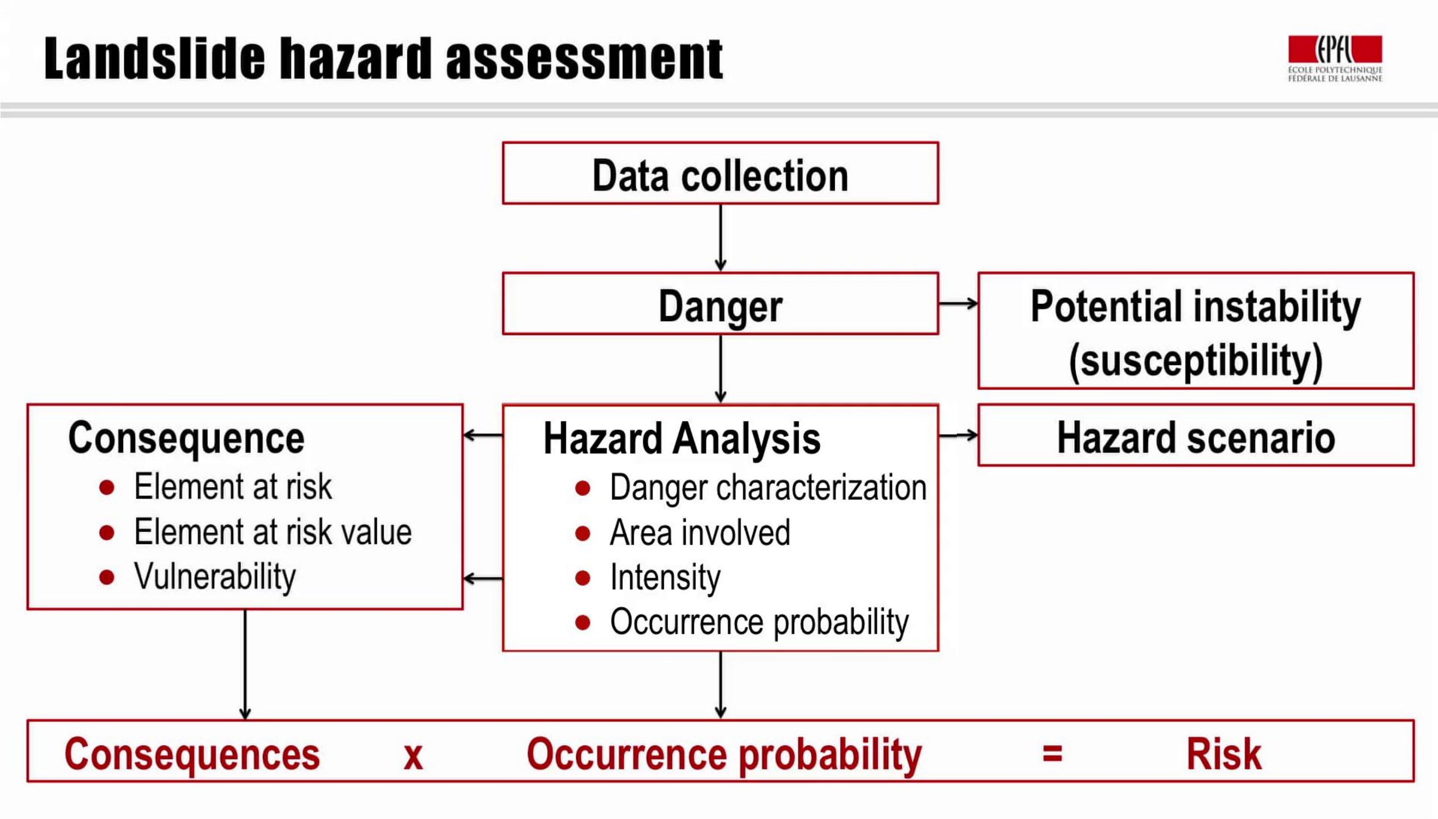


Let's start by trying to clarify what we intend for landslide hazard assessment. Hazard analysis is a fundamental component of risk assessment. For a given situation, we always need to start with collecting data, in order to identify potential instabilities. Each potential instability, the danger, needs to be analyzed with specific tools. The final aim of this operation is to identify the susceptibility of given areas to potential danger. Assessing the susceptibility is an operation which has a qualitative focus, while hazard analysis is performed to provide a quantitative assessment of the possibility of a landslide to occur, and to identify possible hazard scenarios. Each potential danger must be characterized-- identifying with maximum possible precision-- the phenomenon which may occur; namely, the type of landslide it could be, initiated or activated, what is the extension of the phenomena, and the area that can be potentially affected by it. The intensity will provide an indication on the severity of the phenomena. All these mentioned elements, which are part of the landslide analysis, are fundamental ingredients in order to assess the consequences related to the phenomena.

