DIFFERENT PATTERNS OF HANDRAIL USE AT JUNCTIONS OF SWITCHBACK STAIRWAY FLIGHTS

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Observations and documentation of erosion patterns on continuous handrails on the inner side of switchback (dogleg) stairway flights (turning 180 degrees at a landing) have revealed two distinctly different patterns of handrail use. In one, users utilize the full length of the handrail—especially through the 180-degree turn. The other has users make very intensive use of the rail at a highly predictable point, about two steps away from the landing. Descending users' grip is maintained on the few lowest steps of the upper flight, through the landing, and a few steps below that. The behaviour can lead to erosion of paint on the handrail at the heavily used grip point. The phenomenon has been neither published nor exploited through systematic research for important insights on the complex set of factors of biomechanics, other human factors, and design affecting handrail use. It should be.

Introduction

Aside from a field study of aisle stairway use reported by Pauls (1980), which was followed by detailed analysis including handrails use, e.g., whether it consisted of guidance or discrete grips (Rhodes, *et al.,* 1980), there is relatively little research on stairway handrail usage based on detailed field observations and documentation. Over a three-decade period, Dr. Brian Maki and his research colleagues have focused attention on what can be learned in laboratory settings, much to the improvement of knowledge on topics like appropriate handrail height (as affected by stair pitch and user characteristscs), grab response (in simulated fall situations) and graspability (in terms of shape, size and surface characteristics). While making important contributions to the ergonomics literature (for example, Maki, *et al.,* 1984, 1985, 1998, 2006), his published work has, apparently, not yet addressed handrail use behaviour in field settings.

Templer (1974, 1992) included observations of handrail usage in field settings, prominently stairways in subway stations and the Grand Central Station concourse in New York City. Those field observations were concerned mostly with where people walked on stairs and landings however, in passing, he noted use of handrails—and erosion on them—as a factor in where people walked on a stair. At another point Templer referred to evidence of handrail erosion indicating greater handral usage at the beginning and end of stairway flights. Templer also contributed to the work resulting in the comprehensive report by Archea, *et al.* (1979). That report has a section on handrail continuity that has been quite influential. Here is what it recommended.

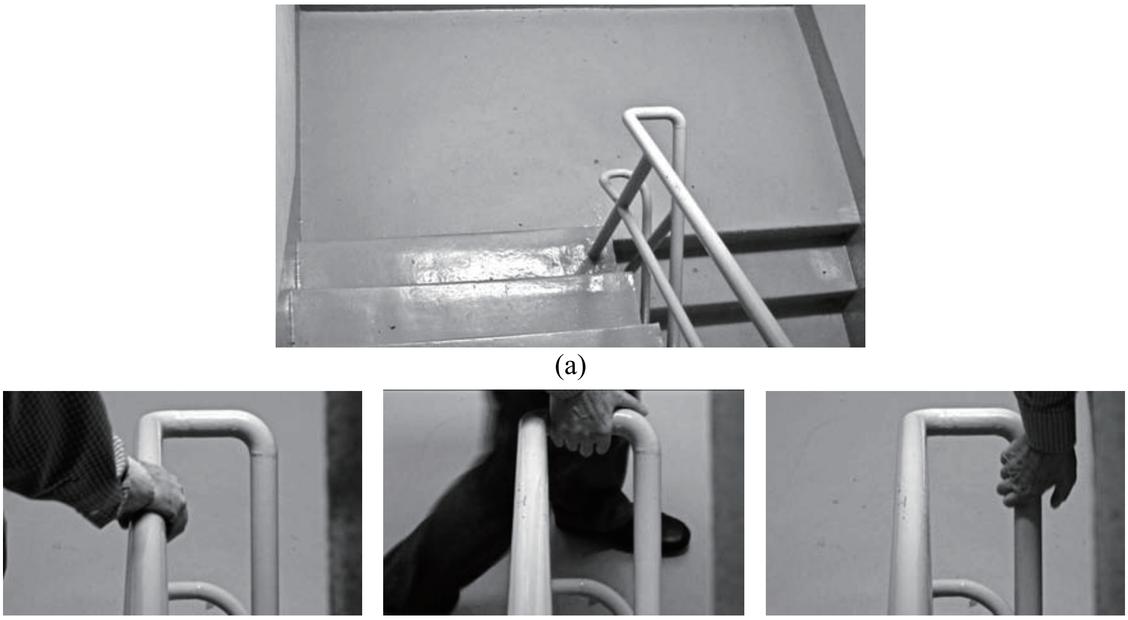
> 2.3.1 Continuous Handrails. IF: an existing handrail is discontinuous at some point in the run of the stair, particularly at points where the stair makes a sharp 90º or 180º turn . . . . THEN: either replace the existing railing with a continuous railing, or fill in the gaps. COMMENTARY - There are at least four critical uses of a handrail on a stair:
> (1) to slide a hand while monitoring one's progress and stability, (2) to use as a pivot at corners or doglegs, (3) to provide support for an elderly or infirm user, and (4) to grab onto for support in the event of an accident. . . . Therefore, secure handrails should be available to the user at every point throughout his use of a stair. Moreover, the handrails should be continuous on the inside of 90º or 180º landings, and should be graspable at any point on the stair or landing.

