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An Analysis of the Behavior of Stair Users

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National Bureau of Standards
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PREFACE

The Architectural Research Program of the National Bureau of Standards (NBS) has been conducting research under an agreement with the Consumer Product Safety Commission (CPSC). The objective of this work was to recommend ways to reduce the frequency and severity of the approximately 350,000 stair, ramp and landing accidents that are treated in hospital emergency rooms each year.

In order to expand our knowledge of stair accidents, several approaches have been explored by NBS to identify potentially hazardous behavior. To this end a videotape data bank of some fifty hours of recordings of people using stairs has been collected. This material has been processed in various ways to provide information on typical human responses to stairs.

In the report that follows, an analysis of the behavior of users of the stairs recorded on the videotape segments is described. Fifty-eight variables were used as measures of the stair user's characteristics, user behavior and environmental conditions. The relationship between these variables and the occurrence of incidents and mishaps depicted in the data has been tested and conclusions drawn. An incident in the context of the study does not necessarily imply a fall. As can be seen from Appendix 2, incidents are categorized not only in terms of severity and outcome, but also by type of precipitating misstep.

The sample of stair users, stair types and environments recorded on the tapes cannot be considered as representative of the general population of stairs and stair users. A representative sample would mandate the selection of a much wider range of stair conditions, and a user population that is less identifiable.

The number of incidents that occurred in the fifty hours of observations is not insubstantial from the viewpoint of illustrating the hazards. But for the meaningful analysis the number of incidents and the number of incidents per flight is small. In fact, on some flights no incidents were detected.

The validity of the conclusions that we have recorded from the analysis, and the recommendations that we have made, are therefore limited by the restricted nature and size of the sample. Nevertheless, until such a time as a considerably more extensive program can be undertaken, the results provide useful indications.

Chapter 1 of this report describes the study and the methods that we used; Chapter 2 sets out the statistical procedures and our findings; in Chapter 3 we have made use of the conclusions from the videotape analysis, and previous studies, to discuss the role of architectural design in stair accidents. We have proposed 44 performance statements which, if applied to stair design, would, we believe, substantially reduce the incidence and severity of stair accidents. These statements are presented and discussed in Chapter 3.

We would like to acknowledge the assistance we have had from the following people in conducting this study:

Dr. Robert Wehrli and Dr. Edward Arens, at the National Bureau of Standards, for their administrative support, and Joan Templer, Michael Jones and Amy Reynolds who were responsible for the coding analysis and who helped with the production of this report.

1. DESCRIPTION OF THE STUDY

The purpose of this study is to:

- °Identify hazardous and potentially hazardous responses by people to various types of stair
- °Diagnose the probable causes of these responses
- °Suggest design guidelines that might contribute to or improve standards of stair safety.

The method selected for the study has five stages:

1. Selecting a sample of videotape material for processing
2. Developing an observation and coding plan
3. Recording of the appropriate data
4. Analyzing statistically the data
5. Drawing conclusions and making recommendations.

1.1 SELECTION OF VIDEOTAPE SEGMENTS

A videotape data bank generated by NBS consists of about fifty hours of recordings of people using stairs. These stairs are located in widely separated parts of the United States, and are used by a variety of people. Both interior and exterior stairs were filmed, and stairs of various layout configurations and surrounding environments.

To reduce the data to a size that could be processed within the constraints of the study, a selection process was adopted. The selection process took into account:

- ° The visual quality of each tape segment
- ° The camera angles
- ° The duration and extent of the recordings
- ° The types of stair users
- ° The types of stairs and their environs
- ° The times at which the recordings were made.

1.1.1 Videotape Quality, Camera Angles and Duration of Recordings

Some segments of tape were excluded because the visual quality of the scene was inadequate for analysis. These were usually a result of technical problems with the equipment, or light levels that were too low for good quality videotaping. Only those videotape segments in which the whole subject is clearly visible for a period long enough to permit reliable coding of all applicable variables were selected for the analysis.

1.1.2 Types of Stair Users

The subject matter of the tapes consists of recordings of:

- Pre-school children at two day-care centers
- Elderly people at lunch programs at senior citizens centers and general community centers
- Adolescents and young adults at a university student center
- A largely undifferentiated group of people at two shopping centers and a memorial library.

From previous studies[1] it has been established that children under the age of four and adolescents have disproportionately high per capita accident rates on stairs, compared to the rates for other segments of the population. Subsequent analysis based on the actual frequency of stair use have shown that persons over the age of 65 also have a disproportionately high accident rate on stairs. In addition to a high risk of accidents on stairs, the injuries resulting from stair accidents tend to be more severe among the elderly than among other segments of the population. For this reason, it was decided to place special emphasis in the analysis on the responses of preschool, adolescent, and elderly stair users.

The fourth category is a largely undifferentiated group consisting of a wide variety of stair users. However, this group may not be representative of the general population of stair users. For example, young middle class white women appear to be over-represented. Nevertheless, this group is sufficiently diverse so that it can be treated as indicative of everyday users of stairs.

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[1]U.S. Consumer Product Safety Commission, NEISS News, January 1974.

1.1.3 Stair Types

The videotapes include material on several types of stairs in various settings as set out in Appendix 1. This enables us to compare responses to these different stairs, so long as the recorded user groups are comparable.

Several of the staircases have "composite" layouts. They are composed from straight flights coupled to landings in various configurations. This permits us to treat these sections of stairs as if they are independent flights with different settings. Segments were selected that would provide us with a sample from each stair type and setting.

1.1.4 Recording Times

The videotape recordings were made at various times of the day, and on various days of the week. It was necessary to consider the possibility that stair incidents occur more frequently at certain times of the day, or on certain days of the week. Therefore, videotape segments that are representative of various recording times were selected for analysis.

1.2 ANALYSIS

Two separate analyses of selected videotapes were conducted. The first compared the personal and behavioral characteristics of people who had accidents, missteps, or other incidents on stairs with the characteristics of a matched sample of users of the same stair who did not have an accident or misstep. From this analysis, the relationships between incident rates and the characteristics of users were established. The second analysis compared the incident rates for representative samples of users of each of the stairs for which data had been collected. From this analysis, the relationships between incident rates and the characteristics of the stairs were established.

1.3 MATCHED SAMPLE

The National Bureau of Standards had already identified from the tapes most of the stair incidents--where users fell, slipped, tripped or experienced an event that might have resulted in a fall. These incidents were edited into six half-hour tapes. While some of these incidents did not meet the selection criteria, those which met the criteria were used to provide data on inter- and intra-user responses.

The characteristics of the people that were involved in incidents on the stairs (the incident sample) were compared to the characteristics of a matching group of stair users who did not have incidents (the matched sample). The matched sample was selected as follows: (1) the original videotapes from which each incident had been edited were identified, (2) for each incident victim a matching stair user from the same videotape segment was randomly selected from the group of users who had traveled in the same direction on the same stair at least one minute before the victim. Except for the fact that the matching subjects had to satisfy all criteria for tape quality, no other selection criteria were used.

This procedure ensured that the matched sample duplicated closely the circumstances of the incident sample in terms of the time of day, the day of the week, the stairway used, ambient environmental conditions, and the general presence of other users. It also assured that the behavior of each incident victim and his or her matching subject would be sufficiently independent of each other. The resulting groups represent a plausible basis for establishing valid relationships between special personal or behavioral characteristics of the users and the occurrence of stair accidents, missteps, or other incidents.

1.4 REPRESENTATIVE SAMPLE

The relationships between the architectural characteristics of the various stairways and the occurrence of incidents was established through scrutiny of a representative sample of users on each flight. From the large quantity of videotape that met all of the initial selection criteria, a second selection procedure was undertaken to identify approximately twenty percent of the total sample which would be representative of the range of conditions under which recordings had been made. After excluding tapes on which the users were predominantly young or old, segments of videotape that represented activity at various times of the day and various days of the week were selected at random.

From this representative sample, the frequency of stair incidents for each flight was established. These incident rates were treated as the dependent [or criterion] variables against which the characteristics of the stairs and other environmental factors were correlated. From these correlations, the relationships between the characteristics of the different flights and the incident rates were established. A further analysis of the location at which incidents occurred within each flight provided a more detailed understanding of the relationships between stairway design and accidents or missteps.

1.5 CODING

Fifty-eight independent [or predictor] variables (See Appendix 2) were selected for the analysis, each chosen for their possible influence on stair accidents. Many of these have been shown in previous studies to correlate significantly with accidents.

The variables fall into three categories:

A. Stair user characteristics - such as age, sex, race, body type, handicaps, clothing, items carried, group ecology, etc.

B. Characteristics of user behavior - including incident behavior, direction of movement, speed, route taken, attention, handrail use, traffic density, gait, reaction to others, etc.

C. Environmental conditions - including riser height, tread depth, nosing, wash, illumination, stair width, handrails, time of day, day of week, orientation factors, etc.

The user characteristics in categories "A" and "B" served as independent variables in the comparison of incident and non-incident users in the analysis of the matched sample. The environmental characteristics identified in category "C" served as independent variables in the comparison of incident rates on different flights in the analysis of the representative sample.

1.6 OBSERVER TRAINING AND RELIABILITY

Observer training occupied about seven hours. Much of the training was directed at raising the observer's reliability to an acceptable level. (The reliability was checked periodically during the data processing phase). During the period, the observer was familiarized with the:

° Operation of the videotape equipment

° Variables to be identified

° Coding procedures

° Recording procedures

The degree of observer precision decreases as the amount of observer required judgment increases. Much of the training period concentrated on improving the precision of recording judgmental factors.

2. ANALYSIS AND RESULTS

The analyses of the data are presented in two parts:

(2.1) An examination of the relationships between incidents[1] and stair user characteristics and behavior.

(2.2) An examination of the relationships between incidents and environmental factors.

