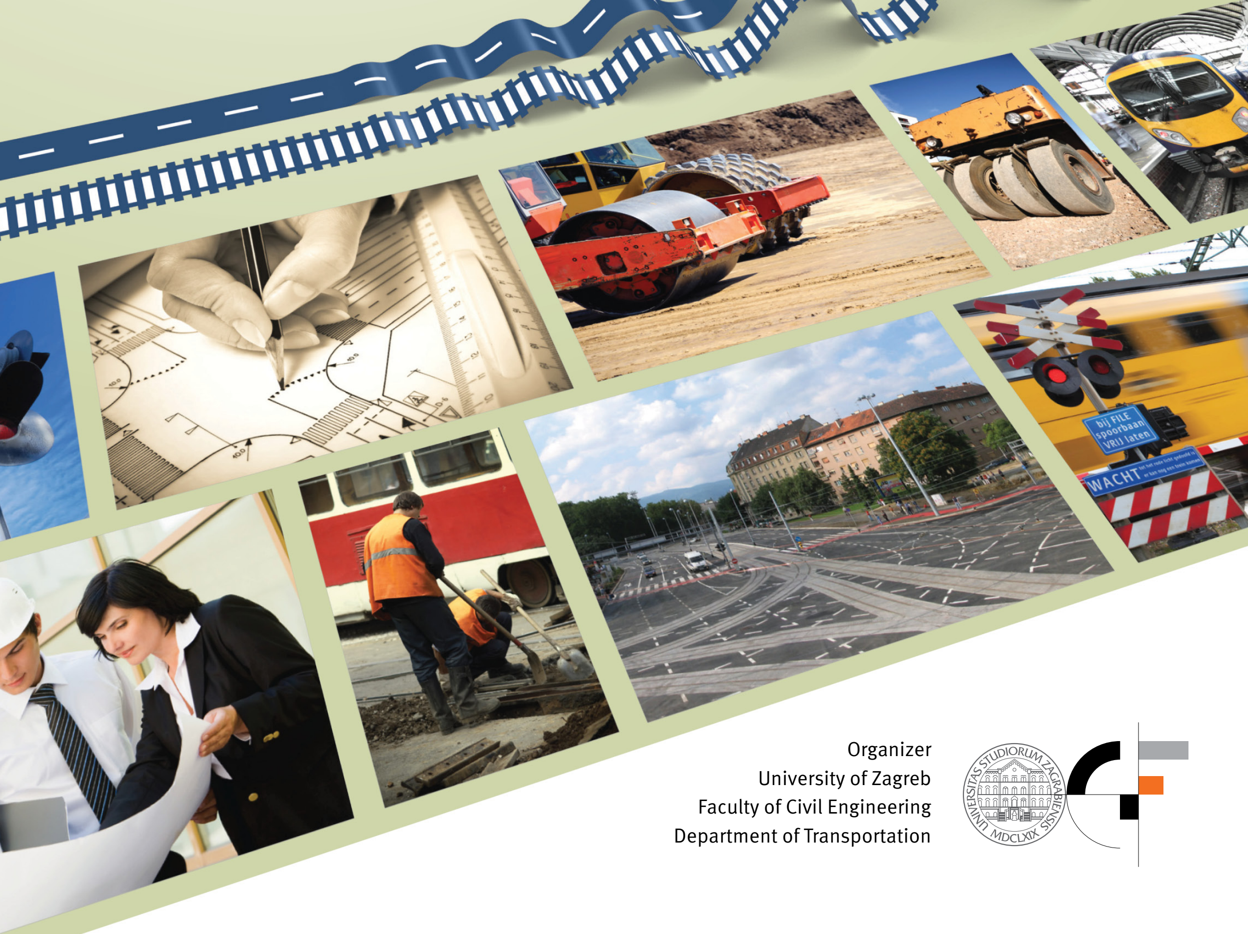
CETRA[2012]

2nd International Conference on Road and Rail Infrastructure

7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA[2012]
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

COPIES
600

A CIP catalogue record for this e–book is available from the National and University Library in Zagreb under 805372

Although all care was taken to ensure the integrity and quality of the publication and the information herein, no responsibility is assumed by the publisher, the editor and authors for any damages to property or persons as a result of operation or use of this publication or use the information's, instructions or ideas contained in the material herein.
The papers published in the Proceedings express the opinion of the authors, who also are responsible for their content. Reproduction or transmission of full papers is allowed only with written permission of the Publisher. Short parts may be reproduced only with proper quotation of the source.

