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FLOOD RESILIENT DESIGN & CONSTRUCTION

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Front Cover Image: Macleay River and Floodplain Bridge, Kempsey, NSW

Image Supplied by *Australian National Construction Review*

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The extreme rainfall and flooding events that decimated Australia's east coast in 2022 underline the importance of flood-resilient design and construction solutions that incorporate strong, durable materials like concrete.

In a world where extreme weather events are increasingly the norm, governments, regulators and homeowners are having to rethink the design and engineering of infrastructure such as roads and bridges, buildings and houses.

In Australia, many of our major towns and cities - both by necessity and design - were established on floodplains, close to water resources.

Over time, these urban centres have grown rapidly, in many cases outpacing development controls.

As a result, many of our cities, towns and infrastructure are today ill-prepared for the escalating impacts of climate change.
Even roads, bridges and houses constructed to contemporary engineering standards and codes have been seriously impacted by recent extreme weather events.

Extreme weather: the new normal

According to the Climate Council of Australia, climate change is driving sharp increases in both the frequency and severity of many extreme weather events.

In its 2022 report, **A Supercharged Climate**[1], the Council says the "rain bomb" that hit Brisbane and south eastern Queensland in March of that year saw around 60 per cent of the region's average annual rainfall occurring within three days.

That's the equivalent of almost the same amount of rain that London in the UK typically receives over an entire year.

The Council says the pattern of more intense rainfall events is now well established in Australia, with the intensity of short duration (hourly) extreme rainfall events increasing by 10 per cent or more in some regions over recent decades.

For each 1°C rise in global average temperature, the atmosphere can hold approximately seven percent more moisture. A warmer atmosphere also means there is more energy to fuel storms that generate heavy rainfall. These factors increase the likelihood of extreme downpours.

1. *A Supercharged Climate: Rain Bombs, Flash Flooding and Destruction, Climate Council of Australia Ltd, March 2022.*

Image: Turners Flat Replaement Bridge, Northern NSW (2022).

Image: Coffs Harbour Eastern Breakwall Project (2014).

What happens to bridges, roads and buildings, in a flood?

Across Australia, local councils look after an estimated 11,000 aging timber road bridges.[1] Many of these are poorly maintained due to a lack of funding, making them even more susceptible to flood damage. In addition to the dynamic force of the floodwaters, debris can cause significant damage to timber decks and safety barriers, while scouring of the riverbed can undermine foundations.

When it comes to roads, water is the natural enemy of asphalt and bitumen. It finds its way through cracks and into the road base, compromising the integrity of the pavement. In heavy rains, the damage shows up as potholes; in a major flood, entire sections of roadway can be washed away – or worse still, dangerous sinkholes created just below the surface of the pavement.

Most older houses aren't designed and built to withstand the record flood events increasingly experienced across Australia.

Apart from the destruction these floods cause to furnishings, floor coverings and household goods, the sheer force of water can cause damage to building foundations and walls, in some cases causing the house to shift from its footings and/or break up.

Structural damage becomes worse the longer water remains inside a building, where it can compromise timber frames, flooring and plasterboard walling.

1. *'Call for action on dilapidated bridges', Government Equipment News, 15 November 2018.*

Flood resilient concrete infrastructure

Physical flood barriers - such as levees, flood gates and seawalls - are a very important way to mitigate flood risk. Once again, the **structural integrity, strength and durability** of concrete lends itself to these more permanent mitigation solutions.

Roads are an essential lifeline before and after a natural disaster, yet they are typically among the first casualties in a flood or major rain event.

Concrete allows you to build strong roads with a service life of 40 years or more, withstanding extreme environmental and operating conditions as well as heavy traffic loads. The durability of concrete means that over its life a concrete road typically requires less maintenance, causing less disruption to road users.

In particular, concrete roads are less susceptible to potholes. In fact, independent lifecycle cost analysis modelling has shown that concrete pavements are a lower cost solution with respect to both construction and ongoing maintenance when compared with full depth Asphalt alternatives modelled.[1]

Concrete's durability and resilience also allows bridges to be designed to last for 100 years and beyond and stand up to the extremes of weather and climate, including flooding. Importantly, concrete offers a low maintenance solution over the design life.

Little wonder that more and more aging timber bridges around Australia are being replaced with strong, durable and sustainable concrete bridges.