Notes

Summary

0m 17s



In particular, the study of the type of danger and the areas that are affected by the landslide, will serve to identify the elements which are at risk. At the same time, the intensity will serve as an ingredient together with the vulnerability of the elements, to quantify the consequences. Even for the case of a simple rock block falling, the quantification of those ingredients may require dedicated analysis. In this particular case, we would need to know the mass and positioning of the block that is likely to fall; the area that can be affected by the fall that will depend mainly on the trajectory of the block; and so the elements that could be impacted can be identified. The speed of the block could serve as an indicator for the intensity, which would let us computing the potential damages done to the infrastructures or buildings impacted by the block. Also the definition of occurrence probability is part of the hazard analysis, together with the quantification of the consequences, is the key ingredient to compute the risk.

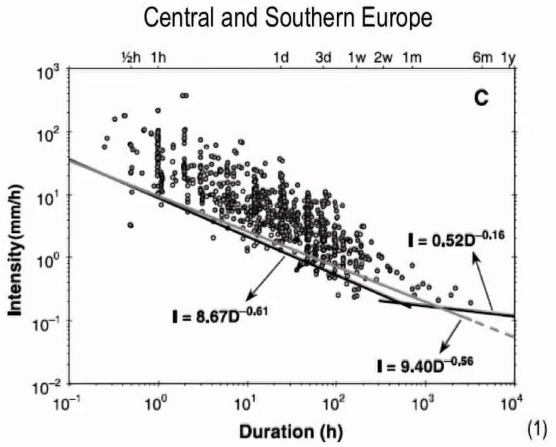
Notes

Summary

1m 37s

Empirical approach

A basic method for hazard assessment



- Based on past critical events

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The example of the block that we've just discussed, is already anticipating how complex hazard analysis for a landslide can be. Scientists and stakeholders often try to overcome this complexity by using simple approaches. Here, we see the example of a hazard analysis for rainfall induced landslides. By collecting information on past events here, in terms of rainfall intensity and duration from which a landslide has been produced it appears reasonable to draw thresholds, like those reported in the figure, for which we can identify events that have produced landslides, and events for which a landslide was not produced. A threshold like this could be used to make a hazard assessment.

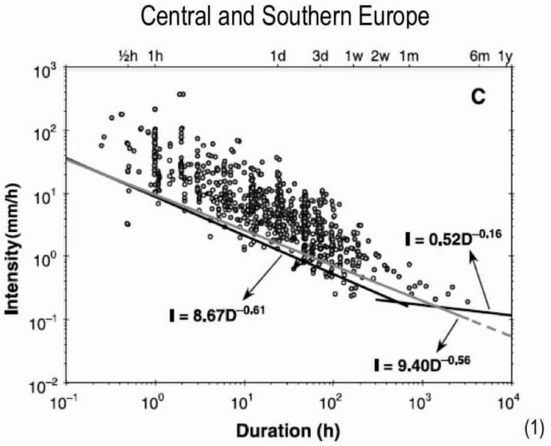
Notes

Summary

2m 40s

Empirical approach

A basic method for hazard assessment



(1)

- Based on past critical events
- Regional validity
- No physics
- No forecast
- Does not require much expertise, instruments or software
- Needs to be updated