2.1 THE RELATIONSHIP BETWEEN STAIR INCIDENTS AND USER CHARACTERISTICS AND BEHAVIOR

In this first part of the analysis, we focus on the characteristics of stair users and their behavioral responses to stairs. The hypotheses to be tested are that some people are more likely to experience incidents on stairs than others. The tests are directed at trying to isolate the reasons. This includes examining the influence of stair user characteristics (from the Group A variables in Appendix 2) such as age, sex, race, body type, and dress. We also scrutinized people's behavior on stairs. Does speed, direction of travel, carrying objects, being alone, where the user is looking, handrail use, or any other of the Group B factors (in Appendix 2) affect the incident rate?

These relationships are examined in two ways -- inter- and intrastair responses.

2.1.1 Intrastair Behavior and Characteristics

For each stair, we have tabulated and described statistically the characteristics and behaviors of those users involved in incidents. By matching we have virtually eliminated the possible contamination effects of the environmental characteristics of time of day, traffic density, ambience differences, etc., and we are left with users' characteristics and behavior only.

2.1.1.1 Results

One hundred and five incidents were recorded from the videotape materials. As there were 43 flights, the number of incidents per flight tended to be small. In fact on some flights no incidents occurred. On only

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[1] Of the 105 incidents that were studied, 52% involved a minor gait or postural adjustment, 30% involved an aborted fall, and 18% involved body contact with the floor (a fall).

two flights were there sufficient incidents for any sort of intrastair examination to be meaningful--stairs #1 and #17.

The characteristics of stair users involved versus those not involved in incidents were compared, using contingency table analysis[2] to the characteristics of a matching sample of users not involved in incidents. The following variables were found to differ at a significance level of .10 or less:

Stair #1

Variable #13	Length of clothing below the waist: More incidents than expected for those whose clothing is above knee level.
Variable #15	Type of footwear: More incidents than expected for those with shoes that were not of the "regular" variety.
Variable #16	Type of heel: More incidents than expected for those with a flat sole flat sole with no heels.

Stair #17

Variable #5	Age: More incidents than expected for those whose ages did not lie between 15 and 44.
Variable #16	Type of heel: More incidents than expected for those with a flat sole with no heels.
Variable #18	Gait: More incidents than expected for those whose gait was "slow and deliberate."
Variable #23	User group ecology: More incidents than expected for those who are accompanied by one or more companions.

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[2] For all contingency tables comparing k independent samples of frequency data in discrete categories, the χ^2 test was used. In the case of two independent samples of two categories each (a 2 X 2 table), the Fisher Exact Probability Test was used. One or the other of these statistical procedures was used with all the tables that follow.

2.1.2 Interstair Behavior and Characteristics

To extend this analysis so that we can generalize for all the stairs in the study is not possible--the user populations are so different. However, it is possible to group all those stairs (at the two shopping centers, the library, and the student center; stairs 1-22 in Appendix 1) whose users represented a (largely) undifferentiated population into one pool. So for this examination, all 51 incidents that occurred on these 22 stairs were pooled.

Once again, the characteristics of the users that were involved in incidents were compared with a matching sample of users not involved in incidents. The number of cases, is, of course, much greater this time and therefore the tests have more power and precision.

2.1.2.1 Results

The following variables were found to differ at a significance level of .10 or less:

Variable #5	Age: More incidents than expected for those whose ages did not lie between 15 and 44.
Variable #13	Length of clothing below the waist: More incidents than expected for those whose clothing is above knee length.
Variable #16	Type of heel: More incidents than expected for those who have flat soles with no heels.
Variable #18	Gait: More incidents than expected for those whose gait was "slow and deliberate."
Variable #23	User group ecology: More incidents than expected for those who are accompanied by one or more companions.

The pooled data are used in this analysis because the users of these stairs represented a comparatively unbiased and representative sample of stair users.

For interest and comparison, a further examination was carried out using a pool of all the incident data from all the stairs including those from the schools and the facilities for the aged. (See Appendix 3, tables 5 to 14). From this analysis the following variables were found to differ at a significance level of .10 or less:

Variable #5 Age:
More incidents than expected for those whose age did not lie between 10 to 44 and are not older than 64.

Variable #13 Length of clothing below waist:
More incidents than expected for those whose clothing was above knee length.

Variable #17 Speed of movement:
More incidents than expected for those in the second slowest speed category.

Variable #18 Gait:
More incidents than expected for those whose gait was "unstable and tottering" and those whose gait was "slow and deliberate."

Variable #19 Carrying objects, how carried:
More incidents than expected for those carrying objects, regardless of how carried.

Variable #23 User group ecology:
More incidents than expected from those who are accompanied by one or more companions.

Variable #35 Type of handrail use:
More incidents than expected for those whose use of the handrail for "pulling up" and for "balance."

Variable #38 Reactions to other stair users:
More incidents than expected for those watching others or another.

Variable #39 Assistance in stair use:
More incidents than expected from those helped by one person.

2.1.2.2 Testing for independence

Several of the latter group of variables may be correlated. Consequently, we have tested them for independence within both the incident group and the non-incident group in all possible pairs in order to help understand the results obtained with these groups. The following pairs were found to be dependent at a significance level of .10 or less:

Incident Group

Age and: Length of clothing below waist, Speed, Gait, Carrying objects, User group ecology, Type of handrail use, Assistance.

Length of clothing below waist and: Carrying objects.
Speed and: Gait
Gait and: User group ecology, Type of handrail use,
User group Ecology and: Reactions to other users, Assistance.

Non-Incident Group

Age and: Length of clothing below the waist, Gait, Carrying objects, User group ecology, Handrail use, Assistance.
Length of clothing below waist and: Carrying objects
Speed and: Gait, Handrail use.
Reactions to other users and: Gait, User group ecology, Handrail use.

Handrail use and: Assistance

2.1.2.3 Dynamic effects

Next, for the incident group, we examined dynamic effects--where the variables are under the user's control. For example, age does not change during a journey on stairs but the object of the user's attention may change and is therefore a dynamic effect.

Forty-three of the 105 incidents showed a change in one or more of these controllable behaviors as the individual went from the last safe step to the incident step. Table 1 shows this relationship.

It is not possible to generate a similar table for the non-incident group since we cannot define a non-incident step. We can conclude that almost half of the incidents showed a change in controllable behavior at the time of the accident. No causality can be implied, however, because we have no basis for comparison with the non-incident behavior.

2.2 AN EXAMINATION OF THE RELATIONSHIP BETWEEN STAIR INCIDENTS AND ENVIRONMENTAL FACTORS

In this part of the analysis, we focus on the frequency of stair incidents (as the dependent variable) in relation to the variables that describe the steps, the stairs and other environmental factors. Again, we examine these relationships in two ways--interstair and interstep.

TABLE 1. BEHAVIORAL CHANGES MADE IMMEDIATELY PRECEDING AN INCIDENT

Variable	No. of Changes
Stair channel	7
Attention: Facing	2
Direction	12
Elevation	21
Apparent object of attention	20
Handrail use	9
Type of handrail use	9
Reactions to other stair users	12

2.2.1 Interstair Patterns of Stair Incidents

Using all the videotape segments from the representative sample, we compared the frequency of incidents on each of the various stair sections (excluding those stairs where the uses were predominantly children or elderly people) on the hypothesis that certain stairs are more dangerous than others.

Fourteen stairs were subjected to this analysis and every individual on each was categorized as an "incident" or as a "non-incident." These data were subjected to a 2 x 14 contingency table analysis to test the null hypothesis that incident rates were homogeneous across the stairways sampled.

The null hypothesis could not be rejected. However, putting the incident data on a per step basis or an exposure risk basis, and using the same type of analysis, it was found that stairs #1, #5, and #20 had more incidents than could be expected by chance alone. Stairs #11, #12, and #22 had fewer.

The characteristics of these high and low risk sets of stairs were then compared statistically (see Appendix 3, Table 14). The characteristics were pooled when necessary to get expected values of 2 or 3. On the basis of these analyses, the differences reported in Table 2 were found at a significance level of .05 or less.

TABLE 2. SIGNIFICANT CHARACTERISTICS OF HIGH RISK AND LOW RISK STAIRS

Variable	Partitioning	Comment
Number of steps	2, 3, 9 versus 12, 18, 24	All high risk in former, low risk in latter
Width	49 or 59 in. versus 60, 61 or 66 in.	All low risk in former, high risk in latter
Riser height	Less than 6.25 in. versus 6.25 in. or greater	High risk stairs had more in former class than expected by chance
Tread depth	12 in. or less versus greater than 12 in.	High risk stairs had more in former class than expected by chance
Nosing projection		All high risk stairs had no projection
Stair surface	Polished terrazzo with insert versus other	High risk had more in former class than expected by chance
Ascent lateral view	Open one side versus open one side rich view versus open two sides rich view	High risk had more in middle class than expected by chance
Descent lateral view	ditto	ditto
Descent frontal view	Open front versus closed front	High risk had more in former class than expected by chance
Ascent overhead view	Open above rich view versus closed view	ditto
Descent overhead view	Open above versus closed above	ditto
Descent orientation gradient	One or less changes versus two or more	High risk had more in latter class than expected by chance

In Table 2, the high risk group of stairs in comparison to the low risk stairs:

- had fewer steps per flight (fewer than 10)
- were wider (60 in. or more)
- had lower risers (less than 6.25 in.)
- had narrower treads (12 in. or less)
- had no nosings
- were finished in polished terazzo
- had a rich view on one side (where a rich view connotes a view with many people or conditions to attract the stair user's attention)
- had a higher magnitude orientation gradient (a larger number of changes in orientation factors such as illumination and lateral, overhead and frontal view)[3].

The high risk of incidents on stairs with few steps is further borne out when all the incidents are considered relative to step number. Fully one-third of stair incidents occurred on either the first or last step; an additional 25 percent occurred on the second or the next to last step; and another 12 percent on the third or the third from the last step.

2.2.2 Interstep Patterns of Stair Incidents

We then examined the three high risk stairs and the three low risk stairs on a step-by-step basis. We analyzed the number of environmental changes that occurred between successive steps (changes in width, wash, handrail extent, riser height and other environmental conditions). The results are summarized in Table 3.

