A 60 m high geogrid reinforced steep slope for the stabilisation of a landslide in Northern Italy

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IFAI Geosynthetics Conference

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DEDICATION

We want to dedicate this presentation to our friend Prof. Robert M. Koerner, a master for all of us !

AGI Associazione Geotecnica Italiana

AGI-IGS Sezione Italiana dell'IGS

IGS

Prof. Robert M. Koerner

In recognition of your outstanding contribution
in geosynthetics and geoenvironmental engineering

Your friends of the IGS Italian Chapter

Milano, 20 March 2006

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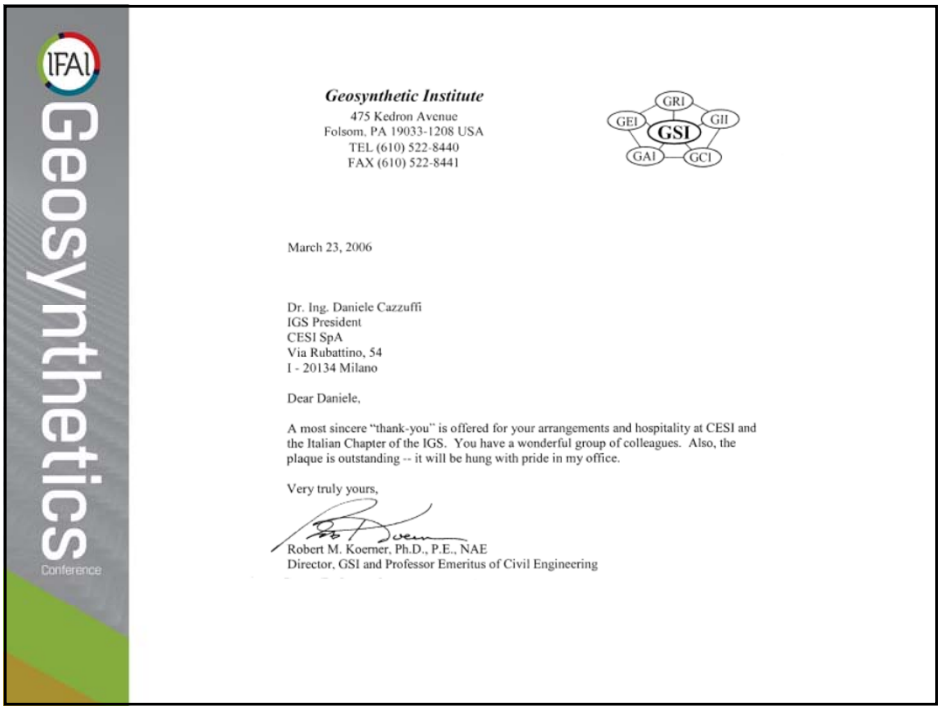

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GRI
GEI GSI GII
GAI GCI

March 23, 2006

Dr. Ing. Daniele Cazzuffi
IGS President
CESI SpA
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I - 20134 Milano

Dear Daniele,

A most sincere "thank-you" is offered for your arrangements and hospitality at CESI and the Italian Chapter of the IGS. You have a wonderful group of colleagues. Also, the plaque is outstanding -- it will be hung with pride in my office.

Very truly yours,

Robert M. Koerner, Ph.D., P.E., NAE
Director, GSI and Professor Emeritus of Civil Engineering

