The Trouble with Mobility Scooters

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Abstract. A fatal accident in South Korea in August 2010 with a mobility scooter user was the first known mobility scooter fatality involving lifts. Products already exist which are said to be designed to withstand the forces exerted by mobility scooters. This paper examines the possible forces involved using actual measurements and video evidence, and compares the likely forces with the requirements for the strength of landing doors contained in EN81-2050 and 71. The conclusions of the paper include implications for designers, specifiers and owners of lifts.

1 INTRODUCTION

Mobility Scooters are the commonly used term for class 2 and 3 Invalid Carriages as defined by the Use of Invalid Carriages on Highways Regulations 1988 as amended 2015 [1]. The regulations consider that mobility vehicles are divided into three main categories. These include:-

- "Class 1 invalid carriage" which means an invalid carriage which is not mechanically
- propelled i.e. a wheelchair.
- "Class 2 invalid carriage" which means a mechanically propelled invalid carriage which is so constructed or adapted as to be incapable of exceeding a speed of 4 miles per hour on the level under its own power;
- "Class 3 invalid carriage" which means a mechanically propelled invalid carriage which is so constructed or adapted as to be capable of exceeding a speed of 5 miles per hour but incapable of exceeding a speed of 8 miles per hour on the level under its own power;"

Research carried out by the Research Institute for Consumer Affairs (Rica) [8] found that:-

Use of mobility scooters has increased significantly over the last 15 years and today there are thought to be over 350,000 units in the UK. The increase can be explained by the reduction in manufacturing costs making the retail prices more generally affordable as well as the emergence of a second hand market, and a growth of overall demand due to increased obesity and an aging population. The market is expected to continue to grow and we can expect more than 500,000 units by 2016.

Other key findings of the Rica research were:-

a) fewer than 10% of scooter users were aged under 45
b) 88% of users used the scooters within buildings.
c) Class 3 scooters made up only 35% of the survey sample.

Although incidents involving electric wheelchairs have been known for many years on lifts in hospitals and residential nursing homes mostly the focus has been on the damage to the lift rather than to the passenger.

There were fatalities involving the failure of lift landing doors in Shirley Towers Southampton in 2001[11]. In that incident two men fighting in a lift lobby fell against the landing door with enough force to push the landing door shoes out of the retaining slot in the sill or bottom track. This became commonly known as a "cat flap" incident. In a resulting prosecution the route cause was attributed by the Court to poor maintenance and the maintenance company was fined £400,000.

Soon after this incident pr EN81-71 appeared and for the first time a test procedure for the resilience of lift doors to impact by deliberate misuse was outlined in a European Standard. The full standard was published in 2005.

In Berlin in May 2010[10] Elzie G, a 66 year old diabetic amputee drove her mobility scooter at full speed into the landing doors of the lift in her apartment block. She had become unwell and was trying to get home to her medication. The landing doors broke free of the door shoes and she and the scooter fell in to the shaft falling about 5 metres. She was rescued by the fire service and survived the incident albeit with severe injuries.

In August 2010 in a South Korean shopping centre [9] Mr. Lee, a 40 year old Mobility Scooter user, tried to enter a scenic lift car whilst the doors were closing. At the time of impact the doors had fully closed and the impact could not have broken the landing door electrical interlock as the lift set off in the down direction. Mr. Lee placed a call on the landing call not realising that the lift was already in transit. Mr. Lee then reversed about 1.2 metres and accelerated his scooter into the doors. The landing doors were two panel centre opening of the stainless steel framed glass type and on the second impact the left hand door panel broke free of the landing sill and swung into the shaft. Not deterred by this Mr. Lee reversed about 1.5 metres before accelerating in to the landing door for a third time. On this occasion the left hand door panel also broke free of the landing sill and the momentum of the scooter pushed up both door panels and Mr. Lee, still aboard the scooter, fell about 6 metres down the lift shaft to his death. The Korean Police investigation held that Mr. Lee's anger was the main cause of the incident.