TABLE 3. A COMPARISON OF HIGH AND LOW RISK STAIRS: ENVIRONMENTAL CHANGES

No. of Environmental Changes	High Risk Cumulative %	Low Risk Cumulative %
0	0	7.8
1	9.1	17.6
2	27.3	41.2
3	81.8	60.8
4	90.9	84.3
5	90.9	88.2
6	90.9	98.0
7	100.0	98.0

[3] See Variable 57, Appendix 2, for additional information about the orientation gradient.

In Table 3, the first row suggests that for the high risk group of stairs, no two adjoining steps are environmentally identical. However 7.8 percent of adjoining steps in the low risk group are environmentally identical. The second row of Table 3 finds 9.1 percent of adjoining steps in the high risk group have one environmental change, but 17.6 percent of adjoining steps in the low risk group have one or no environmental changes. In all, the high risk group of stairs has more environmental changes present for the user who passes from step to step than the low risk group of stairs.

We next looked at all of the 105 incidents, irrespective of the stair on which they occurred. We focused on the number of changes in stair characteristics (riser height, tread depth, etc.) that occurred between the last safe step and the step on which the incident happened. Table 4 takes into account the direction of travel and ignores incidents on the first or last step that would force a comparison with a landing.

Clearly, from Tables 3 and 4 we can conclude that uniformity in stair characteristics from step to step is desirable.

TABLE 4. INCIDENTS VERSUS CHANGES IN STAIR CHARACTERISTICS

Number of Changes	Number of Incidents
0	0
1	7
2	15
3	29
4	7
5	4
6	6
7	6
8	0
9	0
10	1

Finally, it was found that the high risk group of stairs differed significantly ($P < .10$) from the low risk stairs in the magnitude of the orientation gradient (specifically, Variable 58 in Appendix 2). The high risk group had very few steps on which only one orientation factor (illumination, views) changed, and many steps where a large number of orientation factor changes occurred.

2.3 SUMMARY OF FINDINGS

1. There are several variables that differentiate the incident group from the non-incident group of stair users. The most important of these appear to be:

   ° Age
   ° Length of clothing below the waist
   ° Type of heel
   ° Gait
   ° User group ecology

2. There is an association between the stair user's behavioral changes that occurred just before the incident and the number of incidents. In other words, many of the people in the incident group exhibited one or more changes of behavior just prior to the incident. They changed from one channel to another; they changed their attention or the object of their attention; they changed their type of handrail use, etc.

3. It was possible to partition the stairs into high risk, low risk and average, on the basis of their environmental characteristics. The high risk stairs tend to have:

   ° Fewer steps
   ° Wider flights
   ° Lower risers
   ° Treads that are less than 12 in.
   ° No nosing projections
   ° A polished terrazzo finish with inserts
   ° Lateral views that are rich on one side
   ° An open front view
   ° An overhead view that is rich
   ° A high descent orientation gradient

4. All of the findings point to the need for homogeneity of design of the stair environment from step to step. Not only should each step match its neighbors in terms of dimensions, shape, etc., but the surrounding environment that can be perceived from each step should also match its neighbors.

Safety is also related to unchanging behavior as the users walk from step to step on a stair, but obviously it is not possible to mandate safe responses to the environment.

3. PERFORMANCE STATEMENTS TO GUIDE ARCHITECTURAL DESIGN THAT SHOULD REDUCE STAIR ACCIDENTS

The inherent instability of walking makes us prone to pedestrian accidents. Few days go past when we don't put a foot wrong, literally. We slip a little on a slick surface, trip on a cracked sidewalk and recover, or are thrown temporarily off balance pulling open a heavy door. Few of these events are memorable because they are so frequent and so minor, without serious consequence.

A misstep on a stair is obviously potentially much more serious than a similar error on the level floor. It is not surprising that stairs are the loci for so many severely damaging accidents. A stair forces the pedestrian to traverse a rhythmic or arrhythmic sequence of barriers, to which, judging from the evidence of physiological metabolic studies,[1] we are ill suited. We are well suited to walking great distances on the level or over gently undulating ground. But stairs demand from us an unusual gait, coupled with (or producing) a very high rate of energy expenditure.

Stairs are particularly bad places to have accidents. Falls in descent are the cause of most serious stair accidents. To fall down stairs is not only to fall over a cliff, but to fall onto the rocks below, for the nosings of the steps often present a succession of sharp edges.

Any time that we fall as pedestrians, it is because of some physiological, perceptual or behavioral failures (unless the environment has simply collapsed from under us). Some groups of people are more prone to these failures than others. The videotape analysis confirmed other accident studies that the young are more likely to fall. The elderly may not fall more frequently than others, but when they fall, the consequences are far more serious. The question that we must consider here is the relationship between our failures and the environment. There are few failures for which the pedestrian's environment is completely blameless. We may stumble over our own feet, or a game leg may give away, but usually the environment has failed us or at least we have failed to respond to an environmental failure.

Hazardous environments are inevitable and pandemic, and we are reasonably well equipped to cope. Part of our equipment is natural caution. We approach a precipice with circumspection, and we descend broken ground with constant vigilance. This is not the case on stairs--familiarity lulls us into a false sense of security.

Environmental hazards are acceptable where they are natural and predictable. We would not expect a mountain trail to be flat, level, protected,

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[1] Fitch, J. M., Templer, J. A., and Corcoran, P., "The Dimension of Stairs," Scientific American, Vol. 231, No. 4, October 1974, pp. 82-90.

without incident. However, we expect walkways, indoors at least, to be hazard-free.

On stairs, then, as with walking on extended level surfaces, if there are hidden environmental traps, our lack of prudence or skill or perception will eventually be tested. In the sections that follow, we direct our attention to the major environmental traps of stairs and how people respond to them. We offer a number of performance statements which are intended to expose and finesse these usually subtle defects.

The performance statements in this chapter are verifiable from at least one of three general sources, designated G (General Source), T (Templer), V (Videotape), respectively:

G. The stair accident articles by Gowings (1960), Miller and Esmay (1958), and Velz and Hemphill (1953) listed in the references.

T. Studies described by Templer in his forthcoming book, listed in the references.

V. The videotape analyses described earlier.

3.1 ALTERNATIVE VERTICAL COMMUNICATION ROUTES

3.1.1 Stair Avoidance

Performance Statement (G)

Do not include stairs in designs unless they are strictly necessary. Plan to keep staircase use to a minimum.

Discussion

Careful design and maintenance can make stairs safer, but the inherent hazards cannot be wholly removed. One way to reduce accidents is to reduce stair usage. One way to reduce usage in new designs is to avoid staircases unless they are strictly necessary. Frequently a step or a flight of steps can be omitted from the design after alternate solutions have been explored.

If a staircase is unavoidable in design for a new building, then the plan should aim to keep staircase use to a minimum. People should not be required, for example, to use stairs to reach frequently used facilities such as toilets.

3.1.2 Signs

Performance Statement (G)

In public places, alternatives to stairs should be available (elevators, ramps, etc). Information to this effect should be provided at the stair.

Discussion

If the elderly and the handicapped, for example, are unaware that alternative ways to ascend are available, they may try to use stairs. This may be hazardous for them.

To reduce stair usage, all people should be encouraged to use safe alternatives wherever possible.

3.2 STAIR ENTRY AND EXIT LOCATIONS

3.2.1 Traffic Conflicts

Performance Statement (V)

Avoid a layout that will produce conflicting patterns of pedestrian movement in the vicinity of the top and bottom of the stairs.

Discussion

Stairs that are poorly located may bring into conflict pedestrian traffic entering or leaving a stair and traffic passing the stair. Taking the appropriate avoiding action on or in the vicinity of the stair in response to a traffic conflict is to run the risk of a fall on the stair.

Videotape Examples

- A short flight of stairs leads to a landing from which one stair continues down in the same direction as the short flight, and another continues down from the landing at right angles to the other two. A woman at the bottom of the short flight and intending to proceed straight nearly fell when another woman suddenly turned in front of her in order to take the other flight.

- A man intending to descend a stair has to make way for a group ascending. He trips on the stair edging at the top of the stair.

3.2.2 Orientation Factors

Performance Statement (V)

Avoid changes of direction, changes of view and large changes in illumination level in the immediate vicinity of the top and bottom of the stair.

Discussion

In the videotape analysis, it was noted that the incidence of accidents on the top three and bottom three steps of the flight is very high. On these high risk steps, a large number of orientation factor changes occur--route direction changes, changes in view, and very large changes in illumination.

It follows therefore, that stairs should be located such that orientation factor changes are minimized at the top and bottom.

<u>Videotape Examples</u>

° A man looking around at a visually rich environment catches his heel on the first step of a short flight in descent.

° A boy looking down at a flight of stairs that starts at right angles to the landing he is approaching misses the last step.

° A little girl descending is looking back up at the surroundings and anticipates an extra step onto the landing at the bottom of the flight.

° A little girl starts to climb a stair leading into a school. She is looking up into the doorway and her foot slips off the step.

3.2.3 Protective Gates

Performance Statement (G)

If a stair is located where very young children play, the stair should be provided with gates or some protective barrier at the top and bottom.

Discussion

The accident rate for young children on stairs is high. Some falls occur because the child crawls on the top landing and then falls down the stairs.

3.2.4 Dangerous Locations

Performance Statement (G)

Avoid a layout where someone entering or exiting from a stair may be subjected to an immediate and unexpected hazard.

Discussion

From the accident literature we learn of doors that open directly onto a flight of stairs, and stairs that terminate at a street where oncoming traffic is screened from view. In the former case, victims fall down the stairs; in the latter case, victims were struck by other pedestrians or even vehicles.

These are extreme cases perhaps, but it is quite common to find stairs that terminate at a corridor or a walkway. The hazards may be less severe in these circumstances, but the dangers are avoidable by improving the layout.

3.3 STAIR PLAN CONFIGURATION

3.3.1 Mass Movements

Performance Statement (T)

Stairs that may have to carry large numbers of people in the event of an emergency should be designed to facilitate flow and to avoid configurations where people become trapped and crushed at a corner or on a landing.

