LOG JAM OF BRIDGES

SIMULATING EFFECTS ON FLOODING BY LINKING A PHYSICAL AND NUMERICAL MODEL APPROACH

Bernhard Gems[1], Andreas Sendlhofer[2], Stefan Achleitner[3], Matthias Huttenlau[4] and Markus Aufleger[5]

INTRODUCTION

Policies for the decrease of flood-related vulnerability and hazard potential represent basic duties in modern flood protection engineering. With regard to the characteristics of alpine catchments damage causing floods are numerously induced by massive sediment transport rates. The deposition of bed-load in torrents and mountain rivers causes an increase of flood risk. Erosion processes in the near proximity of bridges as well as unstable embankments can lead to local scours resulting in the possible collapse of bridge structures and hillside slides. Driftwood as a second factor increases the flood-risk potential at bridges. The backwater effect due to jammed debris causes an additional increase of the upstream water level. Consequently bed-load material is accumulated leading to extended flooding (Rimböck, 2003). Most decisive criteria for the impact of log jam processes are the amount and composite of the driftwood, the transport characteristics regarding a scattered or batch-wise flow of driftwood, the clear cross section width and height beneath the bridge deck and its structural design (Bouska and Gabriel, 2009), ((Gantenbein, 2001), from (Lange and Bezzola, 2006)).
Comprehensive research is actually done in the field of driftwood and log jam processes. Focus is thereby put on the determination of driftwood potential in the torrent catchments and the transport mechanism. Further the log jam probabilities of single wood elements and possible measures to catch or convey driftwood and to avoid damages are in the focus of current research.
The work presented within this paper deals with the determination of damming up due to log jam by the use of a physical scale model (M = 1:45). The determined water level measurements are used within a 2D-numerical model in order to detect the effects of log jam on flooding.

MODELLING CONCEPT

The study is accomplished for a bridge structure situated along the receiving water course in the Ötz-valley in the village of Sölden (Tyrolean Alps) where historic floods caused severe damages (see Fig. 1, left). The catchment area is 423 km², approximately 30 km² are afforested. The flow conditions are affected by heavy sediment transport.
Within the physical scale model flow conditions from HQ_{10} to HQ_{200} are tested. The amount of associated driftwood is estimated based on empirical equations relating the quantity to catchment characteristics such as the afforested catchment area. The composition of the driftwood is assumed to be similar to observations from VAW - ETH Zürich at two Swiss torrent catchments (Lange and Bezzola, 2006) (see Fig. 1, right for the three applied driftwood mixtures “SHA”, “SHB” and “SHC”). The input of driftwood is done both batch-wise and continuously over specific time duration. In the lab tests, the measurements focus on the water level close to and upstream the bridge to assess the rising water level due to the backwater effects. Totally 145 test runs were carried out under steady state flow conditions excluding bed-load transport. The obtained water level measurements are used in a 2D-numerical model approach covering the settled area of Sölden. The discharge input to the model

[1] Dipl.-Ing. Bernhard Gems. Unit of Hydraulic Engineering, University of Innsbruck. Austria. Mail: bernhard.gems@uibk.ac.at.
[2] Dipl.-Ing. Andreas Sendlhofer. Unit of Hydraulic Engineering, University of Innsbruck. Austria.
[3] Dr. Stefan Achleitner. Unit of Hydraulic Engineering, University of Innsbruck. Austria.
[4] Dr. Matthias Huttenlau. alpS – Centre for Climate Change Adaption Technologies. Austria.
[5] Univ.-Prof. Dr.-Ing. habil. Markus Aufleger. Unit of Hydraulic Engineering, University of Innsbruck. Austria.

(HYDRO_GS-2D) is obtained from a hydrological-1D-hydraulic model. This data input is considered to be “spatially correct” since a spatially distributed hydrological model is used. The calibration is made for various historic flood events using flow data from several discharge gages. Lab and software models are linked comparing the peak discharges. The water levels measured in the lab are used for calibration value for the 2D-modelling approach. Therein the clogging effects due to jammed wood are mimicked by a reduction of the cross section area in terms of lowering of the bridge deck and beam until water level simulations agree with the lab results (under steady state conditions). The flooding effects from the 2D-model simulations are checked for their sensitivity when dealing with different flood waves with equivalent peak intensity. The numerical model takes sediment transport in terms of a single-grain-size consideration into account.

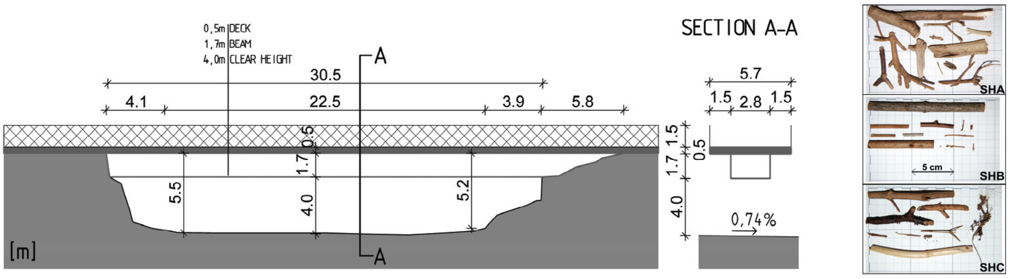

Fig. 1 Left: Bridge cross section (prototype dimensions in [m]), right: physical scale model (M = 1:45) – driftwood mixtures “SHA”, “SHB” and “SHC” (model dimensions) (Sendlhofer, 2010)

Main outcome of the study is to provide and test an extended approach to link lab tests and numerical simulations in the context of debris flow. In extend, the calibrated numerical model is used to evaluate the effects of log jam on flooding behaviour in the nearby settled area. Inundated area, flooded buildings and expectable damage respectively are compared to the situation without log jam.

RESULTS

Results from physical scale model for the bridge structure shown in Fig. 1 illustrate that the damming up effect strongly depends on the composite of the driftwood, the time duration of the input, the initial moment of jamming, on the flow conditions and the river topography upstream of the bridge.
Evaluation of flooding illustrates that the amount of water overtopping the banks is clearly higher for the log jam situation. However, damage of buildings and infrastructure in the flood plain depends on its topographic characteristics and on the location of the bridge structure. A log jam can either increase damage or lead to a reduction when flooding consequently occurs in a non-settled area. The effect is then similar to the one of a detention basin. Setting up an erodible river bed in the range of the bridge local scour leads to lower water levels and thus to less flooding.

REFERENCES

Bouska, P., Gabriel, P. (2009). Results of a research project on flood protection of bridges. In: 33rd IAHR Congress: Water Engineering for a Sustainable Environment, 2009, Vancouver. 6432 - 6438.

Gantenbein, S. (2001). Verklausungsprozesse - Experimentelle Untersuchungen. Diploma Thesis.

Lange, D., Bezzola, G. R. (2006). Schwemmholz - Probleme und Lösungsansätze. In: VAW - ETH ZÜRICH (ed.) VAW - Mitteilungen Nr. 188. Zürich.

Rimböck, A. (2003). Schwemmholzrückhalt an Wildbächen - Grundlagen zu Planung und Berechnung von Seilnetzsperren. In: Strobl, T. (ed.) Berichte des Lehrstuhls und der Versuchsanstalt für Wasserbau und Wasserwirtschaft. TU München.

Sendlhofer, A. (2010). Systematische Versuchsreihen zur Überprüfung der Verklausungssicherheit von Brücken. Diploma Thesis.

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