1. *Life Cycle Cost Analysis, Concrete v Asphalt Pavements Arcadis, 15 November 2017. https://bit.ly/3X3rE0e*

CASE STUDIES - RESILIENT INFRASTRUCTURE

PACIFIC HIGHWAY, NSW NORTH COAST

Prior to 1975, the bitumen section of the Pacific Highway around Clybucca Flat, north of Kempsey, was plagued by repeated flooding and major maintenance problems.

In 1975 it was rebuilt using continuously reinforced concrete pavement, chosen for its stability, durability and relatively maintenance-free performance.

Today, this section of road is part of the Macleay Valley Highway, and continues in operation, exceeded its original design-life by 30-50 per cent, even under flood conditions.

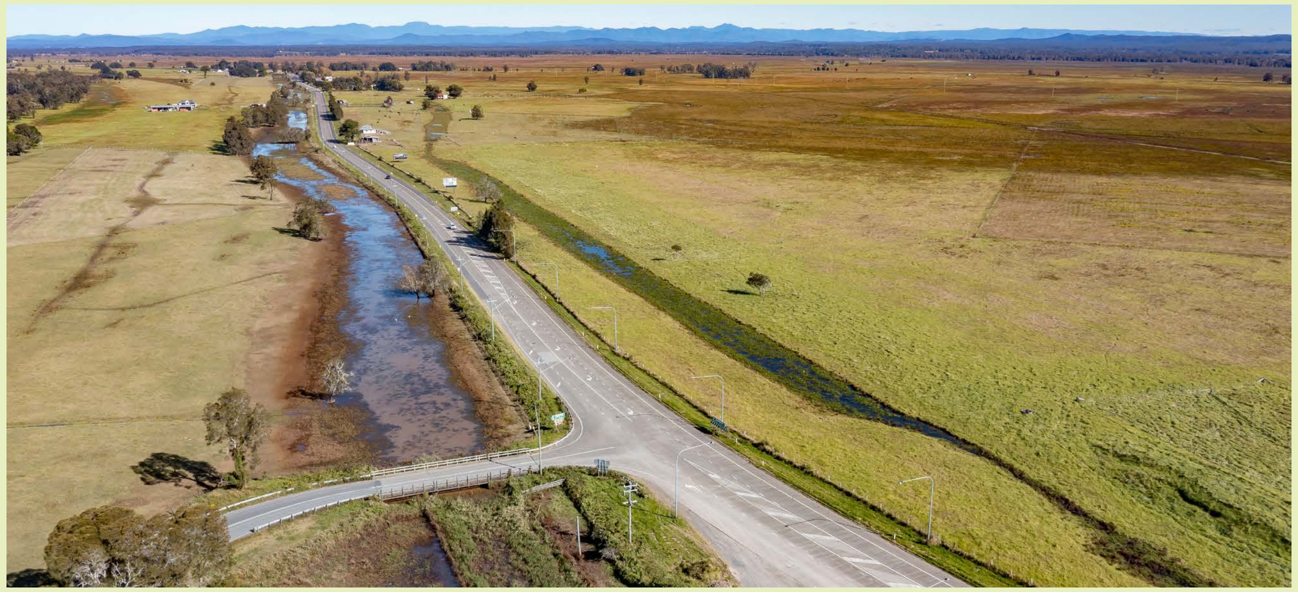


Image: Clybucca Flat (2022).

MACLEAY VALLEY BRIDGE

Completed in 2013 as part of the Kempsey Bypass project, the Macleay Valley Bridge passed a 'flood test' it faced in its first days.

The entire site was under water just four weeks before the contractor started piling in July 2011. In addition to another major flood in February 2013, there were four other lesser flood events during the course of construction.

Designed to cope with a 1-in-100-year flood, the 3.2 kilometre, four-lane bridge is constructed from pre-tensioned, precast concrete Super-T girders, supported on tapered concrete headstocks over twin concrete columns founded on piles. The bridge deck is cast in-situ concrete.

Pier heights across the floodplain vary between three and six metres, depending on the ground's profile.

The decision to use prefabricated elements to minimise site work paid dividends, with the bridge completed ahead of schedule in just 24 months. No mean feat for a structure that, at the time of its completion, was the longest road bridge in Australia.