Discussion

During peak movement periods, a dogleg stair (see stair No. 23 in Appendix 1 for an example of this type of stair) may perform inefficiently but adequately. The flow of the stream of pedestrians will be particularly confused and uncomfortable at the landings. In the event of panic, all flow may cease as the traffic becomes jammed at the landings. The results then may be as catastrophic as in the Iroquois Theater Fire. Five hundred people died within eight minutes, most of them crushed to death on the landings of the staircase leading from the balcony[2].

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[2] Schultz, D. P., Panic Behavior: Discussion and Readings, Random House, N.Y., 1964, p. 9.

3.3.2 Traffic Conflicts

Performance Statement (V)

Avoid stair plan configurations that tend to encourage users to violate the "keep right" rule and to use routes that will bring those descending into conflict with those ascending.

Discussion

It has been demonstrated that with certain stair layouts, pedestrians are more likely to select routes that may bring them into conflict with others.[3] A dogleg stair with the flights winding up to the left is an example. The inside and shortest route, by custom, is for those descending and keeping to their right. As ascent requires much more effort, stair users have been observed to move over to their left as they approach the landing in order to take a shortcut. This brings them into conflict with those descending. With the dogleg winding up to the right, on the other hand, the shortest route is given to those ascending.

There is no evidence that conflicting paths do or do not induce accidents. It is not unusual for pedestrians to come face-to-face, and to take appropriate avoiding action. Stairs are potentially hazardous places to walk and appropriate actions are circumscribed. There are few choices available and the terrain is not level. Therefore, stair layouts should not encourage pedestrian route conflicts.

Videotape Example

- A little girl ascending on the left of a dogleg stair collides with a boy rapidly descending and keeping to his right.

3.3.3 Route Conflicts

Performance Statement (T)

Avoid paths to different areas of the building that cross on a stair.

Discussion

This is a special case of traffic conflicts discussed in 3.3.2. This time it is not the configuraton of the stair that produces the flow conflict, but the location of the stair within the environment. Two streams of traffic may be entering a single flight of stairs in a transportation terminal, for instance, and departing in different directions.

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[3] Templer, J., Stairs and Ramps, Dowden, Hutchinson and Ross, Stroudsburg, PA., forthcoming.

It has been demonstrated that the "keep right" custom on stairs will be violated routinely if there is a shortcut advantage to doing so.[4]

3.4 VISUAL SURROUNDINGS OF STAIRS

3.4.1 Orientation Factors

Performance Statement (V)

At no point on a stair should the user have to experience simultaneously several orientation factor changes--changes in illumination, view, route directions, and floor surface or level.

Discussion

From the videotape analysis, it was concluded that the high risk groups of stairs had few steps on which only one orientation factor change occurred, and many steps where a large number of orientation factor changes occurred. People were suddenly exposed to a different and rich visual environment, to sudden changes in levels of illumination, and to alternative routes that were offered at the top or bottom of the stair. Commonly these orientation factor changes occurred close to the top or bottom of a stair where the user must exercise caution while converting to a complete change of gait.

It cannot be concluded that the distracting nature of the surroundings will induce incidents. However, de-emphasizing the surrounding views, or masking manifestly interesting or changing views, will simultaneously reduce the orientation factor changes. At those places where a number of factor changes are inevitable, such as at landings, this strategy should reduce the accident rate.

Videotape Examples

- A girl descending a stair and simultaneously drinking from a cup and looking around at the surroundings catches the back of her heel on the step.

- A woman descending turns around to look at some historic murals and loses her balance.

- A middle-aged woman ascending is looking at murals and loses her balance and nearly falls.

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[4] Templer, ibid.

3.5 STAIR LAYOUT HAZARDS

3.5.1 Headroom Under Stairs

Performance Statement (G)

Where a stair rises over a walkway or a useable space, ensure that there is adequate headroom beneath.

Discussion

If there is sufficient headroom under a flight of stairs, most people may be able to avoid bumping their heads by ducking down or moving to a less constrained route. However, those that have severe visual impairments may not be able to detect the hazard. For all people there is the possibility that an accident may occur because their attention is distracted from the danger.

3.6 FLIGHT DIMENSIONS

3.6.1 Headroom Clearance (G)

Performance Statement

Ensure that the ceiling and light fixtures and other fittings cannot be bumped by stair users.

Discussion

The ceiling may provide an adequate headroom, but lights and ornamental fittings, etc., that are added often project too low. The hazard is not only the risk of bumping into the object, but also the dangers of a fall caused by a misstep in trying to avoid knocking against the object.

Headroom clearance should permit a substantial percentage of the population to pass without contact.

3.6.2 Very Short Flights

Performance Statement (V)

Special care must be taken in the design of flights of five risers or fewer to draw attention to the steps and to avoid distracting views from the steps.

Discussion

From the videotape analysis, it was clearly apparent that most of the incidents occurred on the first three or last three steps of the flights. This offers a probable explanation for the high accident rate on flights with few steps.

Obviously, there has to be some additional explanation, and it appears that orientation factors play an important role. From the videotape analysis, it seems that where a large number of orientation factor changes occur, the number of accidents increases.

By definition, the transition from stairs to landings is an orientation factor. Other orientation factors are route direction changes, changes in views and very large changes in illumination level. All of these events are more likely to take place close to landings. This suggests that it is necessary to reduce the orientation factor changes on short flights to a minimum, and to focus attention on the stairs.

Videotape Example

° A man ascends a flight towards a landing. From the landing a short flight rises to the right and another to the left. The view of the surroundings is full of interest. The man, looking at the environment, anticipates (wrongly) an extra step at the bottom of the short flight.

3.6.3 Landing Frequency

Performance Statement (T)

Provide landings at intervals such that the distance that an accident victim may fall is minimized.

Discussion

Landings serve at least two functions: (1) they reduce the potential vertical distance that a victim of a stair accident might fall, and (2) they provide a place for the stair user to stop and rest from the effort of ascending stairs.

Stair use (in ascent) demands a high rate of energy expenditure for the stair user regardless of the length of the flight. For the elderly and for those with ill health, these demands are particularly taxing. However, all of these people can slow their rates of energy expenditure by stopping on the stair, or climbing very slowly.[5] Stopping on the

[5] Templer, ibid.

stair rather than on a landing may tend to be inconvenient to other stair users, but then the same may be the case for the user who stops at a landing and there is no place to rest away from the stream of traffic.

We assume that a fall from a greater height is likely to be more damaging than a fall from a lesser height. Furthermore, a fall on a stair is not like a fall on an even surface like a ramp: the stair victim is likely to strike a series of tread nosing edges. Therefore, flight lengths should be kept short in order to reduce the potential vertical distance that a victim might fall. However, as discussed earlier, very short flights also should be avoided since these are associated with increased risk of incidents.

3.7 FLIGHT WIDTHS

3.7.1 Flight Widths for Optimal Flow

Performance Statement (T)

Congestion on stairs is potentially hazardous. Stairs to carry heavy traffic should be wide enough for the traffic to move at a comfortable speed.

Discussion

If a stair is too narrow for the peak pedestrian traffic flow, a point of congestion will occur when the speed of movement will slow greatly or even stop sporadically.

As with walking on the level, a very slow forward speed makes balancing much more difficult, and this is exacerbated on stairs when the body is being raised or lowered past a step. At the same time, the stair users will have to gather much of their perceptual information about the stair's prevailing conditions through vicarious rather than direct viewing.

While there is no evidence that these conditions cause accidents, the potential for a mishap is clearly present.

In the event of an emergency, which requires the space to be rapidly evacuated, the capacity of the stair may be of critical importance.

3.7.2 Flight Widths for Comfortable Movement

Performance Statement (T)

If passing movements or side-by-side travel on the stair are anticipated, the stair should be wide enough to permit individuals to proceed without assuming an awkward gait.

Discussion

There is no evidence to show that there is a relationship between accidents and taking evasive action to avoid others on stairs. On the other hand, there is evidence that any action that engenders an awkward gait on stairs is likely to cause missteps.[6]

For two-way stair traffic, a minimum width of 56 in. between walls and 69 in. for comfort have been recommended.[7] We have made this recommendation, even though wide stairs are associated with increased risk of incidents (see Table 2), because we do not believe that width itself is a cause of stair incidents.

3.8 VISIBILITY AND ILLUMINATION

3.8.1 Glare

Performance Statement (V)

Avoid sources of glare in the field of view when traversing stairs.

Discussion

High lighting contrasts in the field of view may be caused by ill-chosen artificial or natural lighting design. The fault may lie in the presence of a window on a landing at the bottom of an enclosed stair, or the presence of a light fitting hanging from the ceiling halfway down the stair. In both cases, the glare reduces the ability of the stair user to see the stairs.

Videotape Example

° A woman descends a stair slowly and with care, holding onto the handrail, and looking down the stair. There is glare from a bright patch of sunlight from a window in front of her. She misjudges, catches her heel on the stair and loses her balance.

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[6] Fitch, et al., "Dimensions of Stairs."

[7] Fitch, et al., ibid.

3.8.2 Transitional Lighting

Performance Statement (V)

If a threshold, step or stair is located where there is a great difference in light levels, then special care must be taken to reduce lighting contrasts.

Discussion

Thresholds and steps are often located at the entrance to a building where there is a large difference in the light levels between the inside and the outside. The eye accommodates for low light levels much more slowly than for high levels, so entering is often more difficult. If the sudden lighting change occurs on or close to a step, this creates an additional orientation factor. The videotape analysis has shown that there is a correlation between orientation factor changes and the incidence of mishaps.

To avoid this type of hazard, it is necessary to provide natural or artificial lighting in such a way that the abruptness of the lighting level change can be softened.

Videotape Example

- A girl leaving a student center through a darkened lobby does not notice a step's edge because of glare and because bright sunlight has cast a shadow parallel to the step's edge.

3.8.3 Night Lights

Performance Statement (G)

If a stairway is located adjoining or within a pedestrian movement route that may be used at night, and there is the possibility that people may unintentionally enter into or fall down the stairway, then a night light or some other protective or warning device should be provided.

