What Designers, Builders and Code Officials Should Learn About Stairways and Falls

Presentation by Jake Pauls, CPE

Falls and Mobility Network Meeting
Sunnybrook Health Sciences Centre
Toronto, ON, May 10, 2010
This is based partly on a presentation:

**Stairway Usability and Safety:**
Use by individuals in homes and other buildings

Half-Day Educational Presentation by Jake Pauls, CPE
at OAA Continuing Education Conference
Windsor, ON, May 7, 2010
Outline for OAA Continuing Education Session:

1. Introduction
2. Acknowledgements
3. Terminology and Epidemiology
4. Economics and Ergonomics
5. Introduction to model building code grading
6. Key factor of visibility
7. Key factor of geometry
8. Key factor of handrails
9. Special stairs
10. Home stair geometry
11. Home stair railings
12. Home design codes and the double, lower standard
13. Litigation-related and other inspection techniques
14. Good and bad examples
15. Summary
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Outline for OAA Continuing Education Session:

1. Introduction

Goals of Presentations and Discussions

By the end of the session you will have

A. A clear appreciation of how big the problem of stairway safety and usability is relative to other problems addressed in building codes.

Section 3, Terminology and Epidemiology, deals with this, as does Section 4, Economics and Ergonomics.
Based on CPSC/NEISS National Estimates, 1974-2006

What Designers, Builders & Code Officials Should Learn About Stairways & Falls

Annual Estimates: Stair-Related ER-Treatments

Year


0 200000 400000 600000 800000 1000000 1200000 1400000

Stairs

Fire
Over the last few decades the number of stair-related injuries in the USA grew by a factor of two—a greater growth than of population.

At the same time, fire-related injuries were reduced by half.
The trend is not explained by age effects.

Nearly $200$ billion excess total injury cost.
Comprehensive Costs of Stair-related, Nonfatal Injuries for the Year 1995 in the United States (in 1997 US dollars)

Medical costs 4.7 billion
Productivity losses 7.1 billion
Quality of Life losses 38.1 billion
Total Costs 49.9 billion

Factor of ten

Source: Ted Miller and colleagues
National Public Services Research Institute
Landover, Maryland, USA
### 50-year Benefit-Cost Analysis by Pauls
For New Homes Built in USA in 2000

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of new home stairways</td>
<td>US$800</td>
</tr>
<tr>
<td>Added cost if “7-11” stair geometry used</td>
<td>$250-980</td>
</tr>
<tr>
<td>Medical care cost for new-stair related injuries</td>
<td>$3000</td>
</tr>
<tr>
<td>Comprehensive cost of new-stair related injuries</td>
<td>$30000</td>
</tr>
<tr>
<td>Usability benefit for all new-stair users (@$0.002 per use)</td>
<td>$2000</td>
</tr>
<tr>
<td>Total usability benefit for certain elderly users of new stairs with “7-11” step geometry</td>
<td>$7000</td>
</tr>
</tbody>
</table>
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1. Introduction

Goals of Presentations and Discussions

By the end of the session you will have

B. A detailed understanding of three key sets of environmental factors contributing to reasonably safe, usable stairways.

Sections dealing with this: 6, Key Factor of Visibility; 7, Key Factor of Geometry; & 8, Key Factor of Handrails
Visibility of Stairway

Steps that can be reliably seen when approaching and using the stair
Stairway Visibility

Involves more than lighting and illuminance measurement
Stairway Visibility Is an Issue of Context

What Designers, Builders & Code Officials Should Learn About Stairways & Falls
As we age, glare is a growing problem that causes loss of detail in shadowed areas.

- Change layout or window treatment
Air Step Site at Two Steps in Hotel Lobby

Handrail, marking and sign might not be sufficient mitigation.

This is not a good place to have steps.
Evidence for Environment-Based Fall Prevention

Mis-marked stair step nosings

- The often seen recommendation to mark the top and bottom steps in a stair flight does not go far enough and is dangerous.
What Designers, Builders & Code Officials Should Learn About Stairways & Falls

Outline for OAA Continuing Education Session:

1. Introduction

Goals of Presentations and Discussions

By the end of the session you will have

C. Rationale to prioritize inspection goals in relation to stairways.

Sections dealing with this: 4, Economics and Ergonomics; 6, Key Factor of Visibility; 7, Key Factor of Geometry; & 8, Key Factor of Handrails.
How do stair-related injuries occur?

