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Influence of variations in concrete material properties on the serviceability of reinforced and prestressed concrete flexural members

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ABSTRACT

The effect of statistical variance associated with concrete material properties for different concrete mixes, curing conditions and ages are reported in this paper. The concrete mixes that were analysed are the commonly used Australian N32 and N40 mixes. Samples of concrete were extracted from concrete trucks on site to ensure that the concrete had been exposed to batching and transport processes associated with typical concrete supply. Curing times for test samples ranged from 7 to 28 days. The test frequency was significantly increased for testing samples at 7 and 28 days due to their importance as commonly referenced values in design. Variations of recorded material properties with respect to time and curing conditions are established via a statistical analysis. A Monte Carlo simulation, incorporating the statistical parameters of material properties as input, was applied to serviceability deflection predictions. A statistical prediction of member deflection was established and analysed depending on the variability of material properties. This paper presents an alternative approach to predicting deflections based on the variability that occurs with concrete material properties.

1. Introduction

Concrete is a structural material that exhibits a large variability in performance due to the environmental factors as well as the natural variability of its constituents. This variation in performance on site is due to factors such as placement, mix constituents, temperature and humidity [1–4]. The combination of these factors is unique for each construction site. To ensure safe and confident use of concrete, standards require test samples of a specific concrete to pass a required threshold. For concrete supplied in Australia, AS 3600 [5] defines this threshold, or characteristic cylindrical compressive (f'_c) and tensile strengths (f'_r), as the strengths attained at 28 days by 95% of the concrete. Other standards follow similar conventions [1,3,4]. An example of this statistical concept is shown in Fig. 1, where an assumed normal distribution of compressive strength is addressed. The mean compressive strength of this distribution is labelled as f_{cm}.

Reinforced concrete structural design commonly incorporates empirical equations to predict material properties such as the modulus of elasticity (E_c) and tensile strength (f_r) that are functions of the threshold f'_c. Examples of these models are given in Table 1. This method for predicting values of material properties for design is a simple and effective way of converting a probabilistic distribution into an easily applicable deterministic value. However, these deterministic values that are utilised in design are seldom compared to the distribution of in situ values to confirm the accuracy of this process for specific mixes of concrete. Furthermore, this method of converting a statistical distribution into a deterministic value can lead to predictions of serviceability behaviour, such as member deflections, which are not related to field measurements at all. Rather, they are simply related to the design characteristic compressive strength values (f'_c). Factors such as humidity, temperature and placement, which affect the magnitude and spread of the distribution, are not considered in design.

An experimental program was designed to examine the effects that concrete mix and curing conditions have on the statistical distribution of material properties. The material properties monitored in this research included compressive strength, modulus of elasticity and splitting tensile strength. The concrete samples for this research were obtained from a construction site in Adelaide, Australia, to ensure that the concrete had been exposed to batching and transport processes associated with typical concrete supply. Statistical relationships between these material properties were established and analysed. The experimental program incorporated test samples collected from the onsite concrete trucks, and hence two factors have been investigated as the main variables of this research: variability arising from batching and transporting concrete.

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