Discussion

Accident studies provide many examples of people falling down stairs that they did not expect to be there.[8] The presence of a stair on or close to a path or corridor that people use must be made obvious. After dark, a permanent night light may be required.

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[8] Miller, J. A., and Esmay, M. L., "Stairway Falls," Home Safety Reviews, Winter 1958, pp. 23-25.

3.8.4 Light Switches

Performance Statement (G)

Two-way switches controlling artificial illumination for stairs should be located at the top and bottom of stairs.

Discussion

Accident studies have indicated that the use of stairs in the dark is hazardous. If the light switch is at the top or the bottom only, then stair use in the dark may be inevitable. This should be avoided.

3.8.5 Levels of Illumination

Performance Statement (G)

The level of illumination on stairs must be sufficient for the user to be able to see without difficulty.

Discussion

Poor lighting conditions were indicated in one accident survey as contributing to accidents.[9] However, few of the victims listed poor illumination as a primary or secondary factor. Nevertheless, it is self-evident that adequate illumination should always be present for traversing such a potentially hazardous series of obstacles.

3.8.6 Discrimination of Stair Detail

Performance Statement (G)

Ensure that there is a clear visual distinction between the planes representing the treads when viewed from above.

Discussion

It is self-evident that a stair should be clearly seen as a stair and not mistaken for a ramp. Each step should be perceptible.

To achieve this, the eye must be able to discriminate between each individual step and its background. This discrimination will not be achievable if light levels are too low or if the ability to discriminate is reduced by glare, or if the materials of the tread surfaces tend to distract the eye.

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[9] Miller and Esmay, ibid.

There are many ways of emphasizing the discrete nature of each step through the use of illumination and color.

3.8.7 Shadows

Performance Statement (V)

Prevent shadows from being cast on steps.

Discussion

From the videotape analysis, there are strong indications that more incidents can be expected on steps that are partially in shadow from artificial light sources.

There were too few steps shown on the videotapes with shadows from sunlight for reliable analysis, but there is no reason to suppose that the results would be any different.

Videotape Example

° A little boy about to enter a building trips over the first step leading up to it. The step is partially in shadow from bright sunlight.

3.9 RISERS AND TREADS

3.9.1 Dimensional Regularity

Performance Statement (G)

Care must be taken to avoid the construction of stairs with risers and treads that vary substantially in dimension from step to step.

Discussion

Tread depth and riser height dimensional irregularity was found in several accident studies[10] to correlate highly with the incidence of mishaps. The videotape analysis confirms these findings.

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[10] Miller and Esmay, ibid.
Velz, D. J., and Hemphill, F. M., Investigation and Application of Home Injury Survey Data in Development of Preventive Procedure, University of Michigan, School of Public Health, Ann Arbor, 1953.

3.9.2 Riser-Tread Dimensional Relationship

Peformance Statement (T)

Use a riser-tread dimensional relationship for human gait that is safe and comfortable.

Discussion

Risers and treads, singly or in consort, on which it is difficult to walk will engender missteps. For comfort and safety, certain combinations of riser and tread dimensions have been recommended.[11]

7 in.	risers with	11 in. treads
6 1/2 in.	" "	11, 11 1/2, 12, or 12 1/2 in. treads
6 in.	" "	11, 11 1/2, 12, 12 1/2, 13, 13 1/2, or 14 in. treads
5 1/2 in.	" "	11, 11 1/2, 12, 12 1/2, or 13 in. treads
5 in.	" "	11, 11 1/2, or 12 in. treads
4 1/2 in.	" "	11 in. treads
4 in.	" "	11 in. treads

There is no experimental evidence for recommendations using treads larger than 14 in. (which may be appropriate for external stairs). However, to avoid unusual gait responses that are potentially hazardous, certain precautions are necessary. Large treads that force the user into taking unusually large or small irregular paces on the level should be avoided. Treads that force the user to adopt a gait with one leg exclusively used for making the vertical movement up the risers are uncomfortable and probably more hazardous.

3.9.3 Riser Dimensions

Performance Statement (T)

For comfort and safety, risers should not be too large nor too small for human gait.

Discussion

Studies of human gait on stairs have shown that risers that are smaller than about 6.3 in. tend to engender more missteps in ascent. The videotape studies offer some indicative confirmation of this. The high risk group of stairs was found to have risers less than 6.25 in. while the low risk group had risers greater than 6.25 in.

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11 Templer, Stairs and Ramps.

In ascent, every riser is an obstacle so this suggests that the fewer the risers, the fewer obstacles there are. Expressed differently, the higher the risers, the safer the stair is. However, a point is reached when the risers are so large that it becomes difficult to use them in descent. The studies showed that this point is reached when the riser is about 7.2 in.[12] Risers larger than this were found to produce more missteps.

3.9.4 Tread Minimum Size

Performance Statement (T)

Treads should never be so small that they force the stair user to twist the shod foot laterally.

Discussion

If the treads of a stair are smaller than the shod feet of the users, this elicits an awkward gait and a higher number of missteps.[13] A small tread cannot accommodate the whole foot. In ascent, this is of little consequence because often only the front of the foot is set down on tread. In descent, however, the metatarsal heads of the foot must be set down within the tread in order to maintain balance. If the tread is less than about 11 in., then the action can only be achieved by assuming a crabwise gait.

The videotape analysis offers some indicative confirmation of this. It was found that the low risk group of stairs had treads wider than 12 in. and the high risk stairs had treads narrower than 12 in.

3.9.5 Nosing Overhang

Performance Statement (G)

Where nosings are to be used, care should be taken to ensure that the overhang is the same on each step of the flight.

Discussion

Accident studies[14] have shown that nosing overhang irregularities correlate significantly with the incidence of mishaps.

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[12] Templer, ibid.

[13] Templer, ibid.

[14] Gowings, D. D., "Accident Injuries Due to Falls," National Safety Council Transactions, Vol. 6, 1960, pp. 59-62.

3.9.6 Nosing Outline

Performance Statement (G)

Avoid the use of nosing overhangs on which those with artificial limbs can catch the toes of their shoes in ascent.

Discussion

For many people with artificial legs, nosing projections are insurmountable in ascent, or very hazardous. The same problem is present with certain types of open risers. "The American National Standard for Making Buildings Accessible to the Handicapped" specifically prohibits the use of these nosing overhangs.[15]

3.9.7 Nosing Shape

Performance Statement (G)

The edge of the tread at the nosing should not terminate with a sharp edge, nor should the nosing end with a large radius curve.

Discussion

Most stair accidents occur during descent.[16] Generally, in descent the first contact that the foot makes with the step is at the nosing. This does not provide a large area of contact to prevent loss of friction if the nosing has a sharp edge. Furthermore, the sharp edge is likely to be eroded through use fairly quickly.[17]

In ascent, a not uncommon accident is a trip which results in the shin striking the nosing. With a sharp nosing this can be a more serious mishap than with a rounded nosing. On the other hand, if the nosing is constructed with a large radius curve, it reduces the size of the tread and may make for an awkward gait as the foot tries to clear the nosing in descent.

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[15] "American National Standard: Specifications for Making Buildings and Facilities Accessible to, and Usable by, The Physically Handicapped," American National Standards Institute, Inc., New York, October 1961.

[16] Gowings, "Accident Injuries."

[17] Templer, Ramps and Stairs.

3.9.8 Wash

Performance Statement (T)

To avoid water (and ice) forming puddles on treads and landings, they should be given a very slight fall or "wash" toward the nosing.

Discussion

Liquid on the tread surface will reduce the coefficient of friction between shoe and surface to a level that may be hazardous. To avoid rain forming puddles on outdoor steps, some wash is essential. Wash may only be necesary for indoor stairs that will be cleaned periodically with water.

The wash should be very small and imperceptible and certainly not sufficient to significantly increase the risk of slipping on the tread.

3.9.9 Erosion

Performance Statement (G)

Avoid use of materials that will erode quickly as a result of heavy use.

Discussion

Uneven surfaces and irregular surface erosion has been found to be the cause of some accidents.[18] Wear is inevitable. If the traffic is so heavy that rapid erosion is unavoidable, then those portions of the tread that sustain most of the damage should be designed such that they can be replaced easily when necessary.

3.9.10 Coverings

Performance Statement (G)

If the stair is to be fitted with a surface covering such as a carpet, special care must be taken to ensure that the material is securely fixed and will not stretch or bulge through use.

Discussion

Accident studies have shown that poorly fitted carpets can be blamed for some stair accidents.[19] In some cases the poor fit was caused by bad

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18 Gowings, "Accident Injuries."

19 Velz and Hemphill, "Home Injury Survey Survey Data."

installation, and in other cases by poor materials that have not retained their shape.

3.9.11 Surface Texture

Performance Statement (G)

The surface of treads should be smooth, even and adequately abrasive to provide a non-slip surface.

Discussion

Slips on stairs were found by observers[20] to account for more than twice as many falls as any other cause.

Slips in descent tend to be more severe than in ascent. In descent the critical area is at the nosing, the place at which first contact is made while the foot still has forward motion. If the tread is slick at this point, then a slip is likely.

3.10 HANDRAIL LOCATION

3.10.1 Provide a Handrail

Performance Statement (G)

Provide a continuous handrail for the full length of every stair.

Discussion

The accident literature[21] shows that serious accidents often occur where (or because) there is no handrail available. For descent particularly, because most accidents occur during descent, it is necessary for the rail to be continuous to match the patterns of handrail use.

For the elderly and those with balance problems, or those with deliberate or handicapped gaits, the rail must be continuous and must extend sufficiently to enable the first and last steps to be negotiated.

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[20] Miller and Esmay, "Stairway Falls."

[21] Miller and Esmay, ibid.

Videotape Example

- A very old, blind woman with a walking stick is descending some steps. She feels for a handrail. There is none within reach. She loses her balance, but manages to recover.

3.10.2 A Handrail On One Side Only

Performance Statement (G)

On narrow stairs where a single rail is provided, a rail on the right side for descent is preferable.