What are the scenarios?
Step geometry-related scenarios accounted for about 54% of the million or so estimated falls occurring each year in the United States.
Researchers estimated that about 35% of all of the million falls would be preventable with “7-11” (180 mm rise, 280 mm run) step geometry.
Many Falls Due to Step Geometry: Increased Risk with Smaller Runs

### Risk of falls on home stairs with various run or going sizes

Risk estimates derived from Wright and Roys (2008) Figure 4

<table>
<thead>
<tr>
<th>Run or Going dimension</th>
<th>Relative risk of falls</th>
<th>Used for home stairs by</th>
</tr>
</thead>
<tbody>
<tr>
<td>255 mm (10.0&quot;)</td>
<td>0.03</td>
<td>ICC Codes in USA</td>
</tr>
<tr>
<td>250 mm (9.8&quot;)</td>
<td>0.05</td>
<td>BS5395-1:2010 in UK</td>
</tr>
<tr>
<td>245 mm (9.6&quot;)</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>235 mm (9.3&quot;)</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>225 mm (8.9&quot;)</td>
<td>0.12</td>
<td>NAHB in USA</td>
</tr>
<tr>
<td>215 mm (8.5&quot;)</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>205 mm (8.1&quot;)</td>
<td>0.14</td>
<td>NBCC in Canada</td>
</tr>
<tr>
<td>195 mm (7.7&quot;)</td>
<td>0.21</td>
<td></td>
</tr>
</tbody>
</table>


Step Geometry Uniformity Defects

• *Especially top-of-flight defect due to inconsistent nosing projection*
Step Geometry Uniformity at Top Steps of Flights with Nonuniform Nosing Projections

The single most important, easily implemented act to improve the safety of existing stairs is to find and retrofit landing nosings that do not project the same as other nosings of the stair flight!
Generally, the top-of-flight, run non-uniformity defect is only one of several recently suggested factors that could be contributing to the dramatic recent increase in stair-related injuries in US CPSC statistics.
Potential Contributing Factors for Recent Growth of Injuries

(1) Relatively steep stair step geometry permitted traditionally only for homes.

(2) A systemic top-of-flight dimensional non-uniformity on many home stairs, due to flawed code requirements and/or flawed construction and inspection practices.

(3) An apparent reduction—generally—in the code enforcement process for new home construction.

(4) The potential deterioration of movement performance in the US population (among others), stemming from reduced physical activity and increasing prevalence of obesity and overweight.

(5) Increased use of ‘Type II’ handrails for new home stairs.

(6) Increasing differential between public and home stairways.
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(6) Increasing differential between public and home stairways.
What Designers, Builders & Code Officials Should Learn About Stairways & Falls

Power Grip with Type I Handrail

Pinch Grip with Type II Handrail
These standard industry profiles are examples of the two types that share the same upper width and shape.

Profile # 240

Profile # 6010

Power Grip with Type I Handrail

Pinch Grip with Type II Handrail
Much of the current debate about handrail graspability centers on the paper published in Applied Ergonomics in July 2009.

Effect of handrail shape on graspability

Donald O. Dusenberry*, Howard Simpson, Steven J. DelloRusso

Singapore: Gicasper & Hager Inc; 45 Seyon Street, Building 1, Suite 500, Woburn, MA 01801, United States

ABSTRACT

This paper summarizes research performed to evaluate the impact of handrail profile dimensions on graspability. It reports on research performed to determine the forces that stairway users exert on handrails when they fall, tests demonstrating the forces persons with various hand sizes can exert on handrails with different profiles, and comparisons of the probability of loss of grip by stairway users when they attempt to arrest a fall by grasping a handrail. The recommendations based on this work include specific definitions of the shapes of handrails that are deemed to be sufficiently graspable to constitute functional handrails.

1. Introduction

Falls on stairs constitute a major cause of accidental injury in the United States. While various stairway design parameters have significant influences on the number and severity of accidents, there is no available statistical information that establishes a correlation between the cross sectional shape of stair handrails and the height of such falls. In addition to allowing users to develop adequate pulling forces, the grasping surface must be uninterupted along the length of the handrail, be sufficiently distant from adjacent walls allow for free grasping action, and be of appropriate height.

The research described herein addresses the performance of handrail shape as it relates to the last two of the four functions described above. The results also are applicable to the evaluation of functional handrails.
A study, supported by SMA (the Stairway Manufacturers Association), used flawed test.

Maki’s 1985 study, for NRCC, used better test.
The SMA-controlled study tested the worst of the Type I handrails versus the best of the Type II handrails — *modified for better performance*

- **Power Grip with Type I Handrail**
- **Enhanced Pinch Grip with Modified Type II Handrail**

**51 mm 2-inch Diameter**

Modified Profile # 6010
Type II handrail, the 6010 profile, as marketed versus as modified for testing.

Code Requirements
Allow This Profile

Justified by Results of Tests
Using This Modified Profile
Type II handrail, the 6010 profile, as marketed versus as modified for testing

Pinch Grip with 6010 Profile Handrail

Enhanced Pinch Grip with Modified 6010 Profile Handrail
• The situation warrants publication of critical comments on the Applied Ergonomics paper—perhaps even formal withdrawal of the paper.

What Designers, Builders & Code Officials Should Learn About Stairways & Falls

Effect of handrail shape on graspability

Donald O. Dusenberry*, Howard Simpson, Steven J. DelloRusso

Sinapese Enterprises & Regier Inc., 40 Secon Street, Building 1, Suite 500, Wellesley, MA 02481, United States

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Outline for OAA Continuing Education Session:
   1. Introduction

Goals of Presentations and Discussions

By the end of the session you will have

D. Knowledge of techniques for stairway inspection relevant to assessing safety and usability.

Section 13: Liability-related and other inspection techniques.
Two-second handrail grasp test

“Power Grip”
10-second Crouch-and-Sight Test

Crouch down at the top of the flight, sighting along nosings, to confirm that nosings line up exactly. If they do not line up exactly, the stair is non-uniform in rise and/or run dimensions.
If the nosings appear to line up exactly, perform the follow up test to check for equal inter-nosing distance.

