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Climate change impact and risks of concrete infrastructure deterioration

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ABSTRACT

Atmospheric CO₂ is a major cause of reinforcement corrosion in bridges, buildings, wharves, and other concrete infrastructure in Australia, United States, United Kingdom and most other countries. The increase in CO₂ levels associated with global warming will increase the likelihood of carbonation-induced corrosion. Moreover, temperature rises will increase corrosion rates. Clearly, the impact of climate change on existing and new infrastructure is considerable, as corrosion damage is disruptive to society and costly to repair. The paper describes a probabilistic and reliability-based approach that predicts the probability of corrosion initiation and damage (severe cracking) for concrete infrastructure subjected to carbonation and chloride-induced corrosion resulting from elevated CO₂ levels and temperatures. The atmospheric CO₂ concentration and local temperature and relative humidity changes with time over the next 100 years in the Australian cities of Sydney and Darwin are projected based on nine General Circulation Models (GCMs) under (i) high CO₂ emission scenario, (ii) medium CO₂ emission scenario, and (iii) CO₂ emission reduction scenario based on policy intervention. The probabilistic analysis included the uncertainty of CO₂ concentration, deterioration processes, material properties, dimensions, and predictive models. It was found that carbonation-induced damage risks can increase by over 400% over a time period to 2100 for some regions in Australia. Damage risks for chloride-induced corrosion increase by no more than 15% over the same time period due to temperature increase, but without consideration of ocean acidity change in marine exposure. Corrosion loss of reinforcement is not significant. The results were most sensitive to increases in atmospheric CO₂.

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1. Introduction

Infrastructure is a key component of human settlement that facilitates activities of the population via buildings, transport, energy, water, and communication. For example, following the pattern of population distribution and industrial activities, transport infrastructure has been concentrated near the cities of Melbourne, Sydney and Brisbane and along the south east coast of Australia—this region of Australia has a temperate climate zone. Key ports are distributed more widely around Australia and serve as important export functions for primary resources—some of these ports, including Darwin, lie in a tropical climatic zone. In fact, over \$1.1 trillion of Australia's wealth is locked up in homes, commercial buildings, ports and other physical infrastructure assets, which is equivalent to nine times the current national bud-

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E-mail addresses: mark.stewart@newcastle.edu.au (M.G. Stewart), xiaoming.wang@csiro.au (X. Wang), minh.nguyen@csiro.au (M.N. Nguyen). get or twice the GDP of Australia. Concrete construction is the predominant construction type for most critical infrastructure, and its performance is therefore vital to underpinning the nation's essential services and economic activities. Australia is not unique in this regard, as most countries including the United States, Canada and Europe rely on concrete infrastructure for their social and economic well-being, and face similar climatic characteristics to Australia.

Deterioration is regarded as one of the major factors that could significantly change the long-term performance of concrete structures (e.g., [1–3]). It is well-known that the deterioration rate not only depends on material compositions and construction processes, but also relies on the on-going climatic environment during the service phase of the structures' life cycle. Climate change may alter this environment, especially over longer terms, causing acceleration of the deterioration process, causing corrosion-induced cracking and spalling, which will result in more costly and disruptive repairs, as well as strength loss of concrete structures.

Decisions relating to infrastructure development, maintenance, replacement or refurbishment come with a long-term commitment and can have consequences for periods of 30–200 years or



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