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Evaluation of building damage during the July 2021 flash-flood in the Ahr Valley (Germany)

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Heavy flash floods in Germany, which occurred in the aftermath of intense and long-lasting rainfalls (up to 150-200 l/m² within 48 h; CEDIM, 2021) in July 2021, led to serious damage to people, buildings and infrastructure. According to CEDIM (2021), the flash-flood caused at least 170 fatalities and 820 injuries. It is expected that it will take several years for buildings and infrastructure to recover from this catastrophic event.

The Ahr valley on the border between North Rhine-Westphalia and Rhineland-Palatinate (Germany) was particularly affected by the flood and was therefore selected as study area for in-situ investigations. These were conducted approximately one month after the event (August 17-19, 2021), and served to systematically assess the flood-induced building damage in nine villages. Damage was recorded on the basis of photos, flood measurements and personal conversations with affected residents (Korswagen et al., 2022).

In the aftermath of the survey, the information collected was used for describing the flood-induced damage in detail and to assess the processes that led to the structural failures. As key-findings, three main processes were identified as significantly accountable for flood induced damage to buidings:

- Hydraulic loads: The survey revealed that the water that penetrated the interior of the building neutralized the hydrostatic pressure acting from the outside. Nevertheless, hydrodynamic forces were present, leading first to damage to the facade and then to structural failure. Further damage was caused by different water levels around the buildings, which led to structural stresses due to an uneven distribution of the load.
- Scour and bank erosion exposed and undermined building foundations. Shallow-founded buildings adjacent to the river banks were the most vulnerable. Buildings on the outside and inside of river bends in particular need further attention in this regard.
- Debris: The effects of water-borne debris played a significant role during the flood, not only due to direct impact damage, but also because debris accumulated and became entangled, forming

debris-dams upstream of buildings. Accumulations at building openings resulted in increased impact areas and higher water-level gradients inside and outside of buildings, leading to significantly higher structural loads on buildings. In particular, it was noted that buildings located on the upstream part of the villages were more affected by debris accumulation.

Overall, the in-situ study highlights the importance of improving land use planning rules and guidelines, considering lessons learned from the July 2021 flash flood. Examples may include the need to reinforce buildings near river bends or in flood-prone areas with deep foundations, develop debris management plans that take into account the additional effects of debris during flash floods, and review, and if necessary, expand no-build zone regulations currently in place.

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