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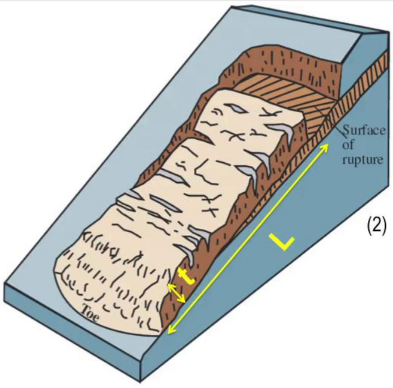
Interestingly, one could relate the occurrence probability of a landslide to the occurrence probability of a rainfall event that may produce that landslide. A tool like this seems very promising, and it is probably the very first type of analysis that one could do when he's called to operate in a given area, especially when no extended databases are available. However, several limitations apply. A method like this can have just a regional validity because it can apply to just the area for which the rainfall and landslide occurrence data have been collected. There is no physics in it, so we are not going to really see what are the physical processes which are triggered in the landslide. And when you have no physics in the process, it's very difficult to make any kind of forecast. It does not require too much expertise, it's quite a simple method, it doesn't involve the use of particular instruments or software, but needs to be updated as soon as new data on landslide occurrence events are registered.

Notes

Summary

3m 26s

Deterministic model: The infinite slope



- Shallow soil cover or existing discontinuities parallel to the slope
- $L/t \gg 1$
- Translational failure mechanism with surface of rupture parallel to the slope

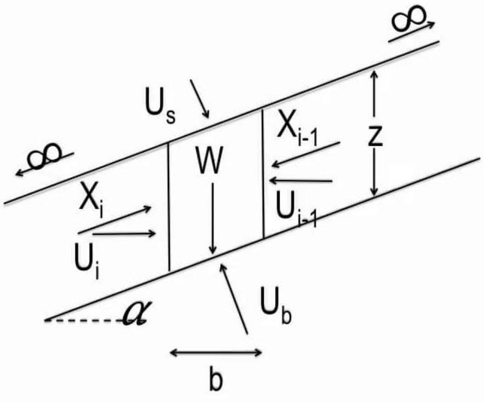
A different approach consists of performing a hazard analysis, trying to include as much as we know, in terms of the physical phenomena which are involved in the processes. This is the case of a simple deterministic approach that can be used to analyze translational slides. It applies to shallow soil covers, or existing discontinuities parallel to the slope when the length of the landslide body is much higher than the thickness of it. Translational failure mechanism with surface of rupture parallel to the slope, can be analyzed thanks to the infinite slope model.

Notes

Summary

4m 30s

Deterministic model: The infinite slope



(3)

$$W = \gamma \cdot z \cdot b$$

Factor of safety

$$F = \frac{c' b \sec\alpha + [W\cos\alpha - (U_b - U_s) - (U_i - U_{i-1})\sin\alpha]\tan\varphi'}{W\sin\alpha + (U_i - U_{i-1})\cos\alpha}$$

Main parameters defining F:

- Soil unit weight, γ
- Geometry, α
- Soil strength parameters, c' - φ'
- Pore water pressure resulting forces, U

