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考虑分层效应的倾斜隧道浮力驱动通风流量预测模型

关键词

倾斜隧道；浮力流分层模式；自然通风流量；烟囱效应

摘要

在如隧道等倾斜狭长空间中，由于长宽比巨大，由浮力驱动的气流模式及其导致的通风流量与围护结构类建筑存在显著差异。本研究针对倾斜隧道内局部热源引发的浮力驱动通风流量进行了探究，通过理论分析并结合非等温/等温浮力源的三组实验（包括大尺度火灾实验、盐水-清水实验及氦气-空气实验），揭示了两种典型的浮力流态：分层流与充分混合流。实验证实温度升高的纵向衰减率及分层模式均与无量纲因子 η=B01/3ΔLsinα/(g0’1/2H3/2) 密切相关，该因子综合了浮力源特征参数与几何构型参数。分层流会导致烟囱效应衰减，进而降低通风流量。研究提出了针对此类空间的浮力驱动流量预测模型，重点考量了分层流态的影响。模型预测结果与实验数据验证吻合，证实了考虑分层所致烟囱效应衰减的必要性。该预测模型具有显式表达式，可为工程设计计算提供便捷工具。

Abstract

In inclined narrow and long spaces such as tunnels, the buoyancy-driven flow pattern and the resulting ventilation flow rate are different from those in enclosure-type buildings, because of their large length-to-width aspect ratios. In this paper, the buoyancy-driven flow rate induced by a localized heat source in inclined tunnels was investigated. Theoretical analysis and three series of experiments including non-isothermal or isothermal buoyancy sources, i.e., large-scale fire tests, brine-water tests and helium-air tests were performed. Two typical buoyant flow patterns were identified in the experiments, which are stratified and well-mixed patterns, respectively. Both the stratification pattern and the longitudinal decay rate of temperature rise were proved to be correlated with a dimensionless factor, η=B01/3ΔLsinα/(g0’1/2H3/2) , which is composed of characteristic parameters referring to both buoyancy source and geometrical configuration. The flow stratification results in stack effect attenuation and consequently ventilation flow rate reduction. A model for predicting the buoyancy-driven flow rate in such spaces was proposed, with special emphasis on the effects of stratification pattern. The predictions were validated with the experimental data, and the necessity for accounting for the stack effect attenuation caused by stratification was proved. The prediction model possesses an explicit expression and can thus provide a convenient tool for design calculations.

Keywords

Inclined tunnel; Flow stratification pattern; Natural ventilation flow rate; Stack effect

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