Proceedings of the
2nd International Conference on Road and Rail Infrastructures – CETRA 2012
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

ORGANISATION

CHAIRMEN

Prof. **Željko Korlaet**, University of Zagreb, Faculty of Civil Engineering
Prof. **Stjepan Lakušić**, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Maja Ahac
Ivo Haladin
Saša Ahac
Ivica Stančerić
Josipa Domitrović

All members of CETRA 2012 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Prof. **Ronald Blab**, Vienna University of Technology, Austria
Prof. **Vesna Dragčević**, University of Zagreb, Croatia
Prof. **Nenad Gucunski**, Rutgers University, USA
Prof. **Željko Korlaet**, University of Zagreb, Croatia
Prof. **Zoran Krakutovski**, University Sts. Cyril and Methodius, Rep. of Macedonia
Prof. **Stjepan Lakušić**, University of Zagreb, Croatia
Prof. **Dirk Lauwers**, Ghent University, Belgium
Prof. **Giovanni Longo**, University of Trieste, Italy
Prof. **Janusz Madejski**, Silesian University of Technology, Poland
Prof. **Jan Mandula**, Technical University of Kosice, Slovakia
Prof. **Nencho Nenov**, University of Transport in Sofia, Bulgaria
Prof. **Athanassios Nikolaides**, Aristotle University of Thessaloniki, Greece
Prof. **Otto Plašek**, Brno University of Technology, Czech Republic
Prof. **Christos Pyrgidis**, Aristotle University of Thessaloniki, Greece
Prof. **Carmen Racanel**, Technical University of Bucharest, Romania
Prof. **Stefano Ricci**, University of Rome, Italy
Prof. **Tatjana Rukavina**, University of Zagreb, Croatia
Prof. **Mirjana Tomičić–Torlaković**, Univiversity of Belgrade, Serbia
Prof. **Brigita Salaiova**, Technical University of Kosice, Slovakia
Prof. **Peter Veit**, Graz University of Technology, Austria
Prof. **Marijan Žura**, University of Ljubljana, Slovenia

PROTECTION MEASURES AGAINST DEBRIS FLOWS, USING FLEXIBLE RING NET BARRIERS IN THE TEUFELSKADRICH, GERMANY

Roland Bucher[1], Corinna Wendeler[2], Vjekoslav Budimir[3]
1 GEOBRUGG Australia Pty Ltd, Australia
2 GEOBRUGG AG, Technical Department
3 GEOBRUGG AG, Representative Office, Croatia

Abstract

The steep, shrouded slope along the river Rhine between the German villages of Lorch and Assmannhausen is called the 'Teufelskadrich'. The railway line of the German Federal Railway and the motorway run alongside the river Rhine, between the toe of the slope and the river bench. In July 2008, after heavy rain and thunderstorms, several landslides and small debris flows occurred in the area, which closed the railway line for several days. Twelve flexible ring net barriers were designed, manufactured and installed within two months as part of an emergency procedure. These barriers were tested and developed with 1:1 field tests in a research project in collaboration with the Swiss Federal Institute for Forest Snow and Landscape (WSL). These light weight, ring net barriers are quick to install, and are suitable for slopes with difficult access. They also have the ability to blend in with nature once installed, which was important in the 'Teufelskadrich' area, as the valley is a popular tourist destination. With the new barriers installed on the slope, mobilised material is drained and retained during a landslide or debris flow, by the filtering–effect of the ring net barriers. As an additional measure, some of the deposited debris has been stabilized using a slope stabilisation system, utilising high–tensile chain link mesh and soil nails. Most of the future material is thus already retained in the catchment area, further reducing erosion and limiting mass mobilisation during an event.

Keywords: landslide, debris flow, flexible ring net barriers, slope stabilisation system, high–tensile chain link mesh

1 The 'Teufelskadrich' locality

Above the Rhine, rise the steep, barren slopes of the Rhenish Massif, an area that experiencesrockfall events and isolated landslides (see Fig. 1). From a geological point of view, the locality is situated in the right–bank massif, approximately 10 km west of the village of Rüdesheim. The mountain range is predominantly composed of very hard quartzites, arranged as slate strata, which in terms of stratigraphy can be assigned to the Lower Devonian. Within the area under investigation, the Rhine flows approximately in a north–south direction at a height of around 80 m above sea level; the top edge of the slope area, which is exposed to the west, is at a height of around 310m above sea level. Apart from the cliffs, which protrude significantly and in some places can be up to 30 meters in height, the entire slope is covered by a layer of scree several meters thick. With a slope inclination of 30 and, in some places, >35°, this is close to the limit value for equilibrium. Due to the slope's overall morphological situation, with a fold structure that tapers off toward the foot of the slope, the rainfall, which at the top of the slope drains over a relatively large area, is increasingly channelled into isolated