This appeared to pass the crouch-and-sight test, but inter-nosing distance was not uniform (353 mm versus 315 mm).
Failure of either test, crouch-and-sight or inter-nosing distance test, should lead to full measurements of step rise and run.

Measure all steps for inter-nosing angle and distance; then calculate rise and run using trigonometry (i.e., sine and cosine).
What Designers, Builders & Code Officials Should Learn About Stairways & Falls

Typical Set of Small Tools for a Qualified Stairway Inspector
What Designers, Builders & Code Officials Should Learn About Stairways & Falls

Additional, Larger Tools for a More-capable Stairway Inspector
Outline for OAA Continuing Education Session:

1. Introduction

**Goals of Presentations and Discussions**

By the end of the session you will have

E. Awareness of current and potential impacts of litigation related to stairways.

Section 13: Liability-related and other inspection techniques.
Elements of Liability:

- **Duty**
- **Breach**
  - Violation of a building code requirement is neither a necessary nor sufficient basis for being found liable by a court of law.
- **Cause**
- **Harm**
Building officials in the US have a double responsibility for the condition of buildings. They create the rules as well as enforce them. Should they then not share liability, including for flawed stairways, particularly if official behavior is unethical?
Outline for OAA Continuing Education Session:

1. Introduction

**Goals of Presentations and Discussions**

By the end of the session you will have

F. An improved basis for meaningful participation in model code development, adoption and enforcement activities nationally and locally.

Section 12: Home design codes and the double, lower standard.
Knowledge, presence and participation in code development are all important to achieving better stairways—and built environment generally—including improved safety and usability.
Outline for OAA Continuing Education Session:

1. Introduction

Goals of Presentations and Discussions

By the end of the session you will have

G. Greater enthusiasm for building safety activities that significantly impact public health generally and the wellbeing of people in your community.

Section 12: Home design codes and the double, lower standard.
Summing up the situation of the model building code development, adoption and enforcement situation affecting public safety — especially stairways in homes and elsewhere:

It is a Colossal Failure in:

• Policy
• Process
• Product
• Outcome
• Response

And this is just the situation in the USA.

In Canada it is worse than in the USA!
At the Centennial Conference of the Canadian Public Health Association, CPHA, on June 15, 2010, in Toronto, Jake Pauls is presenting a progress report on this topic:

Progress on Making the National Building Code of Canada More Responsive to Public Health Problems

*In Canada is it worse than in the USA?*
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Those who control the process, control the product or outcome.
Code development, adoption and enforcement must have more oversight and participation by public health professionals including design professionals.
Responsibilities of public health professionals for solving (or at least mitigating) problems of stairway safety and usability are not restricted to designers, builders and code officials.

A meeting is being proposed, mostly for leaders in the field of fall biomechanics and stairway ergonomics to address two sets of priorities:

- How better to apply what we already know.
- How to improve our knowledge through additional research on stairways.
What Designers, Builders & Code Officials Should Learn About Stairways & Falls

The two priorities come from two recent meetings.

- One-day meeting on stairway safety, usability and research at the UK Health and Safety Laboratory on April 16, 2010.

- This drew participants from EU, CA, US, JP and NZ.
- One recommendation was for a longer, more detailed follow up meeting in 2011 with more US & CA participation.
The two priorities come from two recent meetings.

- A small, follow up meeting to discuss and plan a larger meeting on stairways in 2011 in North America, occurred at the UK Building Research Establishment, April 23, 2010.

Present: Mike Roys (UK), Wen Chang (US) Jake Pauls (CA & US)
• With a current hourly, societal cost on the order of ten million dollars—growing as much as ten percent per year, it is imperative that a major research and technology transfer effort be made to mitigate, if not solve, the problems of stairway safety and usability, especially in homes.

• Responsibilities are not only with designers, builders and code officials; they are with the highly skilled professionals present in this room today.

• 2011 could be a seminal year for stairway usability and safety, especially in homes.
Thank You
Announcing the Availability of a 3-DVD, 1-CD Set of a One-day Workshop

**Stairway Usability and Safety**

**Use by individuals in homes and other buildings**

**Disc 1**
- Introduction
- Acknowledgements
- Terminology and epidemiology
- Economics and ergonomics
- Introduction to model building code grading
- Key factor of visibility

**Disc 2**
- Key factor of geometry
- Key factor of handrails

**Disc 3**
- Special stairs
- Home stair geometry
- Home stair railings
- Home design codes and the double, lower standard
- Litigation
- Summary
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**Disc 4**
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**Jake Pauls, CPE**

Educational Presentation at *Measuring Up the North* Conference in Prince George, BC, Canada, April 2009

Email: bldguse@aol.com

Website: [http://web.me.com/bldguse](http://web.me.com/bldguse)
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