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Design equation for predicting fire resistance of reinforced concrete beams

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ABSTRACT

An approach for evaluating the fire resistance of reinforced concrete (RC) beams is presented in this paper. A macroscopic finite element model is applied to study the influence of various parameters on the fire resistance of RC beams. Data from parametric studies is utilized to develop a simplified expression for evaluating the fire resistance of an RC beam as a function of influencing parameters. The validity of the proposed approach is established by comparing the fire resistance predictions with those obtained from finite element studies as well as from fire resistance tests. Predictions from the proposed equation are also compared with fire resistance estimates from current codes of practice. The applicability of the approach to design situations is illustrated through a numerical example. The proposed rational approach expresses fire resistance in terms of conventional structural and material design parameters, and thus facilitates easy evaluation of fire resistance. The proposed approach provides better estimates than those from current codes of practice and thus can be used to evaluate the fire resistance of RC beams with an accuracy that is adequate for design purposes.

1. Introduction

Reinforced concrete (RC) beams function as critical load bearing structural members in a building, and hence the provision of appropriate fire resistance is one of the major design requirements in buildings. The basis for this requirement can be attributed to the fact that when fire suppression and control systems fail, structural integrity is the last line of defense. The current method of evaluating fire resistance of RC beams is based on prescriptive approaches, and is usually a function of concrete cover thickness and beam width [1]. These tabulated fire resistance ratings specified in current standards are derived from standard fire resistance test data and do not account for critical factors such as load level, fire scenario and support conditions. Alternately, a detailed nonlinear thermal and structural analysis can be used, however this requires significant expertise and effort.

In lieu of tabulated rating and detailed analysis, simplified calculation methods can be applied for evaluating fire resistance of RC beams. This paper presents the development of a rational simplified approach for predicting the fire resistance of RC beams. The approach is derived based on a large set of parametric studies on RC beams and the analysis was carried out using a microscopic finite element model. The proposed approach accounts for critical parameters that influence the fire resistance of RC beams. The validity of the proposed approach is established by comparing the predicted fire resistance values with those obtained from numerical studies as well as from fire resistance experiments. The predictions from the proposed method are also compared with the fire resistance values obtained from ACI, Eurocode and Australian code provisions.

2. Research significance

The fire resistance of an RC beam depends on a number of factors including fire scenario, sectional characteristics, load level, geometric properties and support conditions. The current fire resistance provisions in codes and standards are prescriptive and do not account for many of these factors. The purpose of this study is to quantify the influence of these parameters on the fire resistance of RC beams and to develop a simplified approach for fire resistance design of RC beams under a performance-based code environment.

3. Current methodology

Provisions for evaluating the fire resistance of RC beams are generally specified in codes and standards such as ACI 216.1 [1], Eurocode 2 [2] and AS 3600 [3]. These provisions are based on standard fire tests, and thus they are prescriptive and do not

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