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Flood capacity assessment of confined masonry school buildings for education disruption assessment

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Abstract

Flood is one of the most common natural hazards that causes fatalities and significant disruption to human life, including to the education delivery through schools. Although the functionality disruption is significant, standing floodwater also causes lateral hydrostatic thrust on outer walls of buildings. This study examines the physical capacity of school buildings against flood loads by means of numerical modelling using Applied Element Method. Masonry buildings with varying levels of confinement are subjected to out-of-plane hydrostatic pressure, to assess the failure mechanisms and to estimate the lateral load carrying capacity, thus identifying the critical collapse depth of water. The study also looks at the effect of material degradation on the ultimate flood capacity. This result is further utilized to estimate physical and functional disruption to education delivery at schools.
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Keywords: Flood analysis; Hydrostatic loading; Applied element method; Confined masonry

1. Introduction/Background

Recurring floods disrupt education by causing physical and functional damage to school infrastructure [1]. The vulnerability of masonry buildings to flood loading depends on the characteristics of both the hazard and the exposed inventory [2,3]. Research into the capacity assessment of masonry walls and buildings [4,5] from flood loading is limited. This study examines the physical capacity of the masonry buildings to resist hydrostatic loads from the standing floodwater, by means of numerical analysis using applied element method (AEM) [6]. The functionality and accessibility losses are other significant concerns in the disruption assessment, which are dealt in more detail in [7]. Masonry school buildings with varying levels of confinement around masonry are modelled on the AEM platform, using material properties gathered from literature. Three index buildings- IB1, IB2 and IB3- with increasing design levels, defined in terms of the quality of connections and confinement, are chosen for a comparative discussion of their flood capacities. IB1 and IB2 have minimal confinement, with poor and good connections, respectively, at the interfaces of masonry and confining elements. IB3 has better connections as well as confinement. More details of these confined masonry buildings can be found in [8]. Together with the functionality loss, the physical flood capacity estimates of the school buildings can be used for assessing education disruption at schools, through probabilistic approaches such as Bayesian networks [7].

2. Flood analysis methodology

The loading scenario as shown in Fig. 1, is an extreme case of unbalanced lateral loading. An incremental flood depth analysis [9] is carried out by monitoring the lateral out-of-plane (OOP) deflection of the loaded wall panels, with each increment of floodwater height, until a definite partial or total collapse is observed. The collapse is defined by a large increase in displacement for a small increment of load. The analysis is repeated for a weathered model, where the lowermost 0.5m and the next 0.5m of the masonry are assumed to have 20% and 10% reduced properties, respectively, due to the degradation from repeated flooding, based on experimental studies by [10]. Such quantification is however, very limited in the literature.

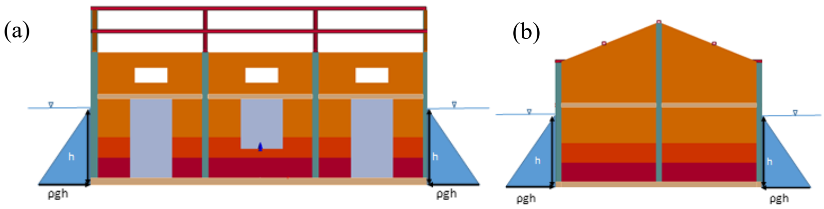

Figure 1. Flood loading scheme (a) front view; (b) side view

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3. Results of the capacity analysis

The lateral OOP deflection vs water height as obtained from the flood capacity analyses is presented in Fig. 2, along with the typical progression of cracking with the help of a skeletal model of IB2. Appreciable deviation from linear behavior is found above 0.5m, 1m and 1.5m for IB1, IB2 and IB3 models, respectively, where the cracks started developing in the mortar joints at the base of the long walls, as shown in Fig. 2a. The original models show an elastoplastic behaviour until the OOP deflection reaches about 15mm. However, in the weathered models, weakening of the lower courses of the masonry limits the elastoplastic capacity to a much shorter region. This is the region where the wall panels progressively develop open cracks as shown in Fig. 2b. Water heights above the elastoplastic range results in sudden drop in the OOP stiffness, leading to failure (Fig. 2c), which is in agreement with the experimental observations [5]. The collapse is governed by the local failure at the connection between the shutter frame and the masonry. The results compiled in Table 1 shows the influence of design level and material degradation. The critical collapse-depths of weathered models were on an average 20% lesser than that of the original models. This range is comparable to the assumed reduction rate of material strength, hence, suggests the need for reliable studies on material degradation from frequent flooding and drying. The results can be used to derive fragility functions and for probabilistic disruption assessment, combining the accessibility losses and use of schools as shelters [7]. The results could also be extended to residential buildings having similar typology of construction.

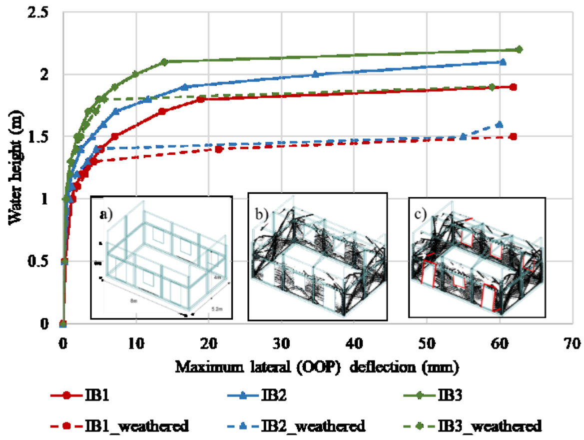

Figure 2. Flood capacity curves and failure progression stages (a), (b) & (c)

Table 1. Critical depth of water

Model	Original condition		
	Elastoplastic range	Critical depth	% increase w.r.t IB1
IB1- Poor Design	1.2-1.7	1.9	
IB2- Low Design	1.4-1.9	2.1	10.53%
IB3- Medium Design	1.5-2.1	2.2	15.79%
	Weathered condition		
IB1- Poor Design	1.1-1.3	1.5	
IB2- Low Design	1.2-1.4	1.6	6.67%
IB3- Medium Design	1.4-1.8	1.9	26.67%

4. Conclusion

This study addressed the gap in literature in the assessment of physical capacity of masonry buildings to flood loads, through numerical analysis using AEM and quantified the influence of design level and material degradation on the capacity of confined masonry walls to resist hydrostatic loads from the floodwater. There is approximately 8% and 21% improvement in the capacity as the design level improves from poor, to low and medium design levels, respectively. Similarly, the critical depths causing collapse of weathered models were on an average 20% lesser than that of the original models. The characterization of material degradation from repeated flood events is crucial in correctly estimating the global flood capacity of the masonry building. The study also illustrated the failure progression and mechanism, highlighting the need for numerical modelling approaches to capture the local and global behavior of masonry buildings, which can be further extended to fragility and disruption assessment of school systems.

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