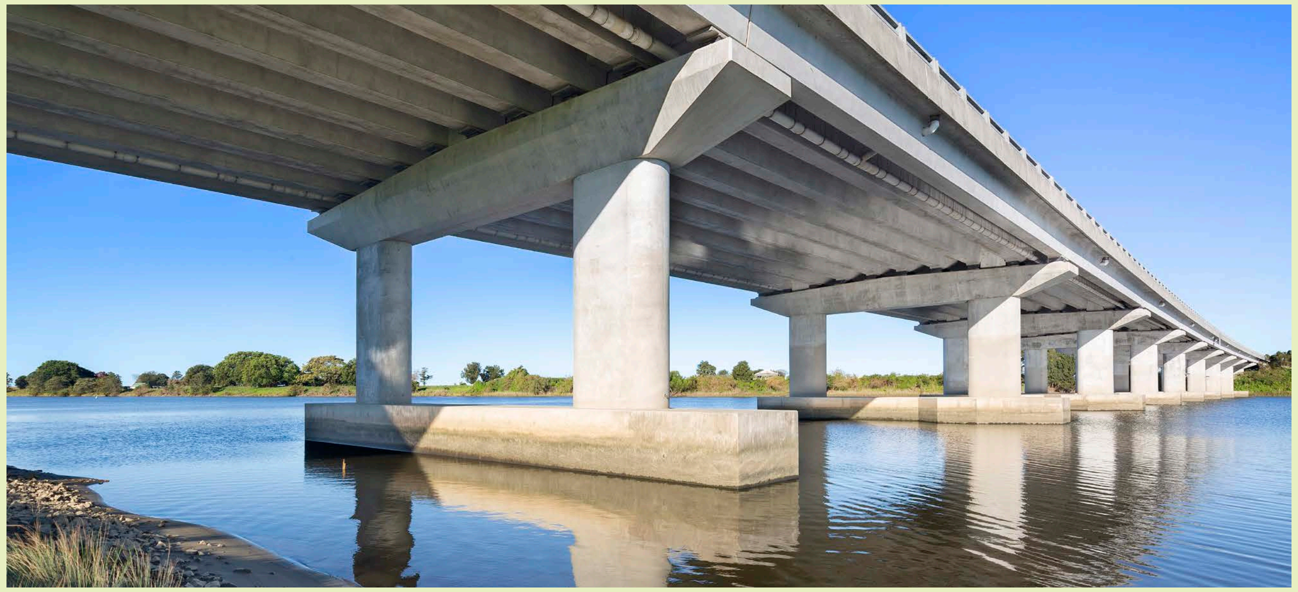


Image: Macleay River and Floodplain Bridge, Kempsey, NSW (2022).

CASE STUDIES - RESILIENT INFRASTRUCTURE

WINDSOR BRIDGE, NSW

The design and construction of the new Windsor Bridge in northwest Sydney created a dilemma for the NSW Government.

The cost of raising the height of a new bridge and its approach roads to something nearing 'flood-proof' would have been prohibitive.

Consequently, the bridge was designed and built to withstand a one-in-three-year flood, just 12 months more than the old timber crossing it replaced.

Since its completion in 2020, the bridge has been closed on a number of occasions due to flooding for periods of up to two weeks.

But because it's concrete, the bridge re-emerges each time it floods. So, when the flood waters recede the bridge can be put back into operation quickly without repair.