Discussion

From the accident literature we know that most serious accidents occur in descent.[22] We also know tht people tend to walk to the right of the stair and therefore use the right handrail during descent.[23] It follows that this location is likely to be the most beneficial if only a single rail is to be provided.

Videotape Example

- A young girl with an artificial leg has to use the only handrail which is to her left.

- A boy descends on the right side of a stair. His foot slips off the edge of the tread, but he is holding the rail and this prevents a more serious fall.

3.10.3 Handrails on Both Sides of the Stair

Performance Statement (G)

It is preferable to provide handrails on both sides of a flight of stairs. This is particularly necessary for the elderly and the young.

Discussion

If no handrail is within reach, then from the accident literature[24] we know that the likelihood of a serious accident increases. A handrail

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22 Gowings, "Accident Injuries."

23 Templer, Stairs and Ramps.

24 Miller and Esmay, "Stairway Falls."

on only one side of the stair may not be within reach. Furthermore, not all people have equal strength or use from both hands and arms; they may be restricted as to which rail they can use.

People tend to keep to the right on stairs[25], so for a handrail to be conveniently at hand, for those in ascent and descent, a rail on both sides is necessary.

For the young who have a disproportionately high accident rate, and for the elderly who have the most serious accidents, it is particularly necessary to ensure that handrails are available on both sides.

Videotape Example

- An old man descending a stair and keeping to his right is forced to move aside for another old man ascending. There is only one rail and the man ascending is using it.

3.10.4 Handrails on Wide Stairs

Performance Statement (G)

If a stairway is sufficiently wide for two or more to walk abreast, then handrails on both sides should be supplied.

Discussion

If the stairway is wide enough for two streams of traffic, then omitting the rail on the one side would jeopardize a person in that stream in the event of a misstep. It is clear from the accident literature that the absence of a handrail within reach is linked to the incidence of accidents severe enough to require hospitalization.[26]

Videotape Example

- A girl descending on the left of a wide stair catches her foot on the tread and reaches for the handrail. There is none on the left side of the stair. She recovers her balance by leaning on the wall.

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25 Templer, Stairs and Ramps.

26 Miller and Esmay, "Stairway Falls."

3.10.5 Channeling

Performance Statement (T)

If the stair in a public place is to be divided into channels, then each channel should be provided with handrails on both sides.

Discussion

The channeling of pedestrians on stairs can be an effective way of controlling flow in heavily used public areas. However, at peak periods when congestion is present, the forward speed of traffic, even is it is channelized, is greatly reduced. For many people, handrails are required during ascent and descent to counteract the inherent instability of their slow motion.

3.11 HANDRAIL HEIGHTS

3.11.1 Handrails for Children

Performance Statement (T)

For preschool age children, handrails should be lower than for the general population.

Discussion

Very young children use a deliberate gait on stairs, first because their walking skills are not fully developed, and second because for them the risers are very high. So this group will tend to crawl up the stairs and back down, or to hold the rail or someone's hand.

From the videotape analysis, and from the accident literature, we know that the very young are more likely to have accidents than the rest of the population; and we know that accidents are more likely to occur (or are more serious) where there is no handrail. To provide for the special needs of young children, it is desirable to locate handrails at a height that is convenient for them.

3.11.2 Heights for Children and Adults

Performance Statement (T)

Handrails for adults and handrails for children should be installed at a height that will be comfortably at hand during stair use.

Discussion

It is self-evident that if handrail heights fall outside of a certain range they will be ineffective for guidance and support.

A handrail should be within reach. A handrail that is low enough for preschool children will be much too low for most adults, and a rail that is high enough to be comfortable for most adults may be useless for young children. There is no single height that is convenient for adults and young children.

There is some consensus, not based on studies, that for adults the top of the rail should be set 30 to 34 in. vertically above the nosing; and for young children a second rail that is 24 in. high should be provided.

3.12 STAIR HANDRAIL DESIGN

3.12.1 Materials

Performance Statement (T)

Handrails should be constructed of materials that are smooth. In places that are not protected from the weather, the handrail should be a poor conductor of heat.

Discussion

Handrails that are too hot or cold for haptic comfort and rails that feel abrasive are likely to discourage use. This would be hazardous for those with gait or balance limitation, and the very young and the very elderly.

3.12.2 Shape

Performance Statement (T)

Handrails should be designed so that they can be grasped firmly with a comfortable grip, and so that the hand can be slid along the rail without encountering obstructions.

Discussion

In ascent, handrails are used with a series of grasping motions as something to pull on. In descent the hand usually slides down the rail, remaining in contact with it. In ascent and descent the rail is used as something to hold onto, lean on to, and to maintain balance with. These actions can be carried out safely if the profile of the rail comfortably matches the hands grip, and if the hand is not forced by supports or other obstructions to loosen its hold on the rail.

Videotape Example

- The videotape segments provide confirmation of the way handrails are used, both routinely and for emergencies.

3.13 GUARDRAILS

3.13.1 Stair Well Protection

Performance Statement (G)

To prevent people from falling off stairs or into stair wells, protection must be provided.

Discussion

The accident literature is replete with examples of people falling into unprotected stair wells, or falling off the sides of stairs, or even falling through balustrading that is spaced too widely. Other accidents occur when the protective guardrail breaks under the load of the impact of someone falling against it.

These accidents are preventable if adequate precautions are taken and there are many appropriate countermeasures.

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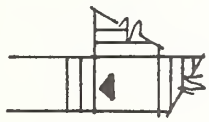
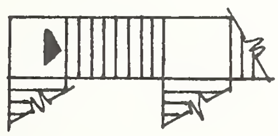
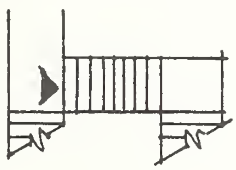
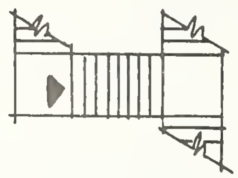
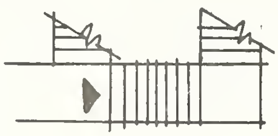
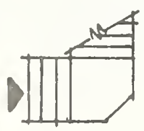
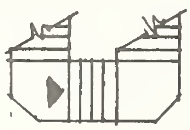
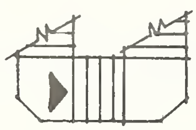
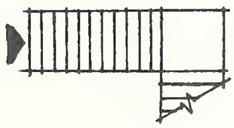
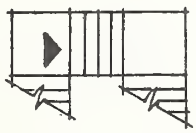
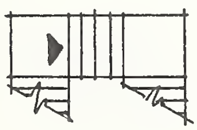
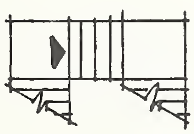
APPENDIX 1

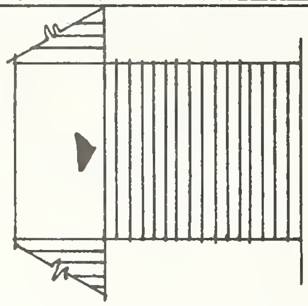
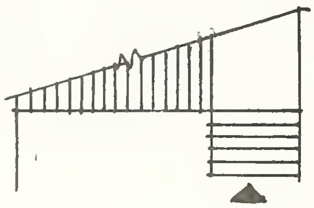
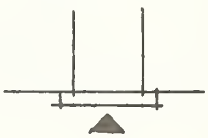
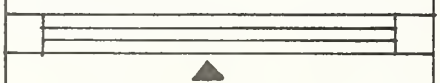
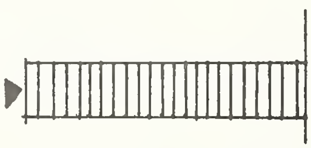
LAYOUT, AVERAGE DIMENSIONS (INCHES) AND SURFACE OF THE STAIR SAMPLE*

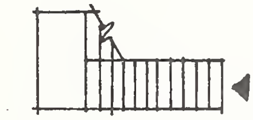
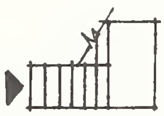
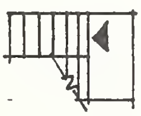
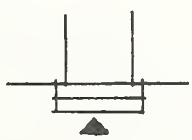
NO.	PLAN	RISER	TREAD	WIDTH	SURFACE
1		6	11	60	Terrazzo
2		6	11	60	Terrazzo
3		6	11	59	Terrazzo

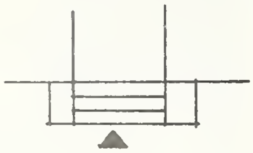
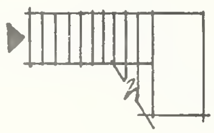
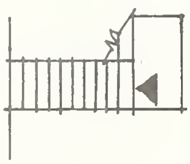
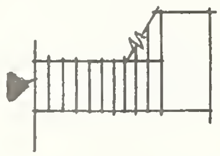
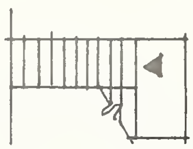
* THE INDEX TO APPENDIX 1 IS ON PAGE 49.