There was the excellent review by Fenney and Webber (1994) who identified what aspects of handrails had the best evidential basis and thus were appropriate for justifying design requirements in standards and codes. They quote Templer (1992) on the matter of handrail use priorities and erosion (with italic emphasis added here):

> The handrail consistently shows more erosion on the descent side of the stair. This seems to suggest that the handrail is mainly used to avoid losing one's balance and falling down stairs (falling up the stairs is obviously less potentially hazardous). However, it must be remembered that *in descent, the hand is slid down the handrail and is therefore likely to cause more erosion than the regularly spaced pulls that are used in ascent.*

Expected handrail use on switchback handrails

Figure 1(a) depicts a switchback (dogleg) stair in a wide, overhead view as seen by a user descending the upper flight (on the left side of the photo). Figure 1 (b), (c), (d) show details of the handrail in use in the expected fashion with the descending user's hand maintaining contact with the continuous, inner handrail throughout its length, especially at the 180-degree turn.



(a)

(b) (c) (d)

Figure 1. Expected, continuous contact of descending user's hand on a switchback (dogleg) stairway's continuous inner handrail

Handrail continuity between stair flights, particularly at the inside turn of switchback stairs, is addressed (with varying degrees of specificity) by model building codes in the US and Canada. This is considered important for people transitioning between flights, and walking within reach of the handrail, i.e., to have the capability of a continuous contact with it when traversing the two most dangerous parts of the stairway, the top and bottom of stair flights adjacent to landings. This could be especially important for more-vulnerable stair users who need such continuity as a tactile cue and for postural support, especially if swinging around on the landing.

Evidence of such use is occasionally seen in erosion, or other marking from hand contact, on the handrail surface at such continuous turns at the inner turn, especially in the area of tightest handrail grasp shown in Figure 1(c). But, as important as continuity of handrail use at the turn is, there is another location where handrail use is quite different—*and worthy of study.*

Erosion patterns on switchback stairway handrails

Recently the author has observed switchback stairways serving facilities with a lot of pedestrian traffic, e.g., on the order of 10 to 100 persons using the stairway each hour of business. Examples shown in Figure 2 are in Toronto, Ottawa and the Washington, DC. They include stairways used for access between floors of parking garages (one serving a heavily used medical center) and a basement-level restaurant accessed only by stairways. All had fairly consistent erosion patterns centered about 400 mm—sometimes as much as 500 mm, from the turns of the continuous handrail at landings.

(a) (b) (c)