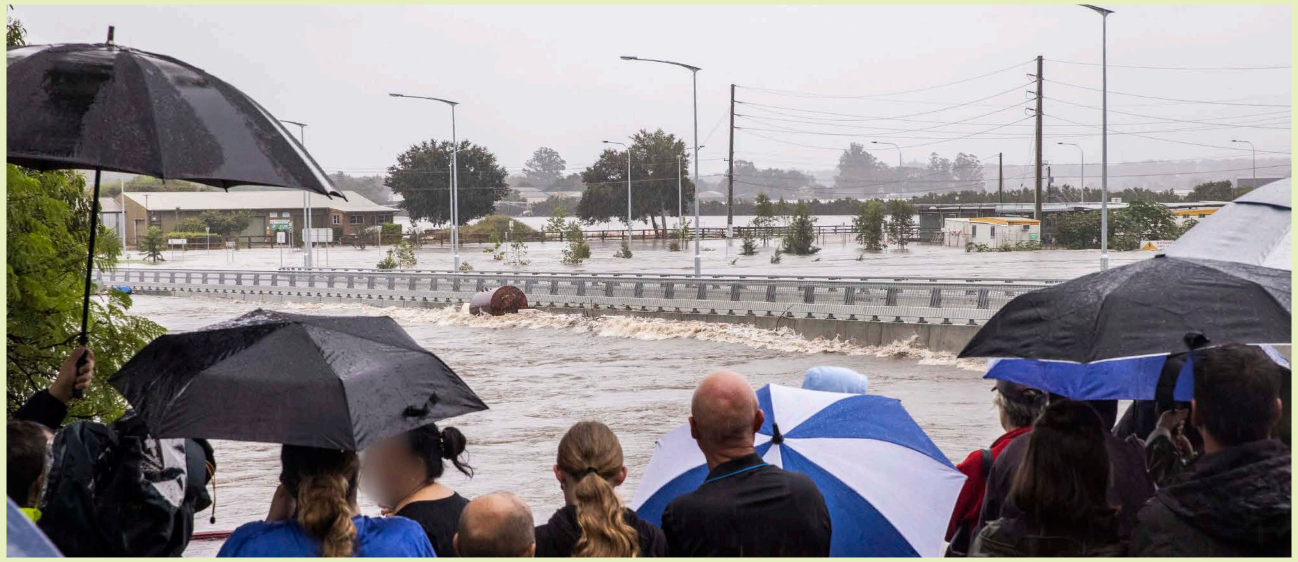


Image: New Windsor Bridge, major flood event (2022).

TURNERS FLAT BRIDGE, NORTHERN NSW

The replacement of the Turners Flat bridge over the Macleay River is typical of the challenge facing councils around Australia.

Built in 1913, the original timber structure was washed away in flooding in 1949. Its replacement - a 130-metre-long, 11-span new timber bridge - was closed for a lengthy period after two spans washed away in 2009.

Faced with an increasing maintenance burden, in 2017 Kempsey Shire Council applied for Commonwealth funding to build a new concrete bridge.

The 144 metre-long, six span bridge is constructed from pre-stressed concrete beams and concrete headstocks sitting on bored piles, with an insitu concrete deck.

Council still expects the new bridge to go under water a couple of times a year, but the big difference is that when the waters recede, it will still be standing and serviceable.

Image: Turners Flat Replaement Bridge, Northern NSW (2022).

CASE STUDIES - RESILIENT INFRASTRUCTURE

TCHANNING CREEK, DARLING DOWNS QLD

In 2021, the Queensland Government replaced an 82-year-old timber bridge on the Roma - Condamine Road with a new two-lane concrete bridge.

The new bridge is designed to withstand a 1-in-20-year flood and withstood its first major test within a month of completion. When the flood waters receded, the new bridge was unscathed.

According to the Department of Transport and Main Roads, the new bridge has significantly improved safety on this flood-prone road corridor by removing narrow points, improving road approaches and traffic flow, and better supporting heavy vehicle movements.