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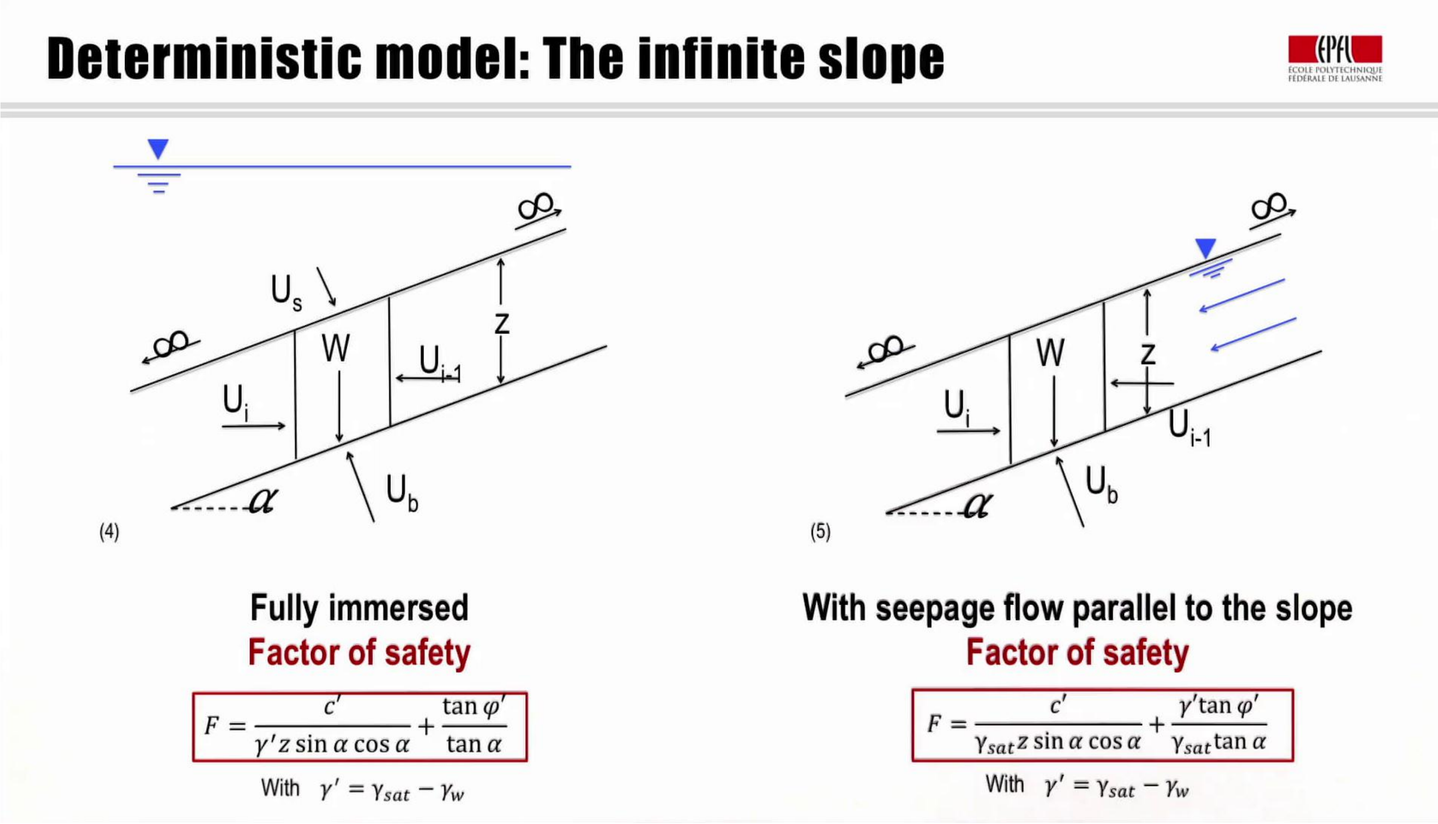
Thanks to the elongated shape of the landslide body, we can make the hypothesis of an infinite slope. We can isolate a portion of the slope, and write all the forces which are applied on it, starting from the weight, considering the forces which are coming from the interaction of the isolated mass from the surrounding masses, and the resulting forces, which are coming from the pore water pressure distribution inside the landslide body.