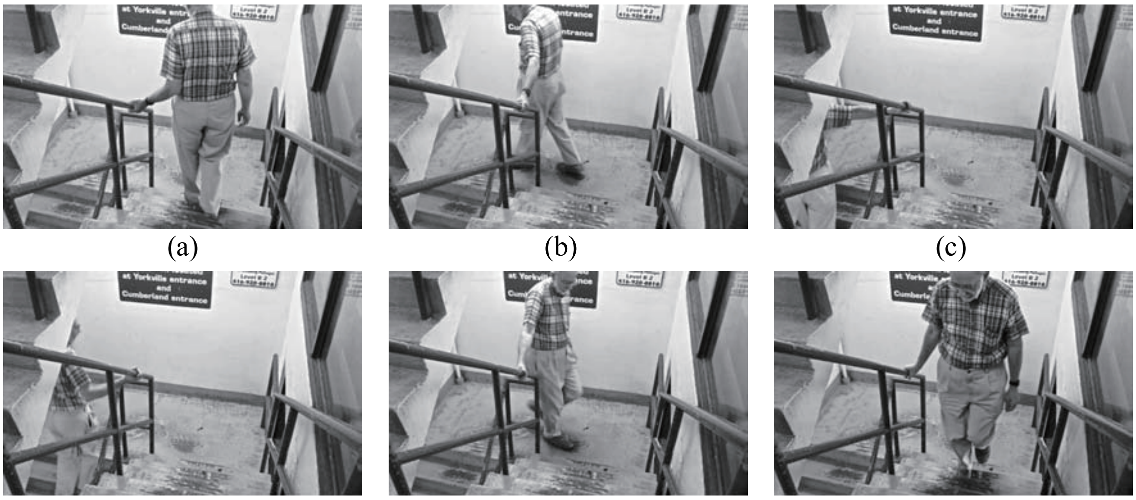
Figure 2. Examples of switchback stairways with very prominent erosion patterns on portions of continuous handrails near landings between storeys (with the centers of such erosion typically 400-500 mm, measured horizontally, from landings)

Most of the stairways shown in Figure 2 lack visual appeal. Due to poor maintenance, there are erosion patterns suggesting several years of use. At predictable locations the paint and primer have been completely eroded off. In some case, central areas of most intense erosion consist of shiny, well-polished steel. The most eroded handrail area shown circled in Figure 2(c) has the polished, bare steel extending around the entire circumference of the handrail. Obviously, the extent of handrail erosion at areas, such as the circled one, is far more extensive and intensive than at the turn of the handrail at the landing. The stairway handrail in Figure 2(b) was finally repainted in early 2013, so monitoring of its future erosion can provide insight into the extent of handrail use needed to again erode the paint. (As the stairway serves the parking garage of a busy medical centre, major stairway traffic will likely continue well into the future.)

Nature of handrail use causing the erosion patterns

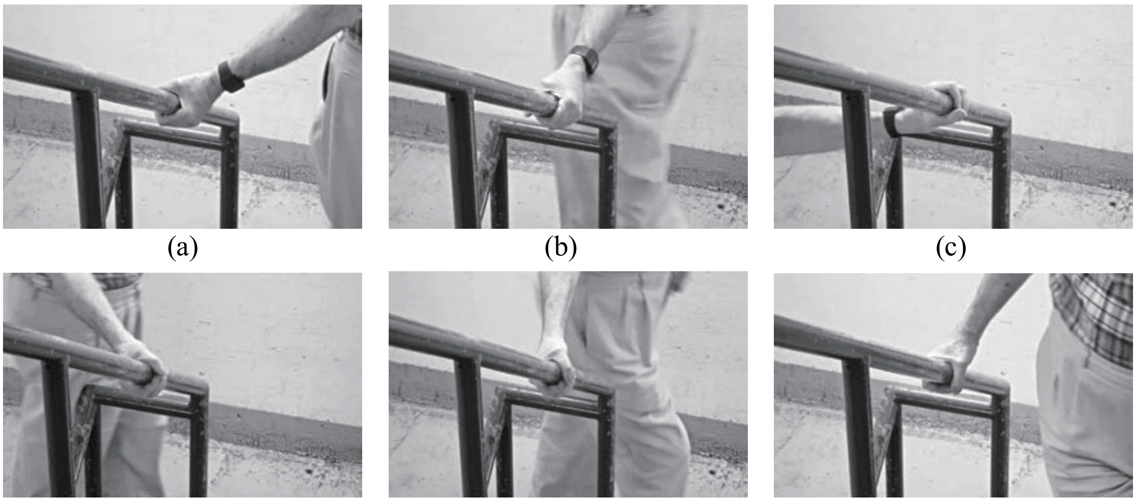
Although all of the stairways, with eroded handrails, examined by the author could easily have their use monitored by video and studied systematically—with large sample sizes, this has not yet occurred. Hence the illustrations in this report, and videos shown in the conference presentation do not depict actual use by the general public. Figure 3(a), (b), (c), (d), (e) and (f) depict, *with wide-angle views*, the author first descending, then ascending the stairway while intentionally using the handrails in ways that are consistent with the patterns of erosion, with regard to hand contact positions both along the handrail length and around its perimeter. Notably, in contrast to what is depicted in Figure 5, the grasp orientations are those that feel most natural and which facilitate the longest period of handrail grip. Details of the grip appear in (approximately) corresponding photos in Figure 4(a), (b), (c), (d), (e) and (f).