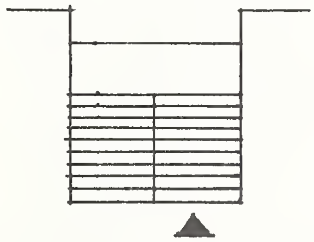
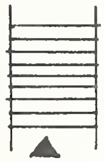
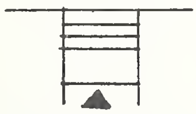
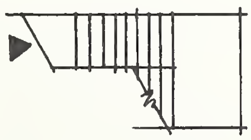
NO.	PLAN	RISER	TREAD	WIDTH	SURFACE
4		5.9	10.9	58	Terrazzo
5		5.9	11	60	Terrazzo
8		6	11	60	Terrazzo
9		5.9	11	59	Terrazzo
10		5.9	11	60	Terrazzo

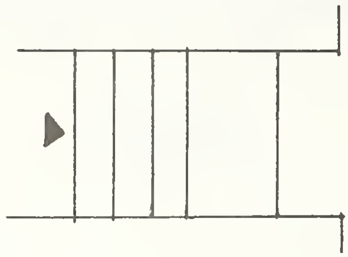
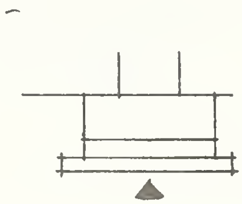
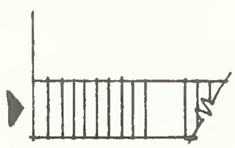
NO.	PLAN	RISER	TREAD	WIDTH	SURFACE
11		5.9	10.9	60	Terrazzo
12		5.9	11	60	Terrazzo
13		5.9	11	59	Terrazzo
14		5.9	11	59	Terrazzo
15		6	11	59	Terrazzo

NO.	PLAN	RISER	TREAD	WIDTH	SURFACE
17		6.5	14.2	173	Travertine
18		6.5	14.2	89	Travertine
20		5.2	12	66	Granite
21		6	12	357	Granite
22		6.9	12.5	49	Concrete

NO.	PLAN	RISER	TREAD	WIDTH	SURFACE
23		7.5	11.3	46	Steel
24		7.5	11.2	44	Steel
25		8.2	13	43	Steel
26		7.6	13	44	Steel
27		6	11.8	81	Concrete

NO.	PLAN	RISER	TREAD	WIDTH	SURFACE
28		5.5	12	90	Concrete
29		7.3	10.6	47	Concrete
30		7	10.6	43	Concrete
31		7.2	10.5	46	Concrete
32		7.2	10.5	46	Concrete

NO.	PLAN	RISER	TREAD	WIDTH	SURFACE
33		6.7	9.7	83	Concrete
34		7.2	10.9	88	Terrazzo
35		6.8	12	71	Stone
36		6.0	14	55	Concrete
37		6.8	12	55	Steel

NO.	PLAN	RISER	TREAD	WIDTH	SURFACE
39		5.3	36	168	Concrete
40		7.1	14	100	Granite
41		5.6	12	59	Concrete
42		7	11	55	Terrazzo
43		6.9	10.9	55	Terrazzo

INDEX TO APPENDIX 1

Stair Number	Stair Location	Building Type
1-15	Shopping Center A	
16	**Excluded from analysis**	
17-18	Presidential Memorial Library	
19	**Excluded from analysis**	
21-22	University Student Center	
22	Shopping Center B	
23-26	Pre-School/Day Care Center A	School
27-32	Pre-School/Day Care Center B	School
33-34	Senior Citizens Center A	Community Center
35-36	Senior Citizens Center B	House
37	Senior Citizens Center C	Church
38	**Excluded from analysis**	
39-41	General Community Center A[a]	
42-43	General Community Center B[a]	

[a] Stair use by elderly observed.

NOTE. The symbol > in the stair diagrams indicates the "up" direction.

APPENDIX 2
CODE VARIABLES

1. Stair Number

2. Time of Day

3. Day of Week

   0. Unknown
   1. Sunday
   2. Monday
   3. Tuesday
   4. Wednesday
   5. Thursday
   6. Friday
   7. Saturday

4. Subject ID Number

GROUP A - STAIR USER CHARACTERISTICS

5. Age

   1. Less than 5 years
   2. 5 to 9 years old
   3. 10 to 14 years old
   4. 15 to 44 years old
   5. 45 to 64 years old
   6. 65 years and over

6. Sex

   1. Male
   2. Female
   3. Doubtful, unclear

7. Race

   1. White
   2. Black
   3. All others

8. Body Type

   1. Very underweight
   2. Average weight
   3. Very overweight

9. Vision

   1. Not wearing glasses
   2. Wearing glasses (including sun glasses)
   3. Unclear

10. Use of Walking Aids

   1. No special aids used
   2. Cane(s) or walking stick(s)
   3. Crutch(es)
   4. Artificial leg(s)
   5. Wheelchair
   6. Walks with a limp
   7. Other

11. Upper Extermity Impairment

   1. No visible impairment
   2. Left arm impaired or missing
   3. Right arm impaired or missing
   4. Both arms impaired or missing
   5. Other impairment

12. Type of Clothing Below Waist

   1. Pants, long or short
   2. Skirt or dress
   3. Other

13. Length of Clothing Below Waist

   1. Above knee
   2. Below knee
   3. Floor length

14. Fit of Clothing Below Waist

   1. Close-fitting, tight
   2. Average
   3. Very loose, voluminous

15. Type of Footwear

    1. No shoes
    2. Lace-up
    3. Lace-up, untied
    4. Strap or buckled
    5. Slip-on
    6. Other or unclear
    7. Boots

16. Type of Heel

    1. Flat sole, no heel
    2. Regular heel
    3. High heel
    4. Platform shoes
    5. Other, or unclear
    6. No shoes

GROUP B - USER BEHAVIOR CHARACTERISTICS

17. Speed of Movement

    (Time taken to traverse 3 steps)

    1. More than 4 seconds
    2. 3 to 3.9 seconds
    3. 2 to 2.9 seconds
    4. 1.5 to 1.9 seconds
    5. Less than 1.5 seconds
    6. No observation possible

18. Gait

    1. Unstable or tottering
    2. Slow and deliberate
    3. Unconcerned, normal
    4. Jaunty, playful
    5. Acrobatic, athletic

19. Carrying Objects - How Carried

    1. Not carrying anything
    2. Carried in hand
    3. Carried on arms
    4. Carried on shoulder
    5. Other

20. Carrying Object - Side Carried

    1. Not applicable
    2. Carried on left side
    3. Carried on right side

21. Carrying Object - Type of Object

    1. Not applicable
    2. Human animate (child)
    3. Non-human animate (pet)
    4. Inanimate

22. Carrying Object - Size of Object

    1. Not applicable
    2. Largest dimension smaller than 12 in.
    3. Largest dimension smaller than 24 in.
    4. Largest dimension greater than 24 in.

23. User Group Ecology

    1. Alone
    2. Accompanied by one other
    3. Accompanied by two or more
    4. Other

24. Direction of Movement

    1. Up
    2. Down

25. Incident Outcome

    1. Non-incident
    2. Sat down
    3. Fell forward
    4. Lost balance but did not fall
    5. Other

26. Severity of Incident

1. Non-incident
2. Minor gait or postural adjustment
3. Aborted fall
4. Body/floor contact

27. Step Number

(The step on which an incident occurred - or no incident)

28. Incident

1. No incident
2. Foot slipped off edge of tread (in ascent or descent)
3. Tripped over riser
4. Foot too far forward on tread
5. Caught heel on edge of tread

29. Stair Channel

1. Left third of stair
2. Center third of stair
3. Right third of stair (always in the direction of travel)

30. User's Attention: Facing:

1. Forward
2. Backward

31. User's Attention: Direction:

1. Left (in direction of travel)
2. Center
3. Right (in direction of travel)

32. User's Attention: Elevation

1. Up
2. Level
3. Down

33. Apparent Object of Attention

1. Steps
2. Other people on stair
3. Other people not on stair
4. Environment
5. Other, or unclear
6. Something carried

34. Handrail Use

1. None
2. Left hand on left rail
3. Right hand on right rail
4. Both hands on left rail
5. Both hands on right rail
6. Left arm against left rail
7. Right arm against right rail
8. Emergency reaction to incident

35. Type of Handrail Use

1. None
2. Physical support
3. Pulling up
4. Balance
5. Guidance

36. Density of Traffic Ahead -- Within six feet there are:

1. No people ahead of the subject
2. 1 or 2 people ahead of subject
3. 3 or 4 people ahead of subject
4. 5 or 6 people ahead of subject
5. More than 6 people ahead subject
6. Unclear

37. Density of Traffic Behind -- Within six feet there are:

    1. No people behind the subject
    2. 1 or 2 people behind subject
    3. 3 or 4 people behind subject
    4. 5 or 6 people behind subject
    5. More than 6 people behind subject
    6. Unclear

38. Reactions to Other Stair Users

    1. No apparent reaction
    2. Watching another or others
    3. Progress impeded by another
    4. Changing direction to avoid others
    5. Other

39. Assistance in Stair Use

    1. Not helped
    2. Physically helped by one person
    3. Physically helped by more than one person
    4. Not helped but holding hands

GROUP C - ENVIRONMENTAL CONDITIONS

40. Lighting Contrast

    1. Step has no shadows on it
    2. Step in part shadow from artificial light
    3. Step in part shadow from sunlight
    4. Step in full shadow
    5. Step in full light

41. Illumination on Step

    1. Very high level of illumination
    2. Average level of illumination
    3. Very low level of illumination

42. Obstruction on Stair

    1. No obstruction
    2. Litter on stair
    3. Other (inaminate objects)

43. Steps in Flight

44. Stair Width

45. Riser Height

46. Tread Depth

47. Nosing Projection

48. Wash

    (forward inclination of a tread)

49. Handrail Extent

    1. Handrail on user's left only
    2. Handrail on user's right only
    3. Handrail on both sides
    4. No handrail present (Always in ascent)

50. Stair Surface

1. Brushed concrete
2. Brushed concrete with insert
3. Brushed concrete with metal edging
4. Steel soil checker plate
5. Granite - rough findish
6. Unpolished terazzo
7. Stone - rough finish
8. Polished terrazzo with metal edge
9. Exposed aggregate
10. Travertine polished
11. Polished terrazzo with insert
12. Vinyl asbestos

51. Ascent Lateral View

1. Open one side
2. Open one side with rich view
3. Open both sides
4. Open both sides with rich view
5. Closed both sides

Note: A rich view connotes a view with many people or conditions to attract one's attention.

