Investigating Catastrophic Stair Falls

Richard Nellis and Bailey Gutkin

Any stair fall has the potential to be catastrophic (resulting in a severe injury or fatality). Contributing factors can include design, construction, maintenance, weather factors and user behaviour. The investigating forensic engineer focuses on site examinations, reported information and review of the injuries to determine the most likely fall scenario and contributing factors.

This article will demonstrate the connection between various contributing factors, and their origins utilizing a specific case study, which demonstrates the complex scenarios and contributing factors relating to catastrophic stair falls (CSF's).

Stair Fall Scenarios

CSF's can be either witnessed or unwitnessed, resulting from a trip, slip, or mis-step, in ascent or descent.

While every stair fall assessment requires an objective and consistent approach, each individual stair fall scenario will ultimately determine the course of the investigation.

Witnessed vs. Unwitnessed

Typically a witnessed CSF has more information available from a number of sources to aid in the assessment.

Unwitnessed stair falls make up the majority of investigated cases and can be difficult to investigate as it is common for the injured party to have limited recollection of the event.

It is crucial that all scenarios be considered and prudently accepted or rejected. Determining the most likely fall scenario requires considerable experience and knowledge in order to correlate the physical attributes of the stairs with the reported injuries.

Determining the fall method ultimately helps identify the cause and contributing factors and must be consistent with the injuries, physical attributes, and reported information. A detailed methodology that is based on the engineer's knowledge and experience, and considers all aspects of the fall, lends credibility to the assessment.

Trips vs. Slips vs Mis-steps

Literature cited in the references defines a slip as "A sudden loss of footing, the result of an unforeseen, unexpected and out-of-control slide of the foot. A trip is defined as a sudden loss of footing, the sequela of an interruption in the natural, rhythmic movement of the swinging leg." A mis-step is an inaccurate placement of the foot causing loss of balance.

Slips on stairs are less likely than trips or mis-steps as most momentum is in the vertical direction rather than the horizontal. A contaminant or lubricant that reduces the slip-resistance of the tread surface, such as ice or snow, will typically be a contributing factor

for a slip. Generally, a slip will cause the person's feet to come out from under them, and they will fall backwards or to the side.

Trips on stairs can occur as a result of a variety of factors such as trip edges, loose carpeting, and inconsistent riser/tread dimensions. Contrary to a slip, a trip will generally cause a person to fall forward.

A mis-step can occur when a person places their foot partially over the edge of a tread, or cannot identify where the stair begins or ends. This type of fall can be a result of inadequate stair geometry, unexpected stairs, confusing carpeting, or user behaviour. A mis-step will often, but not necessarily, cause a person to fall forward, in the direction of their momentum.

Ascent vs Descent

Understanding the differences in gait for ascending and descending stairs is essential to determining the causes and contributing factors in CSF's.

During ascent the centre of gravity is held slightly forward with the leading foot landing with the ball of the foot in a horizontal position. The heel may or may not touch the tread, as the rear foot pushes back against the lower tread and pushes off. The rear foot will swing up and over the leading foot to land in a horizontal position on the tread above.

With very little horizontal or lateral movement slips are unlikely. If a slip occurs in ascent, it is likely due to the presence of a lubricant. Trips in ascent are likely as the rear foot lifts up onto the next tread. If the riser height is greater than expected, or if the toe catches on the nosing of the lower tread, a trip can occur. A mis-step is also possible if the leading foot is placed inaccurately on the edge of the tread. The contributing factors for a mis-step in ascent could include inconsistent or excessive riser heights, or visual deception.

A fall in ascent causing a person to fall backwards can result in injuries to the head which can be serious or fatal. However, as the centre of gravity is held forward during ascent, it can be very difficult to determine the fall origin, particularly if it is unwitnessed. While potential contributing factors can be determined, such as a missing handrail or inconsistent riser heights, it is difficult to specifically determine the fall origin.

In descent, the centre of gravity is held back to maintain balance. The leading foot angles downward such that the ball of the foot will first contact the tread, allowing the foot and leg to absorb the impact. With contact the force is mostly vertical, making it unlikely that the foot will slip forward.

If such a slip occurs, due to ice, for example, it will likely cause a person to land on their buttocks or back, and bounce down the stairs. A mis-step could occur, if the ball of the foot lands on the nosing or over the edge of the stair. This could be caused by inconsistent stair geometry or a visually confusing stair. It is possible to trip in descent, if a trip edge is present, possibly caused by poor construction or maintenance practices.

Investigating Cause and Contributing Factors

Once the fall scenario is understood, it is necessary to identify the cause. This requires expertise relating to stair design, construction, and maintenance, as well as a comprehensive understanding of building codes and bylaws, construction best practices, maintenance, industry standards, and academic research.

The origin of the cause must be logical and readily understood. The reports, site examination, search of records, injuries, and fall scenario must be consistent with both the cause and contributing factors.

As there are contributing factors to falls, there are also contributing factors to the origin of cause. For example, if a woman slips in descent during the winter, the origin could be ice. Potential contributing factors could include the lack of a handrail, stair materials, or the presence of ice.

It is also important to consider contributing factors such as user behaviour. If it can be determined that the person who fell was distracted or was wearing inappropriate footwear, it may be significant to the fall scenario. Considering these potential contributing factors is essential to conducting a complete investigation.

It is important to not only identify the cause of the fall, but also to ask how the physical attributes of the stairs came to be in its present condition.

The following case study illustrates the complexity of accurate determination of cause and contributing factors.

Case Study: Unwitnessed Fall in Ascent

Background: A woman was found at the bottom of a restaurant stair where she was dining. (Among other injuries, she was rendered a quadriplegic as a result of the fall.)

Fall Scenario: The woman was found lying on her left side at the bottom of the stairs. Based on her injuries and her body position when found, it was determined that the woman fell backwards while ascending the stairs.

It was difficult to assess whether the fall was a slip, trip, or mis-step as the incident was not witnessed. Further, the injuries did not specifically imply one specific fall scenario.

For the purposes of this CSF assessment, biomechanical engineering experts were retained and reported that the injured party had fallen backwards while ascending, possibly due to a mis-step. Her body likely rotated during her fall, such that she landed with considerable force on the bottom landing, against the wall.

Once this fall scenario was determined, it was then our role, as the investigating engineer, to determine the cause of her fall.

Origin of Cause: Many code violations were identified including riser heights that exceeded the maximum in the building code. The tread depth was also below the minimum criteria, creating a steep stair. Excessive, varied risers are unexpected and create trip hazards.

Full-scale replica which was used as an exhibit in court.

The handrail clearance was such that fingers could not maintain a continuous grasp of the handrail and did not provide sufficient support.

It was our professional opinion that the condition of the stair, specifically the excessive riser heights and variance of the risers, run and tread width throughout the stairway created an unsafe condition that contributed to the loss of balance and fall.

Assessment: A search of building permit records, building codes and bylaw was conducted to determine contributing factors and cause. We reported the following conclusions:

- The stair dimensions did not comply with the building code in effect at the time of renovations.
- The renovation drawings provided insufficient information but a permit were accepted by the municipality and a permit for the proposed work was issued.
- A break in the hold of the handrail could result in the loss of balance and stabilization.
- The building owners did not ensure that the renovations conformed to safe building code standards.
- The stairs did not comply with the municipal Property Standards By-law.
- The municipality should have identified construction deficiencies and building code compliance issues during the building permit approval and inspection process.
- The municipality was required by the Building Code Act to conduct competent inspections upon completion of the renovations and should have noted the deficiencies and taken appropriate action