BRISBANE RIVERWALK

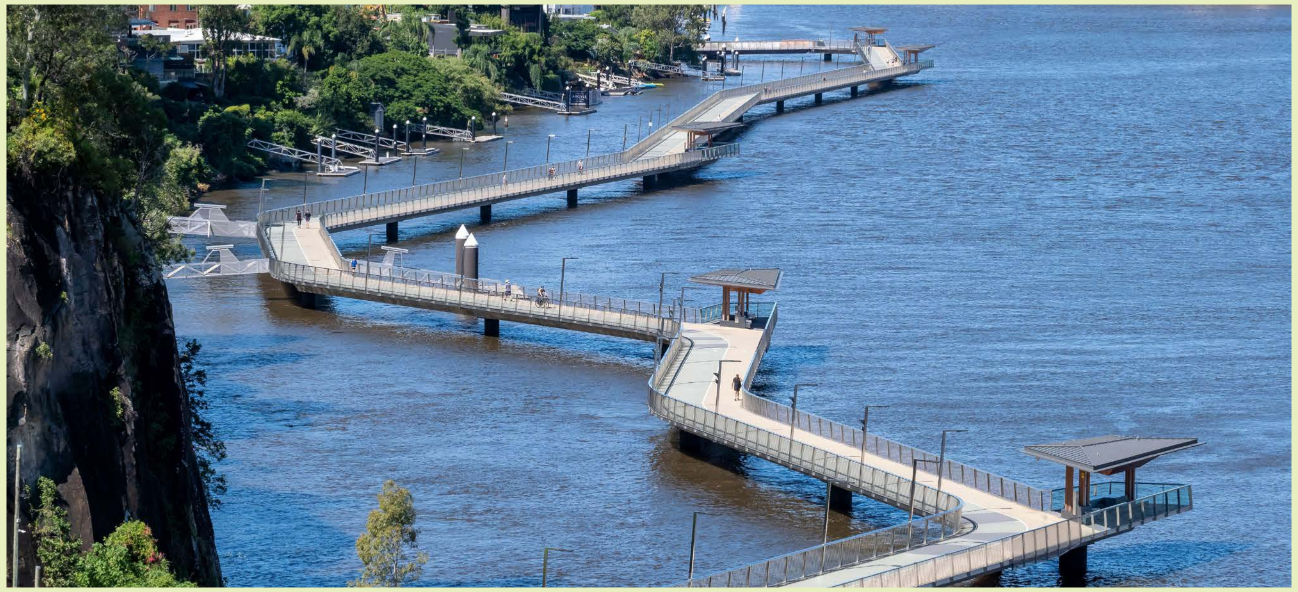
Anyone who has visited Brisbane has probably taken a stroll on the popular Riverwalk around the New Farm bend of the Brisbane River.

The original floating structure was swept away in the disastrous 2011 floods and replaced by a new concrete walkway, secured by concrete pylons bolted to the riverbed.

When the river again inundated parts of Brisbane in March 2022, many feared the new walkway would suffer a similar fate.

However, after two weeks the 870-metre-long concrete Riverwalk emerged from the floodwaters intact and was back in business after council workers removed mud and debris.

Similarly, a number of concrete structures along the river survived the catastrophic 2022 floods – a testament to their strength and durability in the face of fast-moving water and debris.



Why planning, engineering and good design is crucial

No one strategy or material solution can completely remove the risks associated with flooding.

The goal is to mitigate those risks by applying a range of strategies and solutions, within the bounds of what's affordable and practical.

It starts with good planning – understanding current and future risk factors and applying this knowledge to land use and development decisions.

How we design and engineer our buildings and infrastructure also plays a key role. Elevating a building, road or bridge is one obvious solution; so too is 'dry' floodproofing (sealing the part of the structure that's at risk of flooding) and 'wet' floodproofing (modifying the structure by replacing existing materials with more water-resistant ones and raising services and utilities to a high levels).

Another mitigation strategy is to build flood barriers - such as concrete floodwalls - around vulnerable buildings and infrastructure.

Choosing the right materials: concrete's role in flood-resilience

Concrete is widely recognised as a material that complements flood-resilient design, engineering and construction.

In fact, concrete structures are more resistant not just to flooding but other natural disasters such as bushfires, cyclones and severe storms – and that means the cost of reconstruction can be reduced and communities can recover more quickly.

Because concrete is inherently **water resistant**, it's ideal for footings and ground slabs. High density, high strength concrete mixes, as well as additives, can improve these water-resistant qualities even further to ensure the concrete structural elements maintain their integrity over time.

Concrete's **strength-to-weight ratio** also makes it more resistant to damage and movement caused by fast-running flood waters.

So, it stands to reason that homes built with concrete - be it used for floors, walls and/or even roofs – will be **stronger, durable** and **more resistant** to the impacts of extreme winds, storms and floods.

One of the first things to be ruined when flood waters enter a dwelling, for example, are floor coverings. Carpets and timber flooring usually need replacing, at great cost to the homeowner. A polished **concrete floor** not only looks great, but it it's much easier, faster and cheaper to clean up.

Image: Stamp House, Cape Tribulation, QLD. Charles Wright Architects. Photo: Patrick Bingham-Hall.
Set on 26 hectares of beachfront land in the Daintree Rainforest, Stamp House was designed as a cantilevered cyclone proof concrete structure over an engineered water eco-system.
The client had a strong desire to develop a sustainable and robust estate which would ideally operate as carbon neutral in its off-grid location. They had concern regarding the annual cyclone season and associated events such as storm surge associated with king tides.
The Concrete structure is ideal for the location due to its inherent long life cycle efficiency and material properties to deal with the harsh, corrosive wet tropical environment.

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