FORENSIC HUMAN FACTORS ANALYSIS OF SLIP AND FALL INCIDENTS USING A VARIABLE INCIDENCE TRIBOMETER

Terence J Fischer and Jamie S A Fischer

Fischer Forensic Services, LLC
Northfield, NJ 08225 USA

This paper addresses how the application of the Human Factors Forensic Accident Analysis Model and appropriate tools, such as the Variable Incidence Tribometer, provide evidence for expert opinions regarding the causes of slip and fall incidents. This paper addresses the biomechanics and causes of slip incidents and the techniques used in measurement of slip resistance in the laboratory and in the field. This approach has been used successfully in forensic analyses and has been accepted for expert testimony by United States Federal Courts and State Superior Courts. Slip falls occur when there is a loss of balance by the pedestrian as a result of too little friction between the foot and the floor. The slippery conditions are frequently caused by the introduction of contaminants between the shoe and the floor surface. Water and other liquids are frequent contaminants that lead to slip and fall accidents. Applying an Accident Analysis Model is useful in the determination of slip and fall accident causes. The Accident Analysis Model used has five major elements: Design, Remove, Guard, Warn, and Train. Field measurement of the COF can be accomplished using several devices. The Variable Incident Tribometer (VIT) is designed to measure static COF of dry surfaces (Johnson, 2004.) The presence of a lubricant, i.e., water, between the shoe and the ground surface contradicts the definition of COF. In that condition, the slip resistance can be measured by the VIT. The VIT provides readings that are consistent with the judgments of people walking on various surfaces with differing levels of slip resistance. Data from the VIT has been accepted as evidence by state and federal courts in the United States of America.

Introduction

Slips and falls in the workplace and commercial establishments are a primary concern for safety experts. According to the National Safety Council (NSC), in 2007 more than 7.9 million Americans were injured and more than 21,700 Americans died as a result of falls (NSC, 2010).

Slips and falls occur when there is a loss of balance by a pedestrian as a result of too little friction between the foot and the floor. The slippery conditions are typically caused by the introduction of contaminants between the shoe and the floor surface. Frequent examples of contaminants include water, other spilled liquids, and the certain floor finishes.

Two types of slips can occur during normal walking. The heel of the swing foot can slip forward when placed on the ground or the planted foot can slide rearward. The probability of either type of slip is increased in the presence of contaminants.

Accident Analysis Model

The Accident Analysis Model can be used to determine the cause and prevention of slip and fall incidents. The Accident Analysis Model has five major elements: Design, Remove, Guard, Warn, and Train (Askren & Howard, 2004).

Design. The design of the environment contributes greatly to the likelihood of slips and falls. Therefore, when a slip and fall incident is evaluated, the first step must always be to thoroughly evaluate the design of the environment. It is important to determine the source of the contaminant and whether that contaminant would be expected in the subject environment. A good evaluation will address any potential design changes that would eliminate or minimize the presence of contaminants. For example, entranceways from the outside are frequently exposed to rainwater and, thus, produce a potentially hazardous condition. The use of canopies would minimize exposure to the contaminant and reduce the likelihood of slips and falls. If the designer had included a canopy, it is likely that the incident would not have occurred.

Remove. The removal of the contaminant from the environment would greatly reduce the probability of a slip and fall incident. If a design modification is not feasible, the next best step would be to evaluate whether the contaminant could have been removed prior to the incident. For example, if there was an accidental spill, could the spill have been mopped dry prior to the incident? How long was the spill allowed to remain on the floor? This element of the Accident Analysis Model typically involves the evaluation of a property manager's policies and procedures. It is useful to obtain policy manuals and interview employees.

Guard. Guards can prevent the pedestrian from exposure to the contaminant. According to the Accident Analysis Model, there are situations where contaminants can be expected in the environment and it is not feasible to remove the contaminant in any timely manner. In many of these situations, it is feasible to protect the pedestrian when these hazards are present. For example, the use of bars and railings could provide a handhold that will guard the pedestrian against potential falls.

Warn. If the hazard cannot be prevented and if the pedestrian cannot be guarded, a prudent property manager will warn pedestrians of the potential hazard. A forensic evaluation will determine if, for example, warning cones and signs were used to inform pedestrians of temporary or unpreventable hazardous conditions. The warning will enable the pedestrian to make a knowledgeable decision about whether to proceed on the walkway.

Train. The final element of the Accident Analysis Model is to train a person to safely operate in a known hazardous environment. This element is often applied to many workplace situations. Training however, is not an appropriate countermeasure for slip and fall incidents involving the general public.

Slip Resistance Measurement

Slips and falls occur when there is a loss of balance by a pedestrian as a result of too little friction between the foot and the floor. The actual COF (Coefficient Of Friction) is quantified on a continuum from 0 to 1.0, on a flat surface. Studies have shown that the required COF for a person to walk without slipping is typically around 0.30 to 0.40 depending upon gait and other individual factors (Brungraber & Templer, 1991). The Underwriter's Laboratory established in the early 1940's that a COF of more than 0.5 was considered slip resistant (Sacher, 1993). This value has been repeatedly cited and is accepted in the flooring industry as the standard performance measure.