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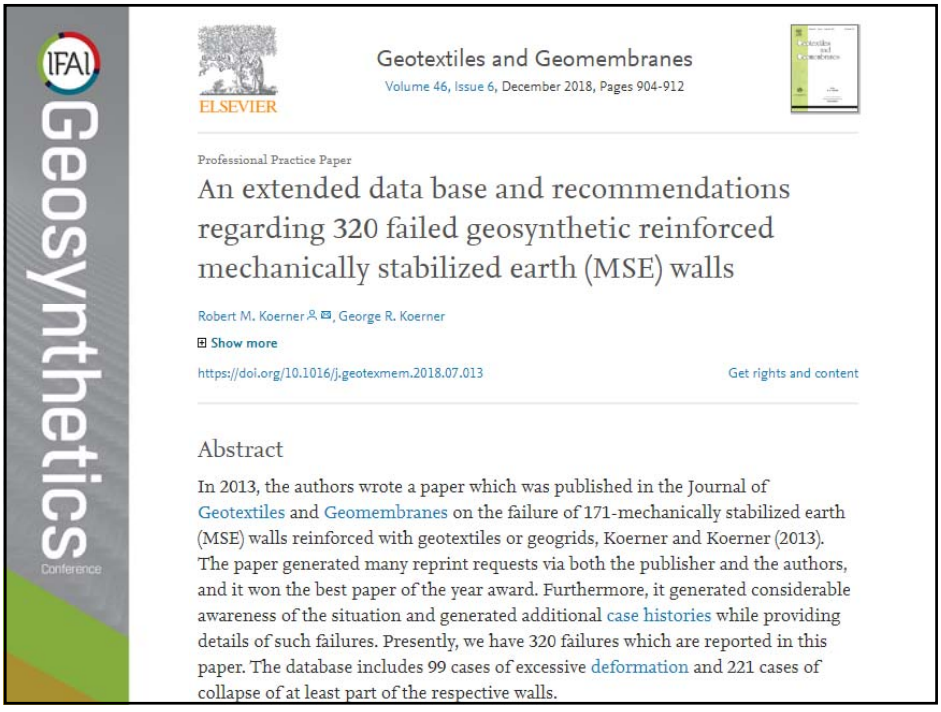

ELSEVIER

Geotextiles and Geomembranes
Volume 46, Issue 6, December 2018, Pages 904-912

Professional Practice Paper

An extended data base and recommendations regarding 320 failed geosynthetic reinforced mechanically stabilized earth (MSE) walls

Robert M. Koerner, George R. Koerner

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Abstract

In 2013, the authors wrote a paper which was published in the Journal of Geotextiles and Geomembranes on the failure of 171-mechanically stabilized earth (MSE) walls reinforced with geotextiles or geogrids, Koerner and Koerner (2013). The paper generated many reprint requests via both the publisher and the authors, and it won the best paper of the year award. Furthermore, it generated considerable awareness of the situation and generated additional case histories while providing details of such failures. Presently, we have 320 failures which are reported in this paper. The database includes 99 cases of excessive deformation and 221 cases of collapse of at least part of the respective walls.

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Summary

- History of the Valpola Landslide
- The Project
- Design constraints
- Construction
- Monitoring
- Conclusions

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Chronology of the events

- July 17-20 1987: Valtellina is interested by heavy rainfalls (305 mm/24 hours). First flooding along the Val Pola (right side of Valtellina) occur. A large fan base obstructs the Adda river, a small lake (25 ha, 10 m) is formed.
- July 25 1987: a large fracture, 600 m long, is observed between 2100 and 2350 m a.s.l. . Fracture enlarges and deepen in the next days.
- July 28, 1987: at 7.23, in 30 seconds, 45.000.000 m^3 of rock collapse into the river 1200 m below, run up 300 m on the opposite side of the valley, destroy villages of Morignone, S. Antonio, Poz, Tirindrè, S. Martino and Aquilone and cause 28 casualties.