Notes

Summary

5m 02s

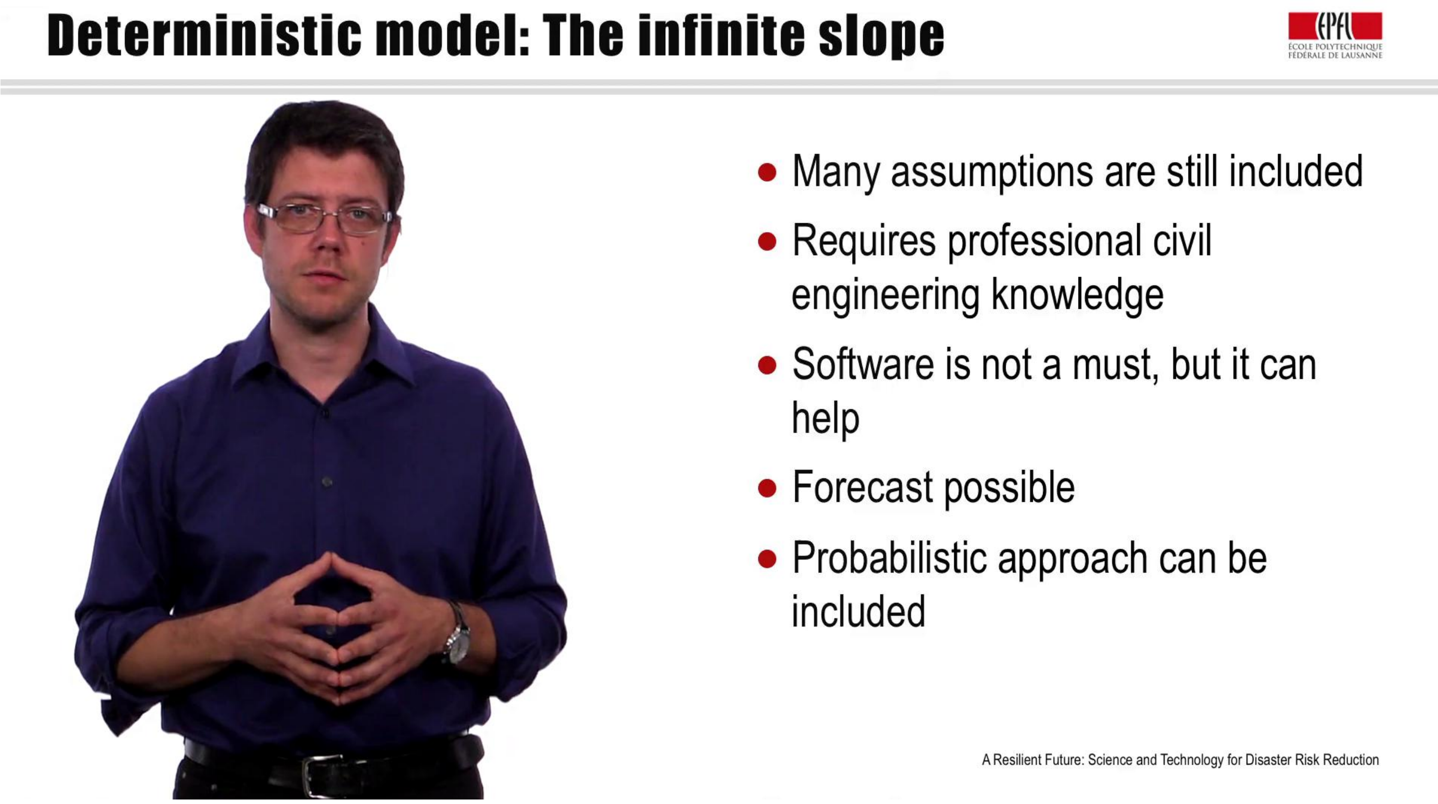


The ratio between the resisting force and the destabilizing force give us the factor of safety. The factor of safety is a very clever way to define and to assess the stability condition of a given slope. The higher this number, it means that we are far from a possible failure of the slope. In this slide, we see how the general formula that we've just seen for the factor of safety, can be easily adapted to different conditions, by considering different scenarios for the pore water pressure. This is the case for a fully immersed slope underwater. If the water is moving inside the slope, in the particular case in which we have flow lines which are parallel to the slope, this is the final formula that we get for the factor of safety.

Notes

Summary

5m 28s



The infinite slope model that we've just seen, is a very effective way to compute the stability or to assess the stability of a given slope that can be used if we are in this configuration that we described at the beginning. Still many assumptions are included in the analysis. It's a method that requires professional civil engineering knowledge. The selection of the parameters that are entering into the analysis should be done with a given experience in dealing with this material. So it's always better to be advised by geotechnical engineers, who know exactly how to compute the shear strength parameters in terms of *c prime* and *phi prime*. Software is not a must, but it can help, especially if you're going to repeat this analysis for different configurations. Forecasts are possible. We have seen that by changing the regime of the pore water pressure into the slope, how the water is moving or resting into the slope, we can anticipate how the failure condition can be produced or not. And the probabilistic approach can also be included, if we make the parameters that are entering in a definition of the factor of safety that are evolving, with a given probabilistic law.

Notes

Summary

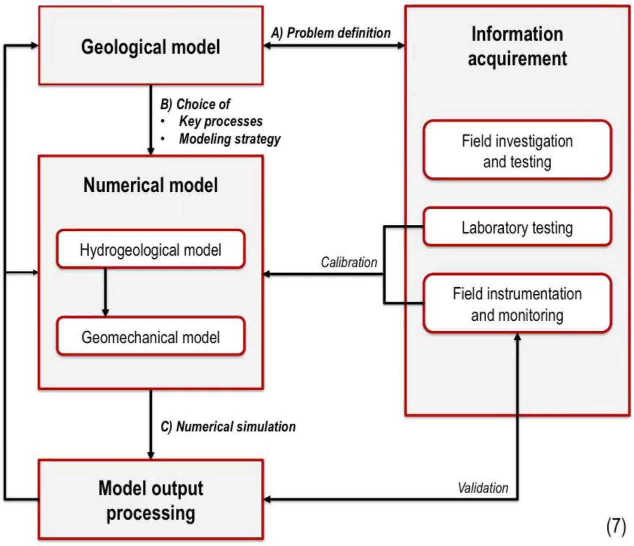
6m 13s

Advanced modeling for hazard analysis

A more advanced model can be used to enhance the physical description of the phenomena involved

but

more information is needed as model input and **a high performing tool for computations**