Field measurement of the COF can be accomplished using several devices. The Variable Incident Tribometer (VIT) is designed to measure static COF on dry surfaces (Johnson, 2004). The presence of a lubricant, i.e. water, between the shoe and the ground surface contradicts the

definition of COF. In that condition, the slip resistance can be measured by the VIT. The VIT provides readings that are consistent with the judgments of people walking on various surfaces with differing levels of slip resistance. The slip resistance measurements of the VIT have been accepted as evidence by United States Federal Courts and State Superior Courts.

The VIT produces consistent slip resistance readings that are independent of the flooring slope. Adjustments can be made mathematically to the slip resistance measurements to accommodate ramped surfaces. Unlike pull meters, the VIT has no appreciable residence time on the lubricated surfaces. This prevents the occurrence of adhesion or stiction, which can provide spuriously high slip resistance readings.

Examples of Cases.

The following section will present cases where the VIT was successfully used by the author in a forensic capacity.

Case 1: Poor Restroom Design Causes Hazardous Flooring Condition

In the first case, the plaintiff was a lunchtime patron that had used a restroom of a restaurant. After leaving the toilet stall, the plaintiff approached the sink counter to wash her hands. The plaintiff did not notice that the porcelain tile flooring was wet in the area near the sinks. The plaintiff was elderly and used a cane to assist her in walking. The plaintiff's cane slipped and she fell to the ground injuring her head, wrists, and knees.

Measurements of the slip resistance of the flooring were taken using the English XL VIT. The testing results indicated that when dry, the tiles had a slip resistance of 0.58, therefore slip resistant. When wetted with local tap water, the slip resistance measured 0.31 and was considered not slip resistant and by code it was classified as hazardous.

Testimony indicated that the plaintiff was wearing flat soled shoes and was walking in a deliberate fashion. Examination of the cane indicated that the tip had a good quality rubber tip.

Witnesses testified that two other patrons were in the restroom at the time of the incident and had just finished washing their hands. An inspection of the restroom indicated that two sinks were located in the countertop. The restaurant installed a paper towel dispenser on the left side wall approximately 2 feet (0.61 meters) from the left sink. Patrons using the right sink had to walk approximately 6 feet (1.83 meters) to obtain a towel after washing their hands. This resulted in right sink users dripping water on the floor as they walked to retrieve a towel.

The restaurant management testified that the restrooms were cleaned every morning before opening. There was no scheduled maintenance or inspection of the restaurant during the day/lunch shift. The management testified that the lunchtime clientele was an older crowd with 75% to 80% over the age of 62. Many of the patrons used canes or walkers. The restaurant typically served a few hundred patrons during the lunch shift. After 4:00 p.m., an attendant is tasked with maintaining the restrooms. The attendant wipes the floors and replenishes the supplies at that time.

It was the opinion of this investigator that the restaurant did not provide an adequate standard of care in designing, maintaining or warning the patrons of the potential hazard caused by the slippery wet floor condition. The application of the Accident Analysis Model indicates that application of the first (Design), second (Remove) and fourth (Warn) principles highlights the deficiencies. These principles would have been feasible to implement yet they were not.

The design of the restroom led to the hazardous conditions. The placement if the towel dispenser on the wall opposite the sink caused patrons to drip water onto the floor. Review of ADA standards and reference safety texts identified the unsafe condition caused by the improper design of the subject restroom, specifically the installation of the towel dispenser. The use of flooring that was not slip resistant when wet exacerbated the condition. The behavior by the patrons was not unexpected given the sink placement and general purpose of the room. As indicated by testimony,

the restaurant had no policy for maintaining or inspecting the restroom during the lunchtime hours when hundreds of patrons were potentially exposed to the hazardous condition. Had routine inspections been performed and necessary maintenance activities been performed, the wet flooring condition could have been removed. Finally, had the restaurant warned patrons of hazardous conditions, through the placement of signs, the plaintiff could have adjusted her path and/or her gait to prevent her exposure to the hazardous condition.

Figure 1. Case 1 incident location. Note the distance from the right sink and the towel dispenser at left.

Case 2: Safety "Diamond Plate"

The plaintiff was a vacationer at a seaside resort town when a slip and fall accident occurred. The plaintiff was walking on the seaside boardwalk when the weather changed and rain began falling. The boardwalk was crowded with patrons all hurrying to escape the rain. The wet boardwalk surface was an amalgamation of concrete and wood with a "diamond plate" aluminum manhole cover located in the man walkway path. The plaintiff unknowingly stepped from the adjacent concrete walkway onto the "diamond plate". The unexpected change in slip resistance caused the leading foot of the plaintiff to slip and the plaintiff was caused to fall. .

