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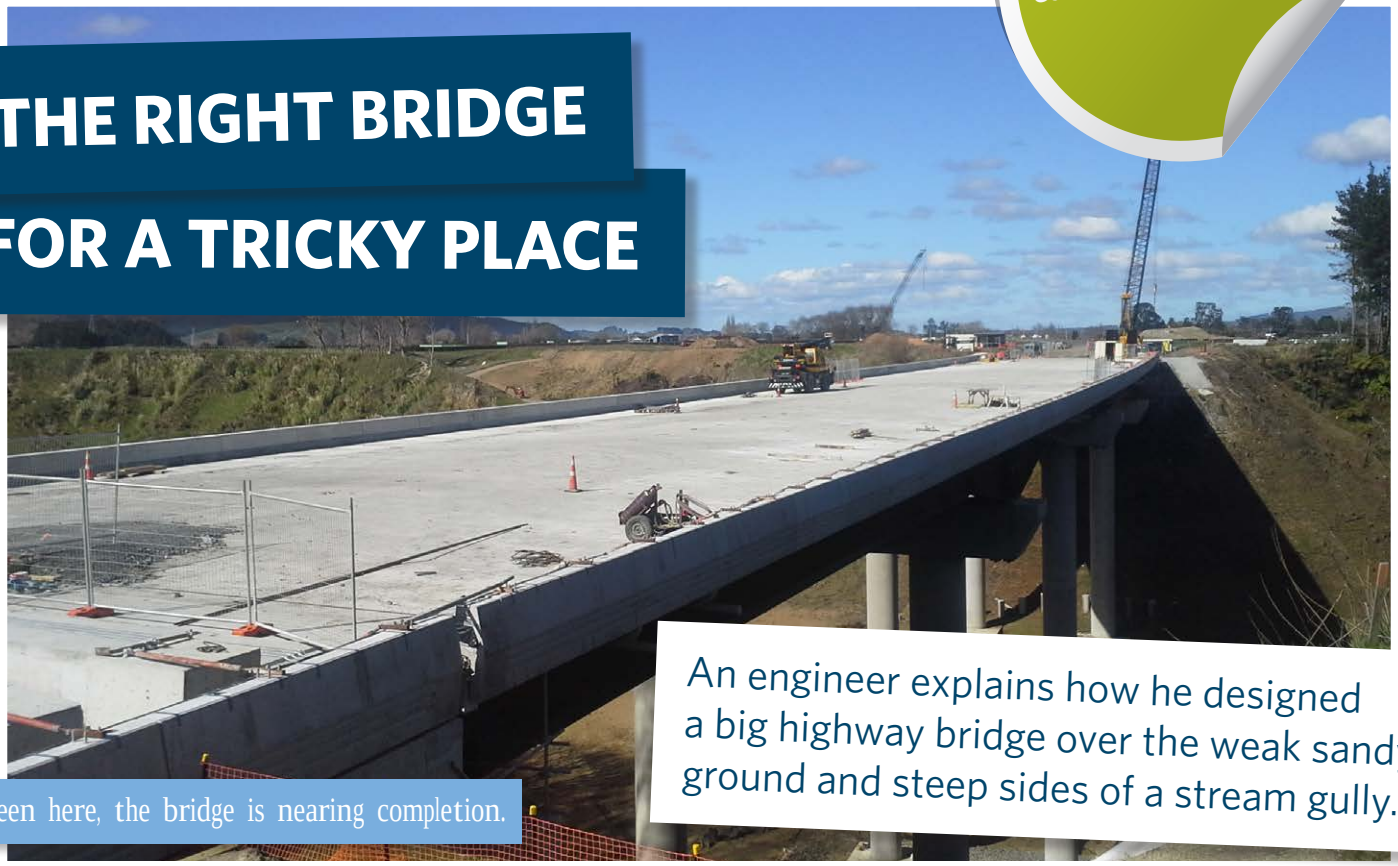
THE RIGHT BRIDGE FOR A TRICKY PLACE



Seen here, the bridge is nearing completion.

An engineer explains how he designed a big highway bridge over the weak sandy ground and steep sides of a stream gully.

The route for the Cambridge section of the Waikato Expressway has been marked down on planning maps since the 1970s. Finding where to put the road was easy, for the most part. The countryside is flat, good country for dairy farms, racehorses and long straight roads.

But on the eastern edge of town, the ground lurches down steeply to the Karapiro Stream. There's no way around it.

A stream may sound small but this stream has gouged out a very deep gully through the land. Getting a four-lane expressway across here was going to need a really big bridge. The bridge was in fact completed in 2015. It is called the Karapiro Gully Viaduct.