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Development of the events

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Development of the events

July 1986 **July 1987**

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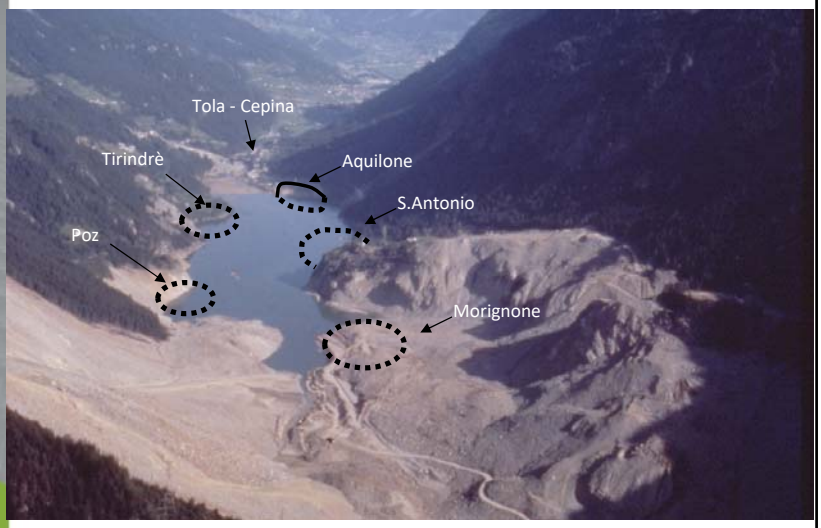
Position of the villages and shape of the lake (20 m deep)



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Design principle: securing the site from any further landslide, then restoring the valley to its original appearance before the landslide

From 1987 to 1990:

- Protect valley and works from landslides with a large dam on the right side of the valley (Arginone).
- Divert the Adda river into hydraulic tunnels bypassing the landslide.

After 2009:

- Excavate over 30 m depth without causing instability of both sides of the valley (micropile walls)
- Moving about 3.000.000 m^3 soil
- Re-use of most of the excavated material to model the valley in the upper part and to create 25.000 m^2 face steep reinforced slopes, 60.0 m high
- Create a new riverbed for the Adda, about 60 m above the original one

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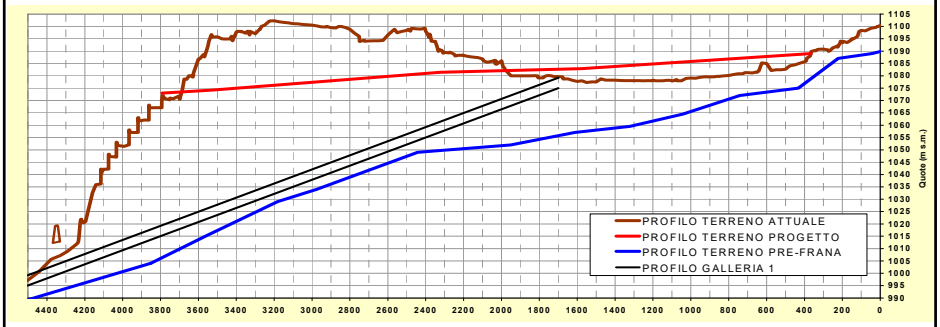
The proposed solution



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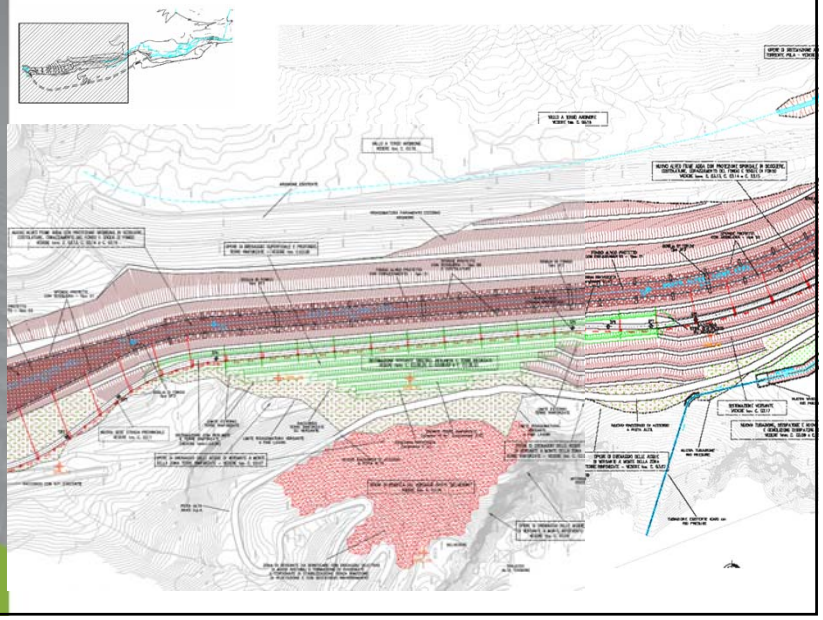
The proposed solution: plain view