(7)

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We will now see the example of an advanced modeling for hazard assessment. A more advanced model can be used in enhancing the physical description of the involved phenomena, but of course, more information are needed as model inputs, and a high performing tool for computation should be used. This is the general outline that we can use when we are dealing with more advanced modeling.

Notes

Summary

7m 30s

Advanced modeling for hazard analysis

- More complex to apply
- Requires knowledge of complex physics
- Addresses most of the assumptions
- Need for good quality data
- High-end software is a must

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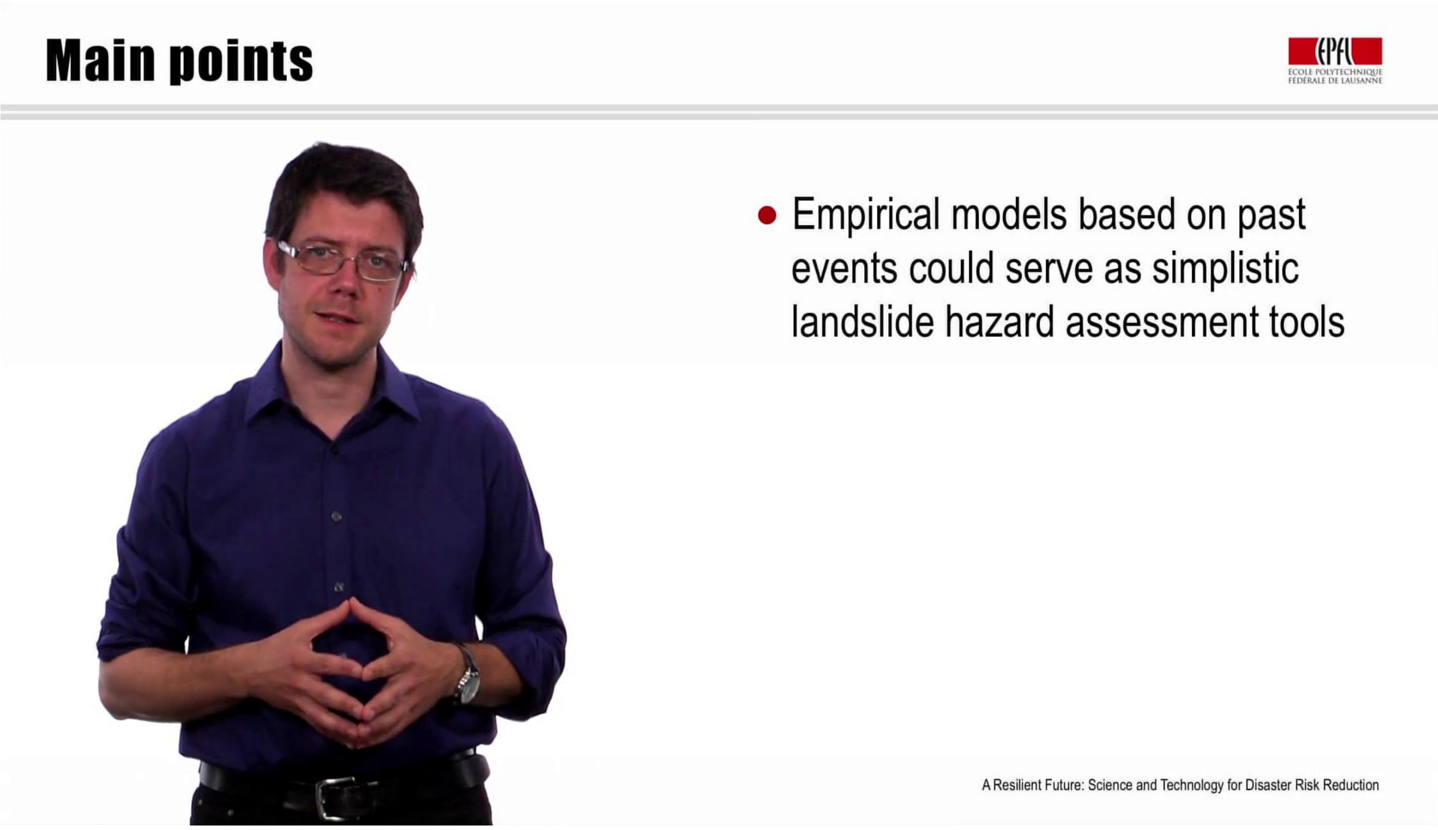
More advanced modeling offers a lot of advantages. Of course there is a price to pay for it. We are dealing with more complex analysis that requires a lot of knowledge about complex physics that you want to involve in your analysis. Most of the assumptions are addressed but in order to do that, you need very high quality data. High-end software is a must. Usually we need quite articulated or advanced numerical codes, like using the finite elements, in order to solve all the complexity which we are putting in our problem.