2 LAWS AND CODES

2.1 S.I. 2015 No. 59 The Use of Invalid Carriages on Highways (Amendment)(England and Scotland) Regulations 2015.

In March 2015 the limit on the maximum unladen weight of a Class iii invalid carriage was increased to 200kg to allow for the additional weight of medical equipment. The basic machine however is still limited to 150kg. Class i and ii invalid carriages are limited to unladen weight of 113.5kg

Class 2 mobility vehicles are designed to be used on pavements and class 3 vehicles are equipped to be used on the road as well as the pavement.

2.2 BS EN 12184:2014 Electrically powered wheelchairs, scooters and their chargers — Requirements and test methods(5)

This standard allows for a single passenger weighing up to 300kg (48 stones) but allows the designer to define the limit for each design and subject it to a suitable test.

Wheelchairs and scooter are classified in one or more of the following three classes, dependent upon their intended use: —

Class A: compact, manoeuvrable wheelchairs not necessarily capable of negotiating outdoor obstacles;

Class B: wheelchairs sufficiently compact and manoeuvrable for some indoor environments and capable of negotiating some outdoor obstacles;

Class C: wheelchairs, usually large in size, not necessarily intended for indoor use but capable of travelling over longer distances and negotiating outdoor obstacles. NOTE Scooters are included within the classes above.

The maximum speed allowed is 15km/hr (9.32mph)

It is therefore clear that there is little consistency between the constraints of UK law and the British and European Standard for these products. UK users of mobility scooters may be operating machines which do not satisfy the legal requirements for invalid carriages and may be breaking the law by using them.

3 FORCE AND ENERGY

Before considering the forces and energy applied by mobility scooters and the forces and energy lift doors are designed to resist under the EN81series of standards let us consider the requirements of other standards controlling the design of building barriers.

BS EN 1991-1-1 2002 [12] requires that balustrades around atria and building perimeters are tested by both pendulum shock tests and applied forces. The requirement for a balustrade is that it can withstand a force of 1.5kn per metre at a height of 1100mm and 1.5kn as a point load on an infill panel. BS 6180:2011 [13] also considers the effect of vehicle impact on barriers.

3.1 A worst case scenario

The worst case scenario is for a 200kg Mobility Scooter carrying a 300kg passenger hitting a landing door at 15km/hr (4.166 m/sec) energy on impact $=1/2MV^2 = 0.5*500* 4.166^2 = 4.39KJ$

$E=1/2\ mv^2$ formula (1)

Where:-

m = the mass of scooter and passenger

v = the rated speed of the scooter assumed to be the velocity of the scooter at the point of impact.

Under BS EN 1991-1-1:2002 barriers in car parks are required to resist the horizontal characteristic force F (in KN), normal to and uniformly distributed over any length of 1,5 m of a barrier for a car park, required to withstand the impact of a vehicle is given by:

$F = 0{,}5mv^2 / (c + b)$ formula (2)

Where:-

m is the gross mass of the vehicle in (Kg)

v is the velocity of the vehicle (in m/s) normal to the barrier

c is the deformations of the vehicle (in mm)

b is the deformations of the barrier (in mm)

If we apply this method to the mobility scooter's impact on a landing door and for example we assume it is a multi-panel door:-

The deformation of the door is limited by design to its clearance from an adjacent panel (usually 5mm).

The deformation of the scooter bumper itself can be ignored as it is a rigid component in most cases.

Then using formula (2) this mitigates the force to $0.5 * 500* 4.166^2/5 = 867N$ acting at 250mm above sill level.

From test results carried out by Thomas Lernet formerly of Meiller and currently head of R&D for door systems at Wittur [6] and the Author it is clear that the maximum acceleration is developed by the motor from start and peaks at 3.33m/sec^2. If the batteries were able to supply the necessary current this would be a worst case scenario of F=M*A = 500*3.333 = 1.66kN.

F= m*a formula (3)

Where:-

m= the mass of scooter and passenger

a= the maximum acceleration of the scooter at a point of impact

The impact of the bumper on a mobility scooter is approximately 250mm above the door sill over an area of approximately 400m2.

In theory these are the worst conditions that a lift door could face from a mobility scooter impact.

