Evaluation of a minimum flexural reinforcement ratio using fracture-based modelling

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Abstract

Minimum reinforcement ratios are specified for reinforced concrete structures to provide enough ductility. The aims are to control cracking in the serviceability limit state and to prevent sudden failure by ensuring sufficient ductility after the loss of tensile stress in concrete due to cracking. This can provide a warning before collapse and time to take preventive or remedial measures. A review of past research reveals that there are large variations, and sometimes contradictions, in proposed minimum reinforcement requirements for flexural members. In this paper, a fracture mechanics-based model is used to study different local phenomena such as tensile and compressive concrete softening to more precisely describe the behaviour of reinforced concrete beams. The findings show a decrease in the minimum reinforcement ratio with increasing beam size. This contradicts the provisions of prevailing codes and standards which suggest no change in the minimum reinforcement ratio with size. Therefore, there is a need to review the minimum reinforcement provisions.

Keywords: Flexural reinforcement; minimum reinforcement; reinforced concrete, fracture, flexural crack.

1 Introduction

A minimum flexural reinforcement requirement is specified in most concrete codes and standards. These provisions are generally intended to control cracking in the serviceability limit state and to prevent sudden failure of structures that have a very small amount of tensile reinforcement by providing a reasonable ductility after the loss of tensile stresses in the concrete. This can provide warning before collapse and time to take preventive or remedial measures. A review of previous research on minimum reinforcement percentages reveals that there are significant variations, and some contradictions, in the results obtained. This may be attributed to two reasons: (1) the minimum reinforcement requirement can be a function of many parameters i.e. the concrete properties, the reinforcement properties, the interaction between the concrete and the reinforcement, the beam shape and size effects; and (2) the derivations of most minimum reinforcement formulae are based on empirical approaches. This has led to a certain controversy over the years. In this paper, a fracture mechanics-based model is used to study the ductility of reinforced concrete and, hence, to inform code provisions relating to minimum flexural reinforcement requirements.

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