Notes

Summary

7m 54s



Let's now summarize the main points that we have discussed in this video. Empirical models, they are based on past events and they could serve as a simplistic model or approach to deal with landslide assessment.

Notes

Summary

8m 28s

Main points

- Advanced models are powerful tools to investigate the behavior of complex systems. Relevant features can be incorporated
- Physically-based models offer the possibility to assess and to design mitigation strategies

Physically-based models, although simple, they provide the possibility to include in the analysis the knowledge about the slope geometry and the characteristics of the involved materials. Advanced models are very powerful tools to perform a landslide hazard assessment. Relevant features can be incorporated. We can add as much complexity as we want, trying to include as much of the physical phenomena that we think are relevant for the processes that we are analyzing. Physically-based models. As simple as the infinite slope analysis, or complex, they offer the possibility to assess and also design mitigation strategies.

Notes

Summary

8m 42s

References

- Eichenberger, J, A. Ferrari and L. Laloui (2013) Early warning thresholds for partially saturated slopes in volcanic ashes, in Computers and Geotechnics, pp. 79-89.
- Ferrari, A., Laloui, L. and C. Bonnard (2009) Hydro-mechanical modelling of a natural slope affected by a multiple slip surface failure mechanism. Computer Modeling in Engineering & Sciences, 52(3), 217-235.
- Ferrari, A., Luna, B.Q., Spickermann, A., Travelletti, J., Krzeminska, D., Eichenberger, J., van Asch, T., van Beek, R., Bogaard, T., Malet, J.P. and L. Laloui (2014) Techniques for the modelling of the process systems in slow and fast-moving landslides. In: Mountain risks: from prediction to management and governance. Springer. Netherlands.
- Guzzetti, F., Peruccacci, S., Rossi, M., and C.P. Stark (2007) Rainfall thresholds for the initiation of landslides in central and southern Europe. Meteorology and Atmospheric Physics, 98(3), 239-267.

NOTE: All "factor of safety" equations are referenced to: Eichenberger, J, A. Ferrari and L. Laloui (2013) Early warning thresholds for partially saturated slopes in volcanic ashes, in Computers and Geotechnics, pp. 79-89.

Notes

Summary

9m 21s

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(1) Guzzetti, F., Peruccacci, S., Rossi, M., and C.P. Stark (2007) Rainfall thresholds for the initiation of landslides in central and southern Europe. Meteorology and Atmospheric Physics, 98(3), 239-267.

(2) Modified from Margo Johnson for USGS-United States Geological Survey (2004) Landslide Types and Processes, Fact Sheet 2004-3072.

(3) EPFL – Soil Mechanics Laboratory

(4) EPFL – Soil Mechanics Laboratory

(5) EPFL – Soil Mechanics Laboratory

(6) EPFL – Soil Mechanics Laboratory

(7) Modified from Ferrari, A., Luna, B.Q., Spickermann, A., Travelletti, J., Krzeminska, D., Eichenberger, J., van Asch, T., van Beek, R., Bogaard, T., Malet, J.P. and L. Laloui (2014) Techniques for the Modelling of the process systems in slow and fast-moving landslides. In: Mountain risks: from prediction to management and governance, Springer, Netherlands.

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Notes

Summary

9m 25s