Influence of pedestrian grouping dynamics on evacuation efficiency in underground flooded stairs: a 3D numerical assessment

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Abstract

The increasingly recurrent urban floods pose significant risks to underground spaces and their users. Often essential in these scenarios, stairs present unique challenges during floods as they serve as pathways for evacuation and for the incoming water. With most of the prior studies focusing on studying a single individual, the impact of group dynamics on flooded stairs remains underexplored. This study addresses this gap investigating how these dynamics influence evacuation efficiency and safety through a 3D numerical analysis. This research introduces realistic human body dummies along the stairs to simulate various pedestrian arrangements under a discharge of 0.423 m ^{3}/s. Hydrodynamic forces and Momentum of Flow (MF) and Specific Force Per Unit Width (SFPUW) safety criteria are calculated to evaluate hazardous conditions. Pedestrian arrangements include a single individual at different positions, as well as tandem and side-by-side arrangements. Results revealed significant variations in the water-dragging forces based on positions and grouping dynamics. Notably, compared to isolated cases, side-by-side arrangements exhibited increased water-exerted force on both side-by-side and downstream individuals, while tandem configurations showed reductions in dragging forces on trailing pedestrians. The affectation of forces diminished when the separation between them increased. This study highlights potential bottlenecks, evaluates evacuation strategies, and provides insights to enhance safety protocols in underground infrastructure during flood events, contributing to urban resilience and flood risk mitigation strategies.

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