erosion gullies as it flows down the slope. Detailed engineering topographical maps revealed around 3–4 larger main gully structures in the section of the slope under consideration. The concentration of water and debris flow in the natural gullies increases above a certain volume of rainfall, which increases the hazards of debris cover of the existing infrastructure at the toe of the slope.
In the wake of heavy rainfall on 30/07/2008, during which up to 100 mm of rain fell in the vicinity, it was reported that approximately 1,000 m^3 of scree had washed onto the railroad tracks, disrupting rail services, fortunately without causing personal injury (see Fig. 1 on right).
It was important for the German Federal Railway to minimize disruption to their infrastructure, so to prevent further danger to rail traffic (and to road traffic on the federal highway that runs parallel to the railway) attempts had to be made to find an immediate solution to the problem. It was decide the best option was to use ring net barriers, which can be installed quickly and efficiently. In addition, experience had shown that a measure implemented back in 2005 had proven very successful (see Fig. 2 on the left).

Figure 1 Steep slope with loose material above the river Rhine (left) and material deposited at the railway line after the event in July 2008 (right).

2 Ring nets as protection against debris flows

2.1 Historical background

Before high–tensile flexible nets were used as protection against debris flows, they were used to contain driftwood as well as snow and rockfall events.
From 2005 to 2008, these nets were tested as debris flow protection in Illgraben, one of the most active debris flow rivers in Switzerland. Utilising 1:1 field tests, their support system was adapted and optimized according to the new requirements. For the first time, specially developed measuring technology was used to measure rope forces in the barriers during a debris flow event, and simultaneously to calculate the density and corresponding pressures exerted by the debris [1]. The field test data and a further 70 complementary laboratory tests were used to derive a load model to dimension these nets. This in turn was implemented into the finite element software FARO [2]. This software will enable engineers in the future to dimension these nets easily and efficiently under practical conditions.

2.2 Ring nets as protection against debris flows in the Teufelskadrich

The first three flexible ring nets were installed as debris flow barriers in the Teufelskadrich back in 2005. This was done at the same time as the research project began (see Fig. 2). During the event of 2008, these nets succeeded in holding back around 100 m^3 of material. Its projected retention volume had been significantly smaller than the total cubage of the event that occurred.

Geologists and engineers were on site the same day the event occurred, in order to assess the damage to the buried railroad tracks and to begin working out appropriate protective measures. It was clear that the material along the slopes had been deposited by debris flows as they swept downhill. It became clear to all involved that the gullies had to be stabilised to protect the railway tracks and the federal highway. It was also important not to cause major disruption to rail services during the construction phase. The safety of the two transportation routes during the construction phase was paramount throughout this process.

Figure 2 Installed ring net barrier of 2005 filled after the event in July 2008 (left) and gully after the same event (right).

2.3 Statement by the rail operator concerning the planned protective measure

Three debris surges in all had landed on the track of the Wiesbaden–Niederlahnstein rail line between the 71.985 – 72.370 km mark. The mass of debris and mud that had been deposited on and around the track caused the line to be closed in both directions. The necessary measures to protect both transportation routes (railroad and federal highway) against landslides or shallow landslides along this section of the line had to be taken immediately to guard against further dangers.

Due to the severity of the incidents, an external assessor was called in to evaluate the potential risks. The first measure to guard against further dangers and to restore rail services was to clear the line and the safety installations already in place and to repair and restore the damaged safety installations. The following section provides a more detailed explanation of the next steps based on the assessor's evaluation.

3 Planning the ring net barriers

3.1 Determining the requisite barrier locations

The engineering office tasked with the planning work carried out an extensive on–site inspection to determine the appropriate barrier locations, on the basis of existing gullies and corresponding deposits of loose material. This inspection resulted in 12 ring net barriers to ensure sufficient retention of material as well as several smaller 'debris brakes' to stabilize the gullies and the slope. An additional barrier made from high–tensile steel wire mesh was also used to reinforce excessively steep sections of the slope in the vicinity of the deposited mounds of scree. The next section discusses the dimensioning of the ring net barriers in more detail.

3.2 Numerical simulation

The volume of debris displaced was used to make an overall assessment for the event that had occurred. This produced a mobilised volume for the northernmost gully of approximately 500m³; the total volume of debris displaced was calculated at around 1,000m³. This value was to be guaranteed as a minimum value for the projected retention volume in dimensioning the protective measures to be implemented. The following input variables for dimensioning the ring net barriers were calculated:

- V_{max} = 500 m³ per main gully
- Maximum channel slope: 45°
- Maximum debris flow density: 2000 kg/m³
- Maximum flow $Q_{max} = 0.135 \bullet V^{0.78} = 17.2$ m/s (calculated empirically [3])

The maximum flow can be used to make an empirical calculation of the maximum flow speed: vmax = 2.1•Q0.34•I0.2 = 5.5 m/s [4].