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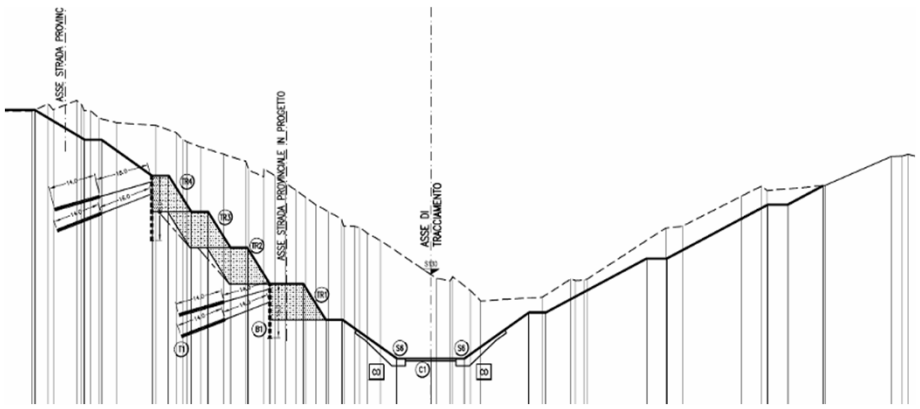
Example of excavation profile



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The site at the beginning of the work

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Micropile walls construction

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Reconstruction with a geogrid reinforced slope

- The whole area was reconstructed with 6 geogrid reinforced slopes, each 10 m high, separated by berms (total height of 60 m)
- A road was foreseen over the first slope
- Slope inclination 60°, spacing between geogrids equal to 700 mm
- Presence of micropile walls was neglected in analysis
- Internal, external and global stability analysis were performed
- Analysis carried out according to NTC ‘08 code (Italian Construction regulation code)

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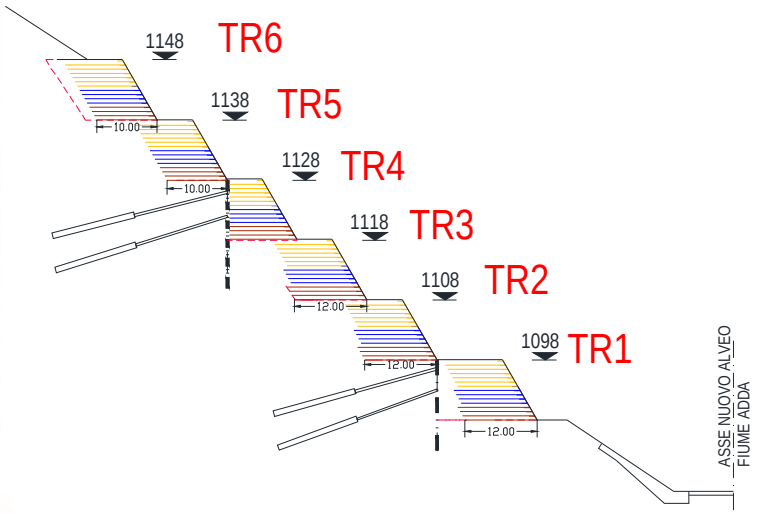
Typical cross-section



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Construction aspects

The slope (25.000 m^2 face) was constructed in less than 2 years

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Sacrificial steel mesh formworks were foreseen because of the speed and easiness of installation

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Wrap-around technique was used

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Construction was stopped during winter months: a heavy biomat (>450 g/m²) was foreseen at the face

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Accurate collection system and drainage of water was foreseen

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Problems encountered during construction

