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Road Infrastructure Resilience to Debris Flow

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Abstract: The provision of safe, reliable and resilient transport networks is a fundamental requirement placed by society on those responsible for our transport systems. Resilience can be viewed at a number of levels ranging from assets, through links, nodes, and routes, to the networks and systems; each must be resilient in order to achieve the goal of providing resilient transport systems and mobility. In this extended abstract a personal view of resilience as it relates to road networks is given. Two case studies are presented to illustrate the potential challenges of both asset redundancy (or diversion) and recovery, the latter in terms of potentially complex governance. The presentation will extend this view to cover the all-important impacts of climate change.

Keywords: ***Debris flow, Road, Risk, Resilience***

Introduction

Road and highway infrastructure perform a fundamental role in ensuring the smooth and effective running of society. They provide a means to move goods in a timely manner and access to education, employment, health opportunities, and to social and leisure activities. Industries that tend to be particularly dependent on transport generally, and road transport specifically, include forestry, fishing, agriculture and tourism as well as manufacturing.

The provision of a reliable and resilient network is thus a key objective for governments and their transport and road authorities. Natural hazards such as inter alia landslides, floods and wildfires present major challenges to the achievement of this objective, and these challenges are significantly compounded in the light of ongoing climate change. In this context resilience can be defined as "the ability of assets, networks and systems to anticipate, absorb, adapt to, and/or rapidly recover from a disruptive event" (Anon, 2011). Reeves et al. (2019a, b) delivered guides to enhance resilience for road and rail and illustrated the components of resilience as the four Rs (Figure 1): redundancy, reliability, resistance, recovery.

In this extended abstract a short overview of some of the key challenges that face geotechnical engineers is given using case studies to illustrate key points.

Typically, the focus of engineers is on assets, and while this often considers how different assets interact at either a nodal or route level, the bigger picture is represented by the route or the network (Fiddes et al., 2024).

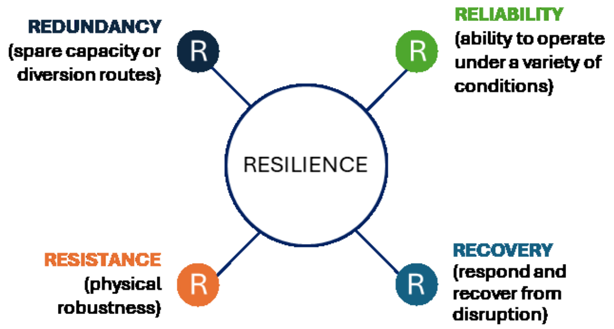

Figure 1, Resilience components (Reeves et al., 2019).

Case studies

Luib debris flow: Isle of Skye, Scotland

The Luib debris flow on the Isle of Skye in Scotland occurred on 30 September 2022 in response to significant rainfall of around 120 mm in the 11 hours prior to the event, with a peak 15-minute rainfall of 7.8 mm (i.e. an intensity of 31.2 mm/hr). The area is subject to high rainfall with a mean for the years 2002 to 2022 of 3,918 mm (minima 2,732 mm; maxima 4,983 mm). Details of the event and a detailed rainfall analysis are presented by Winter and Waaser (2024).

The debris flow blocked the road for slightly more than two hours after which the eastbound (downslope) carriageway was reopened to alternate one-way traffic controlled by traffic lights. The response to the event is an example of recovery (see Figure 1) but it does raise a few issues regarding redundancy.

The section of the A87 trunk (strategic) road in question forms a single link between the village of Broadford to the southeast and the junction with the A863 at Sligachan to the northwest, approximately 26 km. While there is no suggestion that a larger single event, or series of events, that may close the road for a longer period is likely, without a road-based, on-island diversion the question as to what would happen in such a case is relevant.

The potential diversion routes would involve both road and ferry routes via the Outer Hebrides, with between 142 km and 303 km by road and between two and three ferries with a sailing time of between five and six hours (plus waiting times). It seems clear that any longer-term closure in this area would cause major access issues for the largest settlement on the Isle of Skye, Portree, which is located to the north and west.

Kosova landslide: Bosnia and Herzegovina

The Kosova landslide occurred on 19 May 2014 following a prolonged period of heavy rain and flooding that caused significant disruption in Bosnia and Herzegovina and other parts of the Balkans. As of 20 May, an estimated 24 lives had been lost in Bosnia and Herzegovina as a direct result of the floods with a further seven people still missing. The rainfall was the highest in 120 years of recorded measurements.

The landslide is located on the west bank of the Bosna River, which forms the boundary between the Federation of Bosnia and Herzegovina and Republika Srpska. These two entities, along with the District of Brčko, form the country of Bosnia and Herzegovina.

The landslide is described by Winter et al. (2020) including damage and morphology, geology, future impacts, investigation and monitoring, and governance.

The Kosova landslide is a translational slide movement that covers a significant area. It has already caused considerable damage to the village and has rendered a significant number of properties uninhabitable; it would not be inappropriate to describe these properties as having been destroyed. It has also caused significant damage to the main road that runs near the postulated location of the toe. The Kosova landslide clearly presents a major operational risk for the M17 (E73) road and thus to the road authority.

Given the attendant risk to houses on the flood plain there is a case to be made that the Municipality and/or the Canton should be involved. The potential for damming the Bosna River should there be a substantial downslope movement, also brings both the River Basin Authority and the Civil Protection Agency into that forum. However, given that the Bosna River forms the border between the Federation of Bosnia and Herzegovina and the Republika Srpska at this location, any flooding (both upstream and downstream) would affect both the Federation and the Republika; it thus seems appropriate that the relevant agencies from the latter should also be involved. In this context consideration ought to be given to a national, Bosnia and Herzegovina, effort to monitor the landslide and to effect remediation risk reduction where necessary.

The damage to date significant as it is, is relatively slight compared to the potential for future damage. This clearly brings into play a need for a joined-up multi-entity and/or national approach to the investigation, monitoring and remediation of the Kosova landslide.

Closing remarks

The successful operation of a safe, reliable and resilient road network is challenging. Such challenges are significantly magnified by the ongoing process of climate change and its associated uncertainties. The increased frequency (and magnitude) of events such as landslides, debris flows and floods can rapidly lead to a situation in which the time required to recover from an event is greater than the interval between successive incidents leading to an inevitable reduction in resilience.

To achieve resilience a view that encompasses not only the asset but the links and nodes, the route and ultimately the asset must prevail.

Risk assessment can inform decision-making, including the allocation of budgets but also be an important tool for understanding and articulating issues surrounding resilience and the lack thereof.

As climate change progresses, we will experience extreme examples and although largely hypothetical in terms of its likelihood, the Isle of Skye case study articulates a ‘worst case’ scenario in terms of achieving resilience through redundancy. The example of the Kosova landslide in Bosnia and Herzegovina illustrates the challenges associated not only with the impacts of a potentially significant event but also the need for effective and appropriate governance.

There is an exciting and challenging road ahead.

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