At a maximum gully width of b_{max}=3m, the continuity equation gives a maximum flow height for a wave thrust of h_{max}=1m. Five wave thrusts would thus be required to completely fill a five–meter high system [1].

As an example, the dimensioning of the barriers is shown for debris flow barrier 10. Due to its maximum system height and span width and its location directly within a gully, this fence is one of the determinative systems. The barrier geometry is shown in Fig. 3.

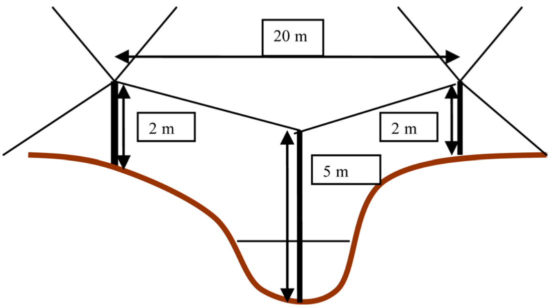


Figure 3 Decisive geometry for dimensioning of the ring net with middle post height of 5m and the two border posts with 2m height.

The net is dimensioned for the dynamic impact of the first debris wave using the input parameters described above. A dynamic wave impact acts on the lower part of the net with a force along the length of the rope of $F_{dyn} = \rho \bullet v2 \bullet h_{max} = 2000 \bullet 5.52 \bullet 1 = 60.5$ kN/m [5].

The corresponding FARO simulation was carried out for this first wave impact (see Fig. 4 on left). For the support system selected, the two lower support ropes had a load factor of just under 60%.

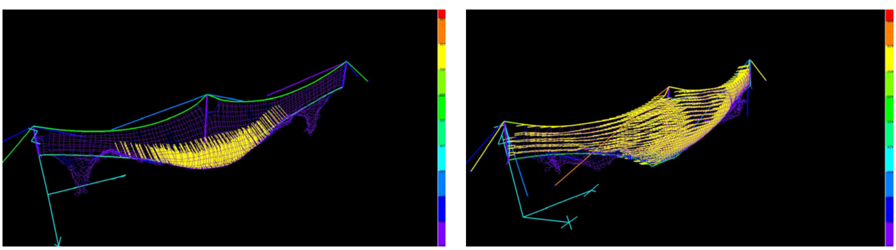


Figure 4 Results of component utilization with FARO for the first debris flow wave impact on the shown barrier geometry of Fig. 3 (left) and Load case of the full barrier in FARO with the utilisation of the components of 80% (right).

The second determinative load situation involves the barriers being completely full (see Fig. 4 on right). Here, to be on the safe side, the ring net must be capable of bearing the full hydrostatic pressure of the debris given that no more detailed information is available on the drainage behaviour of the debris flow material away from the Teufelskadrich. Thus no statement can be made on how quickly the material drains or how the behaviour of the retained material approximates to the active earth pressure state.
The performed FARO calculations can be used for the planned debris flow barriers system, including the effective anchor forces based on the 1:1 field tests It was possible to lay out and dimension the other barriers accordingly on the basis of these calculations.

3.3 Construction

In consultation with the conservation and the licensing authorities, every aspect of the construction work was supervised by a team of ecological specialists to ensure that the sensitive flora and fauna of the UNESCO World Heritage Site was respected, and to keep distruption to a minimum. These authorities were closely involved in planning and implementing the work. As this project was deemed urgent, it was necessary to ensure during construction work that the barriers were installed as efficiently and quickly as possible, without hindering the passing rail traffic. To protect the rail traffic from rockfall during construction, existing catch fences as well as protective elements used in canal construction, were installed on a provisional basis and rear–anchored. It was thus possible to carry out the protection work while maintaining rail services on both tracks. Due to the steep slopes and the poor accessibility, construction work was often challenging (see Fig. 5).

Figure 5 Drilling being carried out on ropes (left) and fixing of the ring net after the installation of support ropes (right).

In order to be able to verify the full load–bearing capacity of the projected anchor loads in unconsolidated soil, 10% of the anchors used were checked in stress tests before the ring net barriers were installed. At the same time, the slope stabilisation with the high–tensile mesh and the debris brakes in the flushed–out gullies were completed (see Fig. 6). In order to meet the planned deadlines for completion of the work, close cooperation was required between the contractors, the product manufacturers, the engineers tasked with planning and the principal on–site.