- In the lower slope, some layers were over-compacted (passing from 700 to 600 mm)
- Further geogrid layers were added on top to reach the expected level
- After the first tier, the problem was not observed anymore, as taller steel mesh formworks were supplied (thickness control easier). Compaction close to the face was operated with light weight machines

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- Sometimes rather big boulder (up to 200 mm) were observed close to the face. Whenever observed and possible, they were removed, leaving only topsoil in the first 300 mm from the slope face to allow an easier vegetation

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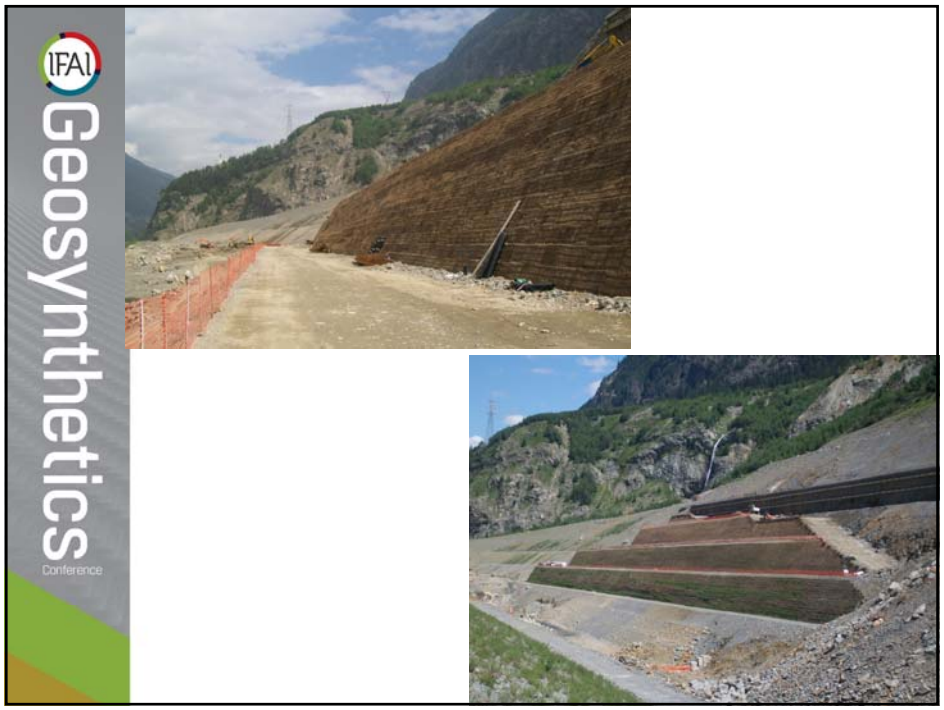
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May 26th 2012: about 25 years after the event, the Giro d'Italia passed over the almost finished reconstructed area

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MONITORING: Six months after the end of the works the structure was attacked by fire; a prompt inspection of the site confirmed that the structure had not suffered any serious damage

