Fire Safety Journal xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Fire Safety Journal

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

Safe evacuation for all - Fact or Fantasy? Past experiences, current understanding and future challenges

Karen Boyce

FireSERT, Ulster University, Shore Road, Newtownabbey, Co. Antrim, Northern Ireland BT37 0QB, UK

ARTICLE INFO

Keywords:
Disability
Mobility impairment
Evacuation
Refuge
Lifts/elevators
Escape route design

ABSTRACT

Statistics show that significant proportions of our global populations have a disability. Demographically we are an ageing and an increasingly obese society which, with increased accessibility, means that buildings are likely to be frequented by an ever increasing proportion of persons with reduced mobility. There is therefore a need to ensure that we can provide an accessible means of egress and a safe evacuation for all. Design guidance related to exit widths varies internationally but in the main has its origins in studies conducted with populations who were able bodied and fit. Furthermore the relationships between speed/density/flow used in hand calculations and computer models have been recognised as being outdated and not necessarily reflective of society today. This paper considers the evacuation of mixed ability populations in the context of increasing accessibility and changing demographics, reviews the basis for current design guidance and explores the design options for persons with reduced mobility. The current understanding of the evacuation capabilities of persons with reduced mobility is critically assessed and lessons from real evacuation experiences and other studies of mixed ability populations are drawn. In so doing, the sufficiency of current design guidance and challenges associated with implementing current approaches are considered and gaps in understanding and future research needs identified.

1. Introduction

The World Health Organisation (WHO) estimates that 15% of the world's population live with some form of disability and that this percentage will increase in the future due to aging and a global increase in chronic health conditions [1]. The establishment of access for all in the regulations of developed countries internationally means that building populations are now more diverse, spanning the spectrum of ability with respect to evacuation. Clearly, the traditional definition of means of escape as a "*structural means whereby a safe route is provided for persons to travel from any point in a building to a place of safety by their own unaided efforts*" [2] is insufficient for those who may access upper floors of a building using a lift, but may not be able to evacuate independently via stairs.

Internationally, means of escape is designed by adhering to prescriptive codes or following design guidance in support of functional regulations. In order to accommodate those with limited mobility, approaches involving the use of refuge areas, assisted escape and/or evacuation lifts are adopted in addition to traditional direct evacuation via stairs [3]. Additionally, in countries with functional regulations, design decisions are supported by safety analyses involving engineering calculations related to movement and the use of computer evacuation models [4,5]. The generalized nature of prescriptive codes has arguably necessitated the adoption of assumptions regarding flows and suitable flow times but these have their origins in research/events from many decades ago [6–8]. Furthermore, the most significant data sets used in engineering analysis of movement are derived from research conducted mainly between the 1950s and 1980s [9,10]. Indeed, the originators of what are considered the most significant North American data sets [11,12] have asked that their data be removed from future design guides stating that they are no longer applicable to building populations today [13].

In a context of increasing access and changing demographics, it is pertinent and timely to review our understanding of mixed ability evacuation and consider whether we are really providing safety for all. This paper will briefly consider access and egress provision in buildings, including the basis for current design guidance and evacuation options for persons with reduced mobility. It will consider the prevalence of disability and current demographic trends as well as current understanding of the evacuation capabilities of those with reduced mobility and the potential impact on flow dynamics. Experiences from real evacuations and studies investigating human factors associated with the use of refuges and options for vertical evacuation (assisted escape and lifts) will also be discussed. In so doing, the sufficiency of current design guidance and challenges associated with implementing current approaches will be considered and future research needs identified.

http://dx.doi.org/10.1016/j.firesaf.2017.05.004
Received 5 April 2017; Accepted 2 May 2017

2. Access and egress

Until the second half of the 20th century people with disabilities were discriminated against in relation to welfare and job opportunities; access to and within buildings was difficult and this in itself was a barrier to participation in society [14]. Access was perceived by many to be too difficult, largely because of the view that the benefits associated with proposed accessibility measures did not justifying the costs [15]. From the mid-20th century onwards, due to human rights movements, campaigning and lobbying of parliaments the social and political climates began to change. Comprehensive guides with respect to minimum standards in relation to access were produced, eg. [16], but their voluntary nature meant limited impact in the absence of legal enforcement [14]. In the UK, there was no legal obligation to provide access to buildings until 1987 when the Building Regulations [17] required that 'reasonable' provision be made for people to gain access to and use new buildings but it was not until 1991 that this extended to upper stories of public buildings, given concerns about the safe evacuation of people with disabilities from upper stories in the absence of guidance in this respect.

Concern for the life safety of people with disabilities in fire was first marked by a seminar held in Edinburgh in 1975 [18]. In 1979 and 1980, the newly formed National Task Force on Life Safety and the Handicapped, USA also organised conferences to address issues related to egress, emergency preparedness, education, and building design [19]. During the late 1980s standards committees and institutions eg National Institute of Standards and Technology, USA (NIST) and Building Research Establishment, UK (BRE), commissioned research into issues surrounding the evacuation of people with disabilities [20,21], recognising that traditional means of escape from upper floors. i.e. stairs was clearly insufficient in light of increasing accessibility. A useful chronological review of key meetings, events and literature related to procedures/technologies for people with disabilities during the period 1975–1988 is provided in [22], while an overview understanding and new research is presented in [21].

