Engineering Structures 33 (2011) 1635–1642

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

The influence of travelling fires on a concrete frame

Angus Law [1], Jamie Stern-Gottfried [1], Martin Gillie *, Guillermo Rein

The BRE Centre for Fire Safety Engineering, The University of Edinburgh, UK

ARTICLE INFO

Article history:
Received 29 September 2010
Received in revised form
6 January 2011
Accepted 30 January 2011
Available online 16 March 2011

Keywords:
Travelling fires
Concrete structure
Design fire
Finite element
Temperature distribution

ABSTRACT

When building fires occur in large, open compartments they rarely burn uniformly across an entire floor plate of a structure. Instead, they tend to travel, igniting fuel in their path and burning it out as they move to the next fuel package. Current structural fire design methods do not account for these types of fires. This paper applies a novel methodology for defining a family of possible heating regimes to a framed concrete structure using the concept of travelling fires. A finite-element model of a generic concrete structure is used to study the impact of the family of fires; both relative to one another and in comparison to the conventional codified temperature–time curves. It is found that travelling fires have a significant impact on the performance of the structure and that the current design approaches cannot be assumed to be conservative. Further, it is found that a travelling fire of approximately 25% of the floor plate in size is the most severe in terms of structural response. It is concluded that the new approach is simple to implement, provides more realistic fire scenarios, and is more conservative than current design methods.

1. Introduction

Since the early 20th century, the Standard Fire test and associated temperature–time curve [1,2] have been used worldwide to give fire ratings to structural assemblies and to design complete structures [3]. The Standard Fire temperature–time curve was created in an attempt to regulate testing between different laboratories thereby ensuring a uniform standard of safety. However, almost as soon as it was conceived, a number of problems were identified with it. Notably, no account is taken of differences in fuel load, fire compartment size or ventilation conditions, all of which profoundly affect the behaviour of a compartment fire. To address some of these shortcomings, other temperature–time curves have been proposed. Perhaps the most widely known in structural design are the "parametric" fires curves. Initially developed by Pettersson [4], these curves have been modified and are incorporated into the Eurocode structural design standards [5]. They allow design fires to be calculated that, unlike the Standard Fire curve, depend on the fuel load, thermal inertia of linings, and ventilation conditions of a fire compartment. Parametric fires therefore predict more realistic temperature–time curves than the Standard Fire and can be roughly replicated by burning wooden cribs in a small fire compartment. Despite these benefits, parametric fires remain very crude representations of fires in any but the simplest of compartments, as will be described in Section 2. Moreover, they are unsuitable for application in the large, open-plan spaces that are a common feature of many modern buildings. Thus, there remain significant shortcomings amongst the traditional design methods for specifying the thermal inputs for use in structural fire design, particularly for large compartments.

By contrast, over the past 20–30 years, knowledge and understanding of how structures respond to elevated temperatures has developed rapidly and to a point where it is now possible to include a large variety of phenomena in structural models and to predict the response of structures subject to known temperature loading with good accuracy [6–8]. Coupled with the recently developed performance-based design codes [9,10], these capabilities have given engineers the freedom to design structures to resist high thermal loadings in innovative, efficient ways.

Thus, while the ability to predict subsequent structural behaviour has reached an advanced level; the thermal inputs used in structural fire design remain simplistic, unchanged, and not representative of actual fire dynamics in large compartments. The various limitations inherent in the traditional design methods mean that it is difficult to justify continuing to develop and use complex structural models when one of the dominating input parameters – thermal loading – remains very crudely defined. Without some development of the method for specifying design fires, it will be impossible to obtain the "consistent level of crudeness" which has been identified as a need within the discipline [11]. In an attempt to rectify the mismatch in the levels of sophistication that are currently used for design fires

* Corresponding author.
E-mail addresses: Angus.Law@arup.com (A. Law), Jamie.Stern-Gottfried@arup.com (J. Stern-Gottfried), M.Gillie@ed.ac.uk (M. Gillie), G.Rein@ed.ac.uk, reingu@gmail.com (G. Rein).
[1] Current address: Arup, Admiral House, Rose Wharf, 78 East Street, Leeds, UK.

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.01.034