3.2 The Requirements of the EN81series of standards

Standard	Force (N) =m*a formula (3)	Energy (J) from pendulum test =m*g*h formula (4) Where: m= mass g=acceleration due to gravity h= height at release above bottom dead centre
EN81-20 without glass	Static force of 300 N, being evenly distributed over an area of 5 cm² in round or square section, is applied at right angles to the panel/frame at any point on either face they shall resist without: 1) permanent deformation greater than 1 mm; 2) elastic deformation greater than 15 mm; After such a test the safety function of the door shall not be affected. Static force of 1000 N, being evenly distributed over an area of 100 cm² in round or square section, is applied at right angles at any point of the panel or frame from the landing side for landing doors or from the inside of the car for car doors they shall resist without significant permanent deformation affecting functionality and safety (See 5.3.1.4 [max. clearance 10 mm]	45*9.81*0.8 =353J applied 1 metre from sill level.
EN81-20 doors with glass	As above	Hard pendulum m.g.h = 49.05 J

EN81-71	As above	Category 1 309J Category 2 442J Retaining force 618J

EN81 does not address or consider the scale of forces applied by mobility scooters or other causes of heavy impact in the way that BS EN 1991does. This means that the balustrade adjacent to a lift in a shopping mall will be more likely to resist mobility scooter impact than the lift doors themselves.

3.3 Reasonably anticipated forces and energy

To be pragmatic in the evaluation of likely forces and energy applied to lift doors by mobility scooter impact the following assumptions could be made

Many lifts are installed in buildings where it will not be possible to accelerate from rest to maximum speed. Therefore if it is unlikely that the straight line acceleration distance is more than 2 metres, the maximum speed is unlikely to exceed 1.4M/sec. This assumption is based on research carried out by Thomas Lernet using high speed video cameras to measure the distance covered by a loaded mobility scooter in fixed time intervals. The findings were corroborated by measurements taken by the author using a Henning tri-axial accelerometer. If a landing door is so placed to be at risk of a high speed collision other measures may need to be considered by either the lift designer or the building designer.

Most Class 3 mobility scooters currently sold in the UK have a maximum weight of 120kg and a maximum passenger load set by the designer of 220kg giving a total load of 340Kg.

The maximum likely force using formula (3) is therefore 340 * 3.333 = 1132N. This is only slightly greater than the static force required in EN81-20 1000N over 100cm^2

The maximum energy is therefore $0.5*340*1.4^2 = 333$J which is only slightly more than the force required under EN81-71 category 1 and less than the retaining force 618J.

Wittur have patented a system for testing lift doors for mobility scooter impact which assumes a combined scooter and passenger weight of 220kg. In the UK as previously stated many mobility scooter users weigh in excess of 75-100kg and so the test weight may not be adequate. However the test methodology used by Wittur is appropriate and could be easily adapted as it allows a single test rig to verify that both force and energy applied in mobility scooter collisions are adequately dealt with by the door design.

4 IMPLICATIONS FOR DESIGNERS

4.1 Risk Assessment.

To follow the methodology of BS EN ISO 14798 [7] the consequence of an accidental impact of a mobility scooter at high speed (like the Elzie G incident cited earlier) is foreseeable in a residential building for the elderly. It has a level of probability somewhere between remote and highly improbable (level D and level E). The level of harm is undoubtedly high (level 1). This means that some form of protective action is required. In public access buildings particularly those which allow a longer acceleration distance in long corridors such as shopping centres (like the Mr Lee incident) and hospitals there is a greater probability of impact incidents with forces and energy greater than allowed for by EN81-20.

In the case of Mr Lee there were two simultaneous acts of imprudence:-

a) repeated attempts to ram the lift doors
b) repeatedly running the scooter on high speed inside a building.

Under the assumptions of EN81-20

“0.4.9 A user may, in certain cases, make one imprudent act. The possibility of two simultaneous acts of imprudence and/or the abuse of instructions for use is not considered.”

A point for further consideration may be (taking this case in mind): has a designer done enough by complying with EN81 to satisfy his or her duty of care? Indeed building owners should consider whether mobility scooters can be used within a building that contains lifts

4.2 Implications for lift door design

Lift doors and lift cars have improved impact resistance under EN81-20 but as has been shown this is not quite enough to protect against low speed mobility scooter impact. Sematic, Meiller, Wittur, and Fermator, all have existing products developed for EN81-71 Category 2 applications. Meiller has developed these products further to resist mobility scooter impact and this was demonstrated at Interlift 2013 and there are testing devices that have been developed to verify door performance.