With a three–week planning phase (which also saw construction work begun in parallel,) the entire project was completed successfully in a period of six weeks, with installation work carrying on through adverse weather conditions.

Figure 6 Slope stabilisation for the loose deposited material (left) and small debris brake at a gully to reduce the flow energy level (right).

4 Conclusions

The completion of the twelve ring net barriers for protection against debris flows was the first time such an overall concept had been implemented in Germany. In the Hasliberg region (Bernese Oberland, Switzerland), a similar protection concept had been implemented for the first time since 2005, following floods [5].

The main benefits of these barriers lay not only in the short construction times and the ease of installation in hard–to–reach terrain, but also in the fact that the project had minimized the necessary impact on the protected landscape of the Middle Rhine Valley, a UNESCO World Heritage Site popular with tourists. Even in winter, when most of the vegetation is devoid of leaves, the protective measures can only be spotted with difficulty from the opposite bank of the Rhine (see Fig. 7). The new debris flow nets are marked in red and the old existing rockfall barriers in green in this figure.

Thus this innovative protective measure appears to have benefited both the principal – German Railway AG – which need no longer worry about disruptions caused by debris flows and landslides on this section of line in future, and the natural environment, which has been given adiscreet protection system, that impacts as little as possible on the plant and animal life in the area. The popular tourist region around Assmansshausen is only affected slightly by the new measure and will thus remain a popular tourist destination for the future.

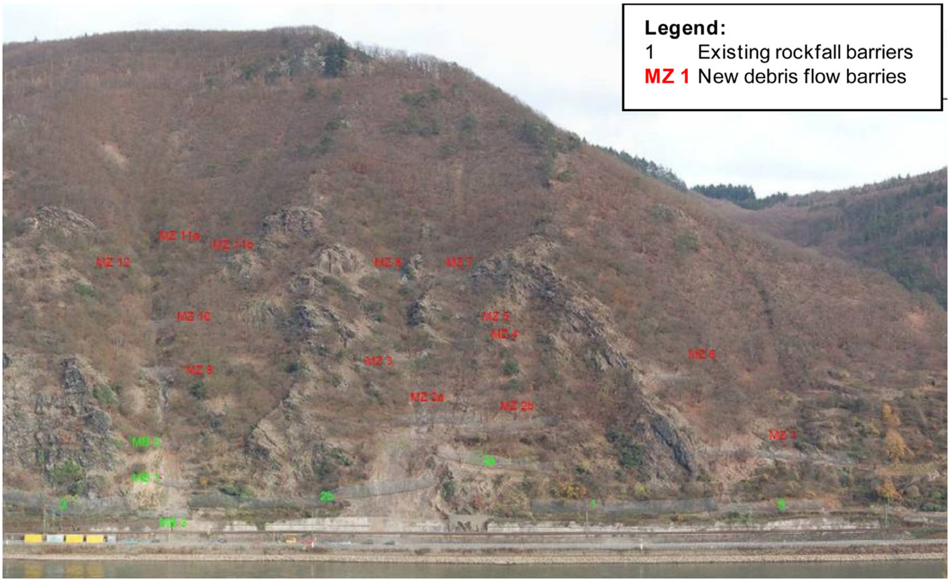


Figure 7 Installation complete with old rock fall barriers and new installed debris flow barriers. (Source of Fig. 7: Institute of Environmental Planning, Dr. Kübler GmbH).

References

[1] Wendeler, C., Debris flow retention in mountain torrents – principles on planning and calculating flexible barriers, doctoral thesis, 2008, Swiss Federal Institute of Technology Zurich, Switzerland.

[2] Volkwein, A., Numerical simulation of flexible rockfall protection systems, doctoral thesis, 2004, Swiss Federal Institute of Technology Zurich, Switzerland.

[3] Rickenmann, D., Empirical Relationships for Debris Flows, 1999, Natural Hazards 19: pp 47-77.

[4] Rickenmann, D., An alternative equation for the mean velocity in gravel-bed rivers and mountain torrents, Proceedings of the 1994 Conference on Hydraulic Engineering, Buffalo. N.Y., American Society of Civil Engineers, Vol. 1, pp 672-676.

[5] Wendeler, C., Volkwein, A., Roth, A., Herzog, B., Hählen, N. and Wenger, M.: Hazard prevention using flexible multi-level debris flow barriers, Proceedings of International Symposium Interpraevent, Dornbirn, Austria, Vol. 1, pp 547-554.