Monitoring precast alkali-activated (geopolymer) concrete bridge with embedded smart aggregates: methodology and validation of performance indicators

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Alkali-activated concrete (also known as geopolymer concrete) has the potential to replace ordinary Portland cement concrete while reducing greenhouse gas emissions by converting various industrial by-products or waste streams into useful by-products. As a potential application scenario, geopolymer concrete can be used for precast bridge members under the conditions of standardized production procedures and a controllable casting environment. However, as a new material for construction industry, despite that much research has been reported in the literature on the material properties of geopolymer in lab conditions, knowledge or design guidelines concerning the behaviour of geopolymer in large-scale structural members with intricate stress distributions is still scarce. Moreover, its response to realistic long-term loading such as prestressing, self-weight, and traffic loading remains uncertain. These knowledge gaps hinder its wide application in the construction industry. To fill the knowledge gaps and promote the application of this material, an initiation was taken in the Netherlands to construct a precast geopolymer concrete bridge using the approach of design by testing. In the project, a precast geopolymer concrete bridge was designed and constructed, while concurrently conducting continuous lifetime monitoring and full-scale laboratory tests to obtain the missing information needed for the design process. As an essential part of the lifetime monitoring, performance indicators (PIs) of the precast beams based on critical structural behaviours are needed. In this paper, our primary focus will be on presenting the structural performance indicators for lifetime monitoring, which were acquired through the use of embedded smart aggregates in full-scale laboratory tests. These tests involve two prestressed geopolymer concrete beams and a solid deck consisting of three beams. These tests have led to identify three key structural performance indicators tailored for long-term monitoring of precast geopolymer concrete bridges: • PI 1 employs the coherency of elastic waveforms to specifically target the detection of crack initiation, which originates from the bottom fibre of the prestressed member. This serves as a means of assessing Serviceability Limit States (SLS). • PI 2 focuses on the identification of cracks that extend to the centroid of the prestressing strands. • PI 3 involves monitoring the formation of diagonal cracks within the shear-critical zone of prestressed beams, providing insights into the progression of shear failure.