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Fire Protection and Sustainability of Structural Steel Buildings with Double-Shell Brickwork Cladding

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Abstract

The proposed paper focuses on the research of sustainability of steel buildings in the case of a double-shell brickwork cladding, assessed under fire protection criteria and fire performance aspects. More specifically, it concerns an approach in designing and evaluating the structural components of energy-efficient steel buildings with regards to their fire performance. It is important to understand what the performance criteria are intended to be applied when selecting a particular material or method, including exposure to fire, duration, aesthetics, cost and maintenance. Application of insulating materials is one of the most common means of protecting structural steel members from fire. The knowledge and the practical outcomes about the fire resistance of the steel buildings with double-brickwork cladding have been derived on the basis of an estimation and evaluation of fire resistance of several construction details of the building's envelope. The study focuses on the thermal analysis of structural steel members, whose cross-section consists of the steel member core, the thermal and fire insulation and other layers. Because of the complexity that governs the equations describing the thermal phenomena, the structural detail models have been studied using finite element analysis. This is a thermal analysis that permits to quantify the response of the respective structural elements in terms of temperature with reference to time. The aim of the expected data is to evaluate the position of a steel member in connection with the double-shell brickwork cladding and promote those construction materials that are efficient under fire taking into account simultaneously their thermophysical, hydrothermal and environmental properties.

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Keywords: Building envelope; Structural Steel; Fire Protection; Insulating Materials; Double-Shell Brickwork; Thermal analysis

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Nomenclature

$f_{y,\theta}$	Effective yield strength of steel exposed at elevated temperature.
$E_{a,\theta}$	Slope of the linear elastic range of steel exposed at elevated temperature.
$k_{y,\theta}$	Reduction factor for effective yield strength of steel exposed at elevated temperature.
$k_{E,\theta}$	Reduction factor for effective slope of the linear elastic range of steel exposed at elevated temperature.
θ_a	Structural steel temperature.

1. Introduction

Passive fire protection is vital to the stability[1] and integrity of a steel-framed building in case of fire. Such protection is applied as a fire protection coat to the steel elements to enhance their fire resistance or is a common thermal and fire insulation material of the envelope. This research work focuses on the sustainability of steel-framed buildings, in the case of a double-shell brickwork cladding, assessed under passive fire protection criteria.

The use of insulating materials is one of the most common means of passive protection of the steel-framed elements (columns and beams) against fire. In this case the influence of all opaque construction elements of the building's envelope is worth to be considered and evaluated. The expected data of this research focus on and estimate the position of a steel-framed member in the external envelope under fire conditions and the outcome is significant in order to reduce the fire risk of steel-framed buildings.

2. Passive fire protection criteria of steel-framed elements

2.1. Passive fire protection and sustainability

Taking into account that temperature changes in the materials lead to changes in their properties and in particular, in strength characteristics, a fact that becomes obvious when temperature is significantly increase, the only possibility to obtain a passive control of steel section strength in fire is to protect it from thermal expansion by an appropriately chosen insulating material or combination of materials applied to the envelope (bricks, coatings etc.). More specifically, the passive fire protection of the building envelope configurations take into account the category of structural members, the type of the insulation materials, the varying thickness of insulation, the position of insulation, and the type/thickness of the assumed coatings. In addition, it is important during a fire event any passive protection system taken into account in the design of the envelope be adequately maintained.

The sustainability indicators of a steel-framed structure exposed to fire can be grouped under three elements of sustainable development. The first indicator relates the safety and the resistance of the structure, the second relates the impact to the society and finally the third relates the passive fire protection design to the environmental protection including life-cycle aspects of used materials. The impact of the first indicator is mainly influenced by two different levels of reliability, 1) life safety and no-collapse requirement and 2) fire resistance of steel-framed structure and damage limitation. No-collapse requirement impact means that the structural performance is evaluated to avoid local or global failure and collapse. On the other hand fire resistance impact means that the structural resistance is taken into account damage limitation requirements. This is an evaluation in respect to the limitation of use and the costs that would be disproportionately high in comparison with the costs of the structure itself.

2.2. Critical temperatures of steel elements exposed to fire

For the purposes of Eurocodes, fire resistance is the ability of a structure to fulfil its required function for a specified load level, for a specified fire exposure and for a specified period of time. For a given (thermal due to fire) load level, the temperature at which failure is expected to occur in a structural steel element characterized as the critical temperature where an effective yield strength $f_{y,\theta}$ is truncated to provide a yield plateau[4]. The relationship