Assessing the Internal Health of Earthworks for more Stable Infrastructure

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SUMMARY

We rely heavily on the earthworks that support our roads, railways and watercourses. If they fail it can cause loss of life, disruption to transport services and the expense of repair. As earthwork infrastructure ages and faces pressure from climate change, we need a fast and economical way to assess the earth.

Dr Shane Donohue from UCD School of Civil Engineering is researching seismic-wave-based technology to help major transport and infrastructure managers rapidly assess earthwork assets at scale. This will enable timely maintenance, reducing the risk of failure.

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Earthworks Under Pressure

When we take a train or drive on a road, we may not think too much about the embankments and slopes that we whizz by, but without them, the rail or road could fail. In many cases the earthworks that support transport structures are old – some may bear the wear and tear of more than a century – and the severe conditions of climate change such as droughts and floods can also put earthworks under stress.

Dr Donohue is developing and testing efficient ways to detect signs of trouble in earthworks or ‘geotechnical assets’ such as embankments, slopes, cuttings and dams that support railways, roadways and flood defences.

“The traditional approach has been to deal with the failure of such earthworks after they happen, but we want to detect issues in advance so we can avoid hazardous and expensive failures,” he explains.

In projects funded by the Engineering and Physical Sciences Research Council (EPSRC) and the NERC (UK Natural Environment Research Council) in the UK, Dr Donohue and colleagues have looked at using seismic waves to assess the condition of the earthworks along transport networks and flood defences.

“We transmit the seismic waves into the earthwork, then using geophones we can measure the velocity of the waves as they

travel through the structure," he explains. "We found that we could pick up changes in soil moisture and pore pressure, which are related to the stability of the structure, and use that information to build up 2D and 3D images to help identify where a failure could occur."

A Seismic Shift to Relieve a Growing Problem

Dr Donohue's research has opened up the previously underexplored option of using seismic wave technology for rapid and non-invasive assessment of earthwork stability. And rapid assessment is needed: in the UK rail network alone, it's estimated that around 5,000km of earthworks are in a poor or marginal state, and the annual costs of maintenance and dealing with failure run to tens of millions of pounds sterling.

"The stability of earthworks is a big issue for the transport networks and those who manage them, and it's only going to get more serious," explains Dr Donohue. "2012 was a particularly wet year and there were 144 Network Rail failures in the UK, with the knock-on effects of wider transport disruption. With climate change, we are expecting more extreme weather events as well as drier summers and wetter winters, which will put embankments under more pressure as they shrink in dry periods and swell in wet periods, causing more problems."

At the moment, earthworks are generally inspected visually, or by invasive site investigation carried out at individual points on the surface, but these have their drawbacks, notes Dr Donohue. "Looking at the ground surface, either by walking inspection or using satellites or aerial photography does not tell us about the internal condition of the earthwork, so it limits our ability to detect problems early on, and boring a hole into a single point won't tell you much about the geotechnical health of the rest of the asset," he says.

The benefit of the seismic wave-based method that Dr Donohue has researched is that it can **assess that internal structure and could be used to monitor and diagnose signs of problems across large expanses of earthworks**, not only for rail but for road networks and for water-retaining structures that prevent flooding too. "This is the advantage of this method," he explains. "It can assess the internal structure and stability of these geotechnical assets rapidly and on a large scale."

Protecting Critical Infrastructure

Being able to pick up the problem early will offset the cost – both human and economic – of dealing with the aftermath of a failure. As an example, Dr Donohue cites the breach of the River Douglas levee in Lancashire, UK, in 2015. "That happened because of a loss of internal stability, which could not be predicted using current risk assessment based on surface observations," he says. "The cost of initial emergency repair works to close the breach and subsequent reinstatement of the embankment were in excess of £2.5 million."

Dr Donohue moved from Queen's University Belfast to UCD in 2018 and is continuing to work with major infrastructure managers in the UK to validate the seismic-wave method for assessing stability. Several organisations are currently working with and assessing the technology, including Network Rail, Environment Agency, Canal & River Trust, Northern Ireland Water/Aecom and geophysical service providers RSK and Apex Geoservices. He is now seeking to extend project partnerships in Ireland and in China, where he is coordinating a dual degree in Civil Engineering Infrastructure between UCD and Chang'an University in Xian.

Dr Donohue's research into using seismic-wave methods for assessing slope and geotechnical infrastructure has **won awards**, including the European Association of Geoscientists and Engineers (EAGE) "Best of Near Surface 2014" and the 2017 "Telford Premium Prize" for best paper in the Institution of Civil Engineers (ICE) journal, Forensic Engineering.

"The research has opened a major opportunity for monitoring this critical infrastructure," he says. "Using it will save money by averting failure, it will spare the frustration and cost of disrupted services and most importantly it will potentially save lives."

Research References

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