Figure 4 depicts, for each direction of travel—descending, then ascending, *with close-up views*, the detail of the hand-handrail contact at three times each, respectively beginning, middle and end of the hand grasp, an effective power grip completely encircling the handrail and rotating through large angles of rotation combined with large ranges in arm position. The behaviour depicted in Figures 3 and 4 are perceived as completely natural to the author who, in hindsight, is becoming aware that he has unconsciously performed this behaviour for a long time on many stairways—just as countless others have done.



(a) (b) (c) (d) (e) (f)

Figure 3. Wide-angle views of author descending, then ascending a stairway, using the handrail in ways that feel natural and are consistent with the handrail erosion



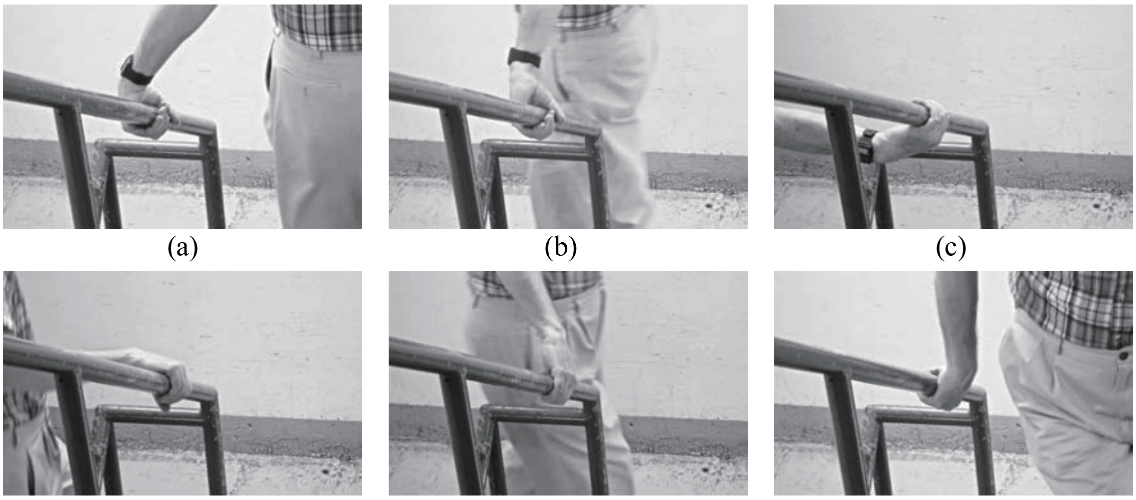
(a) (b) (c) (d) (e) (f)

Figure 4. Close-up views of author descending, then ascending a stairway, using the handrail in ways that feel natural and are consistent with the handrail erosion

Figure 5 (a), (b), (c), (d), (e) and (f) depict, also with close up views, a second, noticeably different and perceptively less natural-feeling, indeed uncomfortable behaviour, especially in the wrist, with orientation of the hand opposite to that depicted in Figures 3 and 4. Grip duration was also shorter.

Factors that apparently affect the nature of handrail use

Clearly the behaviour is unlikely to occur with handrails not having circular cross section, with a size (about 40 mm diameter) readily usable with an encircling power grip, and a reasonably smooth surface, with the smooth polished metal finish of the most eroded areas being (at least in the view of the author) best suited to the behaviour. Handrail height might be a factor, along with user anthropometrics and other physiological factors, in determining the most favoured grip position along the handrail. The lower the handrail, the further from the landing will be the favoured grasp point. General fitness, flexibilty, user speed, presence of others, etc. might also affect handrail use. Presence of others might might reduce occurrence of the phenomenon as this affects both speed and demand for use of what might be termed the use of the “sweet spot” on the