There are some simple changes all manufacturers can make which can improve the impact resistance:-

a) Use of stainless steel or cast iron door sills.

b) Improved strength of door shoes and fixings to door shoes.

c) Retaining plates located in between the door shoes to prevent the door panel from cat flapping.

d) Use of 2 panel side opening door arrangements which provide greater impact resistance at the centre of the door entrance.

e) Use of spring fixings to allow temporary deflection of top tracks and sills to dissipate impact energy.

NB The rear walls of single and adjacent entry lift cars will also need to be suitably strengthened.

4.3 Implications for mobility scooter design

Mobility scooters main braking is by the retardation provided by the motor when disconnected from the battery. Operator error and unintended operation of controls (by shopping baskets etc.) are common and predictable events. It would be inexpensive and would greatly improve safety if proximity sensors were fitted as standard to all Class iii scooters and as an option on Class ii scooters.

The spirit of the UK legislation which requires a device to limit a Class iii scooter to 4 mph except when on the road is being flouted. All that is normally supplied by manufacturers is a separate switch for high speed operation which many scooter passengers use as their default speed. A greater safeguard is required if further accidents including those not related to lifts are to be avoided.

4.4 Implications for Building Designers, Managers and Owners.

Can the building reasonably refuse access for mobility scooters? If so this is a simple building management solution.

If not is the lay out of the lift such that it is possible to have a straight line journey greater than 2 metres and impact the landing door panel at any landing? This is likely to apply to most hospitals, shopping centres, supermarkets, large retail outlets, Airports etc. In these cases consideration should be given to either:-

a) Creating a lift lobby to reduce the risk of full speed impact or

b) Improving the resilience of any applicable landing doors to the parameters suggested in 3.1 above.

NB in the buildings cited above other vehicles such as luggage carts, food trolleys, portable X ray machines, pallet trucks etc. may also present risks in the same environment.

5 CONCLUSIONS

With the growth of mobility scooter usage inside buildings the risk of accidents increases, albeit from a very low base.

Usage of mobility scooters is not currently restricted in the UK by capability or improved by training and the registration system for Class iii scooters is ineffective. The UK government is not minded to tighten laws but to the contrary has recently relaxed them.

The UK has an aging population and one which is becoming increasingly obese. All of this means that the frequency of risk is increasing and in the circumstances identified appropriate control measures are required for all lifts.

Laws and Standards do not address the issue so it is for specifiers, designers and building managers to assess the risks on a site specific basis and adapt designs appropriately.

In buildings where space does not permit mobility scooters to accelerate to an impact speed of more than 1.4m/sec (have more than a 2metre run up) doors manufactured to EN81-71 category 2 should be sufficiently robust to prevent door failure.

In buildings where space permits mobility scooters to accelerate to an impact speed of more than 1.4m/sec additional measures are required to prevent further fatalities.

REFERENCES

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[4] BS EN81-71 Safety rules for the construction and installation of lifts. Particular applications to passenger lifts and goods passenger lifts. Vandal resistant lifts.

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[7] BS EN ISO 14798 Lifts (elevators), escalators and moving walks- Risk assessment and reduction methodology.

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[12] BS EN 1991-1-12002 Eurocode 1: Actions on structures Part 1-1: General actions, Densities, self-weight, imposed loads for buildings.

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See also http://www.gainesville.com/article/20080607/NEWS/854300487 details of an earlier incident in the USA in 2008.

BIOGRAPHICAL DETAILS

Michael Bottomley joined MovvéO Ltd. formerly Lerch Bates Ltd. in 2002 after working for Gregson & Bell Lifts for 21 years. He holds a degree, with honours, in Engineering and Marketing from the University of Huddersfield, and has over 34 years' experience in lift engineering and lift design. In 1999 he was the second lift designer in the UK to achieve Notified Body approval under the Lifts Regulations. He is a member of the International Association of Elevator Engineers and a Past Chairman of the CIBSE lifts group.