In 1988, BS 5588 Part 8: Code of Practice for Means of Escape for Disabled People [23] was published. Finally, there was recognition that persons with disabilities had the right, not only to access buildings, but also to be afforded what was hoped to represent equitable life safety options in the event of an emergency. BS5588 Part 8 (superseded by BS9999 [24]) recommended the use of refuges to temporarily accommodate persons with mobility difficulties, the use of appropriately designed lifts as a means of vertical evacuation and recognised the key responsibilities of management in developing and implementing evacuation procedures, i.e. concepts which are now accepted and integrated in many guidance documents across the world.

The introduction of the Disability Discrimination Act 1995 [25] in the UK (superseded by the Equality Act 2010 [26], and similar acts elsewhere, e.g. the Americans with Disabilities Act [27] and the Australian Disability Discrimination Act 1992 [28], were game changing with respect to the provision of equal opportunities for access to buildings and services. These regulations not only applied to new buildings but placed a responsibility on providers of existing buildings to make 'reasonable' adjustments to the premises [26] or make adjustments except where this would involve 'unjustifiable hardship' [28]. For the first time there was a real expectation that all buildings would be populated with persons with more diverse capabilities with respect to evacuation.

An accessible environment has been defined [29] as "*one which facilitates equal opportunity independently to participate in the full range of activities and responsibilities which define our society. It is an environment free of barriers which exclude, endanger or inconvenience those with acquired or inherited physical impairments*". This definition reinforces that the provision of access to and within buildings and the need to provide egress from those buildings, particularly in an emergency such as fire, are inextricably linked; indeed the need for accessible emergency egress has been identified internationally [30–32]. The nature of current design guidance with respect to escape provision, with examples, is discussed in the following section.

3. Current design guidance and performance based design

Although regulatory frameworks, codes of practice and design guidance vary internationally, recognition of the need to provide an egress system (travel paths and protected spaces) that ensure the safety of those exposed to fire is inherent across the globe. An excellent overview of the concepts, methods and strategies currently used globally in egress system design is provided in the recently published SFPE Handbook [8].

Internationally the general principles of escape provision are that there will be alternative means of escape from most locations, the distances of travel to a storey exit will be limited (and appropriate to the occupancy) and that sufficient exit capacity (storey exits, stairs and final exits) will be provided to allow the safe passage of occupants deemed likely to use them (based on occupancy load factors or actual design figures).

Detailed historical reviews of the evolution of emergency egress provision in relation to storey exit sizing and stair widths in both the US and UK have been presented previously [6–9]. Similarities have been noted across the globe [7], albeit that some stair widths are based on the number of occupants served on an individual floor whilst others are determined by the total number of occupants deemed likely to use them [7]. According to Pauls [6,11] the minimum stair widths proposed in US codes (44 in or 1120 mm) have their origins in work conducted in the early 1900s with underlying assumptions of flows of 45 people per unit width (22 in.) per minute. The current 44 in. minimum width is intended to support two 22 in (560 mm) queues of occupants either standing still or moving down a stair whilst allowing counter-flows, with the 22 in. (560 mm) lane dimension supposedly originating from work in 1914 representing the shoulder width of soldiers standing in line [8,11]. The choice of flows as a basis for recommendations were primarily based on a consideration of studies of movement of people in government buildings during fire drills and exiting railway terminals during rush hour [33]. Although the lane model was subsequently challenged (based on the work of Fruin [12] and Pauls [11]) and has been largely eliminated from building code requirements in the US over the last decades, it is still the most widely used basis for regulating minimum stair widths in the US today, albeit that a wider minimum exit stairs (56 in or 1425 mm) are recommended for certain high occupancy contexts to facilitate counter flow [13]. In the UK, current guidance for both storey exit sizing and stair sizing is based on the same historic evidence. The Post War Building Studies Report [34] which informed the development of guidance reviewed the rationale for codes developed in the US including the report by NBS [33] and considered the results of tests conducted in France in 1938 and 1945 [34]. Codes that followed were based on similar assumptions to those being developed in the US [7]. The current 5 mm/person exit width [35] is based on an assumption of an exit flow of 80 people/m/min and an aim to restrict the flow time to 2.5 mins (a time deemed acceptable following what was considered a successful evacuation of the Empire Palace Theatre, Edinburgh in 1911) [7,34]. Current guidance with respect to stairs adopts the same underlying assumptions with regards to flow in the stair whilst making assumptions regarding the holding capacity of the stair (between 2 and 3 persons/m^2) [7].

A basic tenet of building law is that access provision should be complemented by egress provision and it was in this vain that egress codes and standards started to address the needs of people with disabilities. Recommendations for the safe egress of people with disabilities, eg, [23] have been in place since 1988 and been addressed in design codes to a greater or lesser extent internationally since [8]. A recent study in Japan compares regulations, codes and standards of evacuation safety for 'physically challenged people' across 16 countries [36]. Such provisions recognise the temporary use of refuges for those who cannot use stairs and the need for assistive measures and/or