(a) (b) (c)

(d) (e) (f)

Figure 5. Close-up views of author descending, then ascending a stairway, with an uncomfortable and less natural grip that was not sustainable as long as in Figure 4.

handrail, especially as one user’s hand is effectively locked on one point for a much longer time than in other forms of handrail use—as the user requires use of a small part of the handrail for the time taken to traverse as many as four or five steps plus a 180-degree turn at the landing (although, due to one’s arm being fairly stretched out while doing the turn means it will be close to where the continuous handrail turns 180 degrees). This matter could benefit from even relatively simple research. Moreover, it might be done with automatic data acquisition and analysis using video, a computer and readily available software.

Not yet at all clear is whether the erosion occurs because of the rotation of the grip, its movement along a short section of the handrail, or both. Answers to these questions, as well as matters of forces and moments exerted on the handrail will benefit from laboratory-type instrumentation techniques available to researchers such as Dr. Brian Maki in Toronto, a leader in handrail research internationally. Clearly the mechanics of the hand-handrail interaction are complex generally and perhaps even more so for this phenomenon. Also, to what extent is the erosion due to the nature of the grip (as opposed to its frequency) relative to the much simpler, hand-handrail interaction depicted in Figure 1? Finally—although this is hardly a compete discussion of factors, as the author’s observations have been conducted in mostly unheated facilities in climates still subject to freezing winter temperatures, what is the role of gloved hands in accentuating the erosion? For example, the stairway shown in most of the Figures in this paper, is in Toronto, Canada, in an enclosed, but unheated exit stairway, one of four serving the unenclosed parking garage that will be below freezing termperature for about 100 days per year.

Why is this phenomenon important and worthy of research?

Handrails are an important feature of stairways, a relatively dangerous product (as a commonly used building feature associated with large costs of injuries and poor usability) but one very important to human movement in many buildings. Like brakes for our automobiles, handrails are the most important safety feature to prevent or mitigate dangerous events such as falls—overall a greater source of injury than even all motor vehicle crashes. Does the phenomenon described in this paper increase one’s safety in descent because in traversing the most dangerous steps in a stairway—those nearest the landings, one has (in effect) a type of anchoring hold on a biomechanically useful handrail. Then a misstep in the top two steps of a flight, a common starting point for the most dangerous falls, can be effectively mitigated with a handhold situated at a biomechanically advantageous height—shoulder to head height (a preferred height of handhold on vertical grab bars on subway cars for example). And, for what may be half the stairway uses described in this paper, handrails serve other purposes—beyond controlling unintended movement, i.e. missteps and falls, for example by facilitating stair ascent by assigning a significant share of the effort to upper body muscles.

Generally, are there aspects of stairway use that we unconsciously adopt because they are biomechanically beneficial or adventageous? And, if the origins of the subject phenomenon are biomechanics—as suggested by its predictability, incidence, etc., should we not view it as more adaptive than odd, quirky or even pathological?

At the very least, we should consider more than one behavioural model when setting rules for important safety features like handrails. Yes, continuity at a turn of a 180-degree (or other angle) stairway landing might be essential to some users—specifically, older or, generally, less agile users. But preferably round, readily grasped handrails serve all users, and all types of use, best. And, as has been argued repeatedly in deliberations on handrail requirements in building codes and safety standards, a stair user's hand can predictably approach a handrail from a great variety of directions—even from below as occurs with the subject phenomenon, as depicted in Figure 5(c). The vast majority of handrails currently being installed in new homes in the US and Canada, serve only hands approaching the railing from a narrow range of directions and, even with those limited approaches, the grasp possibilities and effectiveness are relatively poor and highly subject to hand size.

To repeat the famous words of long-gone stairway safety genius John Archea, "there are people committing data" on stairways and "we need to do something about that." Some of the data are in the proverbial class of "low-hanging fruit" (clearly an impetus for preparation of this paper). Some phenomena will benefit from our best research techniques and academically honed skills. This author hopes that, in sharing these ideas, with illustrations that are not language dependent, this paper will spur investigation on a number of fronts in a variety of cultures, befitting its presentation at an international conference held on the Pacific Rim of Asia.

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