The subject location was examined by the slip resistance tester was used to measure the slip resistance of the manhole cover surface. Six measurements were taken under dry conditions and six measurements were taken after the surface was wetted. The average slip resistance of the manhole cover was 0.75 when dry and 0.25 when wet. The slip resistance of the adjacent concrete was 0.74 when wet. Statistical analysis of the slip resistance measurements indicated that the average slip resistance when wet was significantly smaller than the average slip resistance when dry. Additionally, the slip resistance of the manhole cover was significantly smaller than the adjacent concrete when wet.

The use of a slip resistant treatment for the "diamond plate" was recommended as an economical method to increase the wet slip resistance and remediate the hazardous condition.

Case 3: Uncontrolled Environmental Factors

The plaintiff was spending the day at the beach before she returned to the Beach Bar to clean off. The Beach Bar had a boardwalk surface leading from the beach to an outdoor shower area and then onto a bar and the hotel. As the plaintiff approached the shower area, the boardwalk surface changed from dry to wet. The plaintiff's foot slipped causing her to fall and sustain a wrist fracture.

Testimony from the plaintiff and witnesses indicated that there were no mats, slip resistant tread material or other devices to provide slip resistance. In addition, there were no warning signs in the area to warn that the boardwalk was slippery in the area of the shower.

Inspection of the location indicated that the boardwalk consisted of 2x6 timbers with nominal separation to allow drainage and expansion. The slip resistance in the area of the showers was measured using the English XL VIT. The area was cleaned and dusted to remove contaminants. The slip resistance was measured as 0.72 when dry and 0.55 when wetted with bottled spring water. An adjacent area was then tested after applying a thin layer of sand. With sand present, the slip resistance was 0.32 when dry and 0.26 when wetted. The testing identified that the boardwalk decking was slip resistant when the only contaminant was water. When sand was introduced either on the patron's foot or by other's having showered, the problem significantly increases to a hazardous state.

During the inspection, the work areas for employees were examined. The employer had placed mats on the work areas of the boardwalk to lift the employee feet off the boardwalk and allow the sand and water to drain away.

Based upon the examination, the plaintiff's human factors investigator opined that the third (Guard) and fourth (Warn) principles of that Accident Analysis Model were applicable. Due to the outdoor location and purpose of the shower area, the hazard could not be eliminated by design nor could the hazard be removed. As indicated by the facility's use of mats under the employee work area, the employer knew of the hazard and guarded his employees from the hazard. The patrons were left exposed to the hazard. In addition to mats, handholds and/or railing should have been installed near the shower area. As reported in testimony by witnesses, there were no warnings posted to inform the plaintiff of the hazardous condition. A warning would have enabled the plaintiff to make a knowledgeable decision about whether and how to proceed on the walkway.

Case 4: Adequate Slip Resistance

The plaintiff was a guest at a local casino hotel. The plaintiff had spent the night in a guest room. She awoke in the morning to use the toilet. As she walked from the toilet into the bathroom area, the plaintiff fell to the ground and sustained a proximal fracture of the left humerus. The plaintiff alleges that the floor was slippery and caused her to fall.

Casino-hotel employees are trained on proper cleaning techniques. Supervisors conduct random written inspections and daily walk-in inspections of housekeeper performance. One written random inspection is performed each week for each housekeeper. The floor was cleaned with a disinfectant and then with a hydrogen peroxide solution.

The plaintiff testified that she did not know if there was any water on the floor at the time of her incident. The plaintiff's testimony indicated that neither the sink nor the shower had been used that morning and that the shower was not used on the previous night. The plaintiff was unsure whether the toilet or the sink was used the previous night. The investigative reports characterized the bathroom floor as dry and clear. The plaintiff reportedly stated to security personnel at the time of the incident that the floor was dry.

The incident location was examined and the slip resistance of the flooring was measured during an inspection. The inspection indicated that the slip resistance of the floor in the area of the subject incident, 0.73, exceeded the industry accepted standard of 0.50. The slip resistance measurements indicated that the subject location was non-hazardous and would be considered slip resistant.

Based upon an analysis of the subject case, a site inspection, and the references cited above, it was concluded to a reasonable degree of human factors and biomechanical certainty, that the subject flooring did not pose a slipping hazard and the flooring was not the cause of the subject incident.

Summary

The application of Human Factors principles can be used to determine the causal factors in slip and fall incidents. Slips and falls occur when there is a loss of balance as a result of too little friction between the foot and walking surface. The Coefficient of Friction (COF) can be measured using instruments such as the Variable Incident Tribometer (VIT). Data from the VIT method has been accepted as evidence by United States Federal Courts and State Superior Courts.. The Accident Analysis Model identifies the steps that property owners and business managers should use to ensure their property is safe and employees and patrons are protected. The Accident Analysis Model uses five major elements including Design, Remove, Guard, Warn, and Train. Three cases were reviewed where the VIT and the Accident Analysis Model were used by the author in a forensic capacity.

References

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