The bridge is 200 metres long and stands 40 metres above the gully floor. People driving over the bridge are almost as high up as vehicles on Auckland's Harbour Bridge.

Steel beams ready for placement The cargo containers give a sense of how massive each beam is.

HOW DO YOU DESIGN A BRIDGE?

Liam Edwards

Someone making a new phone or washing machine can build working prototypes and test them. But it would be really expensive, dangerous and quite slow to build full-size prototype bridges in a real place like the Karapiro Stream and then find a way to test which of your bridges stands up strong.

Liam Edwards is the engineer who designed the bridge and he explains what he did.

'Designing this bridge was done by modelling it on a computer programme. Plus we draw on our experience and knowledge of other bridges, including bridges from overseas.'

Plus, what engineers learn over the years about good bridges gets written down in documents called standards, codes and manuals. Liam read these as well.

He's 27 years old. He studied engineering at university. Karapiro is the biggest bridge he has designed so far.

Liam works at the engineering design company that won the tender for the Cambridge section of the Waikato Expressway, in partnership with a construction company. He and his colleagues brainstormed several bridge types for their design.

DECIDING ON THE BEST BRIDGE

'We looked at many different design ideas for the bridge,' he says.

The bridge could have had lots of columns holding it up, but some columns would need to stand on very steep slopes. It could be dangerous for construction teams to work on those slopes. The top of the bridge could be reinforced concrete. But concrete is heavy. It is difficult to keep a heavy bridge safe during an earthquake. A deck made of steel beams would be better – but what size and number of steel beams?

Liam settled on a bridge with three sets of columns and a mix of steel and concrete on top. It was not too heavy to hold up, and it used less steel than some other ideas. It was the simplest design to build, and diggers and cranes could stay away from the steep slopes.

Liam was hard at work on his computer for a long time to figure all this out.

'It took me around nine months full-time to design the bridge. It took me almost as long to design it as it took the contractors to build it,' he says, smiling.

"I represented the entire bridge structure as a 3-D model, which I can see on my computer screen. Every beam and every column is modelled."

On his computer, he set the strength and stiffness of each bridge part to simulate real-world materials like steel and concrete. This aspect of modelling is a bit like how blocks in Minecraft have different properties.

Next, Liam tested his virtual model, using the computer software to apply virtual loads that mimic the different things that would put strain on a bridge in real life. These loads include the weight of the bridge itself, the weight of traffic, and the impact of an earthquake. This testing helped him to know with confidence that the bridge would do the job once built for real.

WITHSTANDING AN EARTHQUAKE

Liam figured out how deep the bridge's 'legs' would need to go underground to keep the bridge standing strong. An earthquake could shake the sandy soils of the gully floor until they moved like a liquid. If the bridge rested on these soils, it could crack or fall over.

'Because the ground is so soft in the gully, you can't just put a concrete pad on the ground like you could do with a house. You need to put piles down to a stronger layer to support the bridge.'

In the end, steel piles were driven up to 55 metres deep into the ground to find dense sand for the bridge to stand on. This means even if the upper layers of loose sandy soil sloshes around in an earthquake, the bridge won't budge.

FROM THE DESIGN TO AN ACTUAL BRIDGE

Liam showed his bridge design to engineers at another company. This process is called peer review. The other team checked his design before signing paperwork to say they think the bridge will be safe and sound.

After construction began, Liam visited the Karapiro stream site to check the bridge was being built correctly. A crane lifted him high into the air so he could see high up.

'We were in a steel cage a little larger than a dining table. At the top of the crane's movement, we were 70 metres above the gully floor. You wouldn't want to be up there if you were afraid of heights,' he says.

Up high in the cage, he inspected the construction work, and got an early look at his bridge design coming together in real life.

Construction of the Karapiro Gully Viaduct, seen from the air.

THE STEPS IN DESIGNING THE BRIDGE

There were a few stages to the design process for the bridge

- Some years ago, specialists called geotechnical engineers drilled deep into the ground next to the stream to work out what types of soil and rock were there. They found weak sandy soils, with stronger ground far below. This would make it harder to build a strong bridge.
- The NZ Transport Agency sought a rough plan from an engineering company. This 'specimen design' gave everyone an idea of what sort of bridge was needed.
- The agency then invited companies to put forward their ideas for how to design and build the Cambridge section of expressway, which includes the bridge over the Karapiro Stream. This process of choosing a company is called a tender.
- The companies who won the tender made a final detailed design for the bridge, and a plan on how to build it.

In this aerial shot, all the columns are in place, and the first steel parts of the top structure are installed.

Very tall cranes were needed to lift steel beams from the gully floor up to the top of the bridge.

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