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AFTER THE FIRE

3 MONTHS LATER

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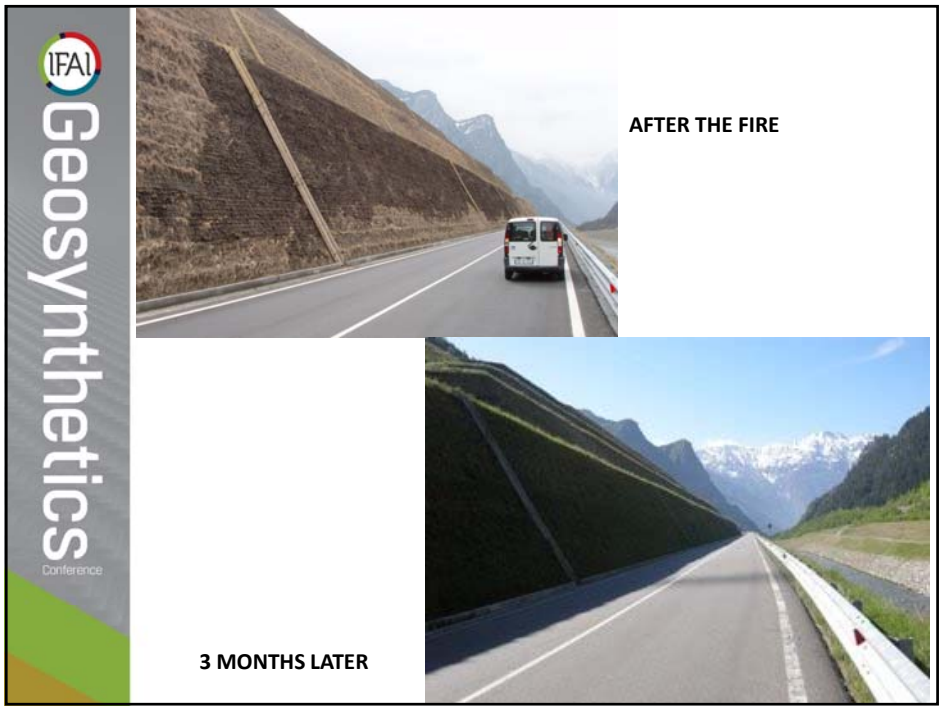
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AFTER THE FIRE
3 MONTHS LATER

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Samples of geogrid excavated from the burnt area were subjected to a tensile strength test; the residual strength was showing how the fire was not affecting the resistance of the geogrid

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Conclusions

- The project is an interesting application of the use of soil reinforcement in extreme environmental conditions
- It is one of the tallest structure constructed in Europe and probably one among the first with such a complexity to be designed according to the new Italian regulations
- After 7 years from the end of the construction the whole work is in perfect shape although attacked by a fire, and the road is regularly open to the traffic
- Vegetation on the face has grown and the project is very well inserted in the surrounding environment; such structure, once vegetated has demonstrated to be resistant even to fire

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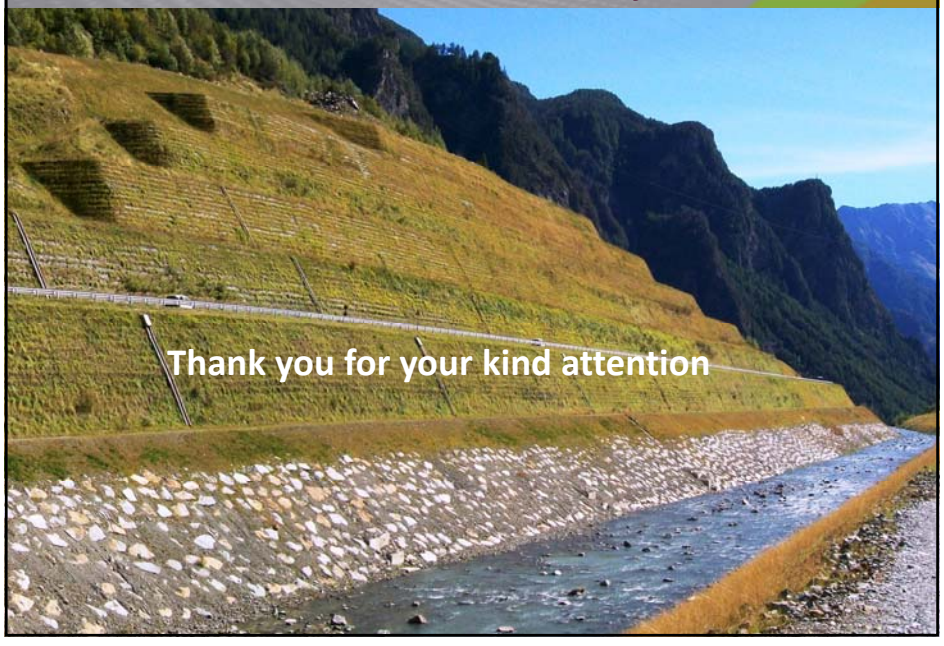

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