52. Descent Lateral View

1. Open one side
2. One one side with rich view
3. Open both sides
4. Open both sides with rich view
5. Closed both sides

53. Ascent Frontal View

1. Open front
2. Open front plus rich view
3. Closed front

54. Descent Frontal View

1. Open front
2. Open front plus rich view
3. Closed front

55. Ascent Overhead View

1. Open above
2. Open above with rich view
3. Closed overhead

56. Descent Overhead View

1. Open above
2. Open above and rich view
3. Closed overhead

57. Ascent Orientation Gradient*

1. Constant, no change
2. Change of 1 factor
3. Change of 2 factors
4. Change of 3 factor
5. Change of 4 more factors

58. Descent Orientation gradient*

1. Constant, no change
2. Change of 1 factor
3. Change of 2 factors
4. Change of 3 factors
5. Change of 4 or more factors

* Note: Orientation gradient is a measure of the cumulative effect of the orientation factors that are presented to stair users as they pass from step to step. The following factors, in the form of a checklist, were used to code variables 57 and 58: changes in lateral, frontal or overhead views; changes in illumination on the step; changes in ambient conditions; changes that will induce a gait alteration such as will occur at a landing; and changes of direction of pedestrian movement at the top or bottom of a flight.

APPENDIX 3

TABULATIONS OF STATISTICAL MATERIAL

TABLE 5 INCIDENTS AND ASSISTANCE IN STAIR USE

COUNT ROW PCT COL PCT TOT PCT	NON-INCIDENT 0	INCIDENT 1	ROW TOTAL
LIGHT 1 NO SHADOWS ON ST	84 48.6 86.6 41.6	89 51.4 84.8 44.1	173 85.6
2 PART SHADOW - ARTIFICIAL	1 11.1 1.0 .5	8 88.9 7.6 4.0	9 4.5
3 PART SHADOW - SUNLIGHT	8 72.7 8.2 4.0	3 27.3 2.9 1.5	11 5.4
4 STEP IN FULL SHADOW	4 44.4 4.1 2.0	5 55.6 4.8 2.5	9 4.5
COLUMN TOTAL	97 48.0	105 52.0	202 100.0

RAW CHI SQUARE = 5.46952 WITH 2 DEGREES OF FREEDOM.
SIGNIFICANCE = .0649

TABLE 6 INCIDENTS AND REACTIONS TO OTHER STAIR USERS

COUNT ROW PCT COL PCT TOT PCT	NON-INCIDENT 0	INCIDENT 1	ROW TOTAL
REACTIONS 1 NO APPARENT REACTION	91 50.8 93.8 45.0	88 49.2 83.8 43.6	179 88.6
2 WATCHING OTHERS	6 31.6 6.2 3.0	13 68.4 12.4 6.4	19 9.4
3 PROGRESS IMPEDED BY OTHERS	0 0 0 0	3 100.0 2.9 1.5	3 1.5
5 CHANGING DIREC-TIONS TO AVOID OTHERS	0 0 0 0	1 100.0 1.0 .5	1 .5
COLUMN TOTAL	97 48.8	105 52.0	202 100.0

RAW CHI SQUARE = 6.32231 WITH 3 DEGREES OF FREEDOM.

SIGNIFICANCE = .0969

TABLE 7 INCIDENTS AND TYPE OF HANDRAIL USE

COUNT ROW PCT COL PCT TOT PCT	NON- INCIDENT 0	INCIDENT 1	ROW TOTAL
HANDRAIL USE			
1 NONE	64 50.4 66.0 31.7	63 49.6 60.0 31.2	127 62.9
2 PHYSICAL SUPPORT	0 0 0 0	2 100.0 1.9 1.0	2 1.0
3 PULLING UP	0 0 0 0	7 100.0 6.7 3.5	7 3.5
4 BALANCE	3 15.8 3.1 1.5	16 84.2 15.2 7.9	19 9.4
5 GUIDANCE	30 63.8 30.9 14.9	17 36.2 16.2 8.4	47 23.3
COLUMN TOTAL	97 48.0	105 52.0	202 100.0

RAW CHI SQUARE = 21.21480 WITH 4 DEGREES OF FREEDOM.

SIGNIFICANCE = .0003

TABLE 8 INCIDENTS AND USER GROUP ECOLOGY

COUNT ROW PCT COL PCT TOT PCT	NON- INCIDENT 0	INCIDENT 1	ROW TOTAL
ECOLOGY 1 ALONE	56 57.7 57.7 27.7	41 42.3 39.0 20.3	97 48.0
2 ONE COMPANION	18 42.9 18.6 8.9	24 57.1 22.9 11.9	42 20.8
3 2 OR MORE COMPANIONS	22 35.5 22.7 10.9	40 64.5 38.1 19.8	62 30.7
4 OTHER	1 100.0 1.0 .5	0 0 0 0	1 .5
COLUMN TOTAL	97 48.0	105 52.0	202 100.0

RAW CHI SQUARE = 9.09998 WITH 3 DEGREES OF FREEDOM.

SIGNIFICANCE = .0280

TABLE 9 INCIDENTS AND OBJECTS CARRIED: HOW CARRIED

COUNT ROW PCT COL PCT TOT PCT	NON- INCIDENT	INCIDENT	ROW TOTAL
OBJECTS CARRIED 1 NOTHING CARRIED	58 51.8 59.8 28.7	54 48.2 51.4 26.7	112 55.4
2 CARRIED IN HAND	30 43.5 30.9 14.9	39 56.5 37.1 19.3	69 34.2
3 CARRIED ON ARMS	2 18.2 2.1 1.0	9 81.8 8.6 4.5	11 5.4
4 CARRIED ON SHOULDER	7 70.0 7.2 3.5	3 30.0 2.9 1.5	10 5.0
COLUMN TOTAL	97 48.0	105 52.0	202 100.0

RAW CHI SQUARE = 7.06557 WITH 3 DEGREES OF FREEDOM.

SIGNIFICANCE = .0698

TABLE 10 INCIDENTS AND GAIT

COUNT ROW PCT COL PCT TOT PCT	NON- INCIDENT 0	INCIDENT 1	ROW TOTAL
GAIT 1 UNSTABLE	1 10.0 1.0 .5	9 90.0 8.6 4.5	10 5.0
2 SLOW AND DELIBERATE	15 34.1 15.5 7.4	29 65.9 27.6 14.4	44 21.8
3 UNCONCERNED -NORM	61 61.0 62.9 30.2	39 39.0 37.1 19.3	100 49.5
4 JAUNTY-PLAYFUL	20 43.5 20.6 9.9	26 56.5 24.8 12.9	46 22.8
5 ACROBATIC-ATHLET	0 0 0 0	2 100.0 1.9 1.0	2 1.0
COLUMN TOTAL	97 48.0	105 52.0	202 100.0

RAW CHI SQUARE = 18.18885 WITH 4 DEGREES OF FREEDOM.

SIGNIFICANCE = .0011

TABLE 11 INCIDENTS AND SPEED OF MOVEMENT

COUNT ROW PCT COL PCT TOT PCT	NON- INCIDENT 0	INCIDENT 1	ROW TOTAL
SPEED 1 MORE THAN 4 SECONDS	0 0 0 0	3 100.0 2.9 1.5	3 1.5
2 3 TO 3.9 SECONDS	2 25.0 2.1 1.0	6 75.0 5.7 3.0	8 4.0
3 2 TO 2.9 SECONDS	30 65.2 30.9 14.9	16 34.8 15.2 7.9	46 22.8
4 1.5 TO 1.9 SECONDS	14 60.9 14.4 6.9	9 39.1 8.6 4.5	23 11.4
5 LESS THAN 1.5 SECONDS	10 55.6 10.3 5.0	8 44.4 7.6 4.0	18 8.9
6 NO OBSERVATION POSSIBLE	41 39.4 42.3 20.3	63 60.6 60.0 31.2	104 51.5
COLUMN TOTAL	97 48.0	105 52.0	202 100.0

RAW CHI SQUARE = 14.93048 WITH 5 DEGREES OF FREEDOM.

SIGNIFICANCE = .0107

TABLE 12 INCIDENTS AND LENGTH OF CLOTHING BELOW THE WAIST

COUNT ROW PCT COL PCT TOT PCT	NON- INCIDENT 0	INCIDENT 1	ROW TOTAL
CLOTHING 1 ABOVE KNEE	19 33.3 19.6 9.4	38 66.7 36.2 18.8	57 28.2
2 BELOW KNEE	5 55.6 5.2 2.5	4 44.4 3.8 2.0	9 4.5
3 FLOOR LENGTH	73 53.7 75.3 36.1	63 46.3 60.0 31.2	136 67.3
COLUMN TOTAL	97 48.0	105 52.0	202 100.0

RAW CHI SQUARE = 6.87369 WITH 2 DEGREES OF FREEDOM.

SIGNIFICANCE = .0322

TABLE 13 INCIDENTS AND AGE

COUNT ROW PCT COL PCT TOT PCT	NON- INCIDENT 0	INCIDENT 1	ROW TOTAL
AGE 1 LESS THAN 5 YRS OLD	2 15.4 2.1 1.0	11 84.6 10.5 5.4	13 6.4
2 5 TO 9 YRS OLD	17 37.0 17.5 8.4	29 63.0 27.6 14.4	46 22.8
3 10 TO 14 YRS OLD	30 60.0 30.9 14.9	20 40.0 19.0 9.9	50 24.8
4 15 TO 44 YRS OLD	39 58.2 40.2 19.3	28 41.8 26.7 13.9	67 33.2
5 45 TO 64 YRS OLD	4 23.5 4.1 2.0	13 76.5 12.4 6.4	17 8.4
6 65 YRS AND OVER	5 55.6 5.2 2.5	4 44.4 3.8 2.0	9 4.5
COLUMN TOTAL	97 48.0	105 52.0	202 100.0

RAW CHI SQUARE = 17.75401 WITH 5 DEGREES OF FREEDOM.

SIGNIFICANCE = .0033

TABLE 14 SIGNIFICANT CHARACTERISTICS OF HIGH AND LOW RISK STAIRS - A COMPARISON*

	HIGH RISK	LOW RISK		HIGH RISK	LOW RISK
No. of Steps					
< 10	14	0	p<.01	2.88	11.12
≥ 10	0	54		11.12	42.88
Width					
< 60 in.	14	0	p<.01	2.88	11.12
≥ 60 in.	0	54		11.12	42.88
Riser Height					
< 6.25 in.	14	30	p<.01	9.06	34.94
≥ 6.25 in.	0	24		4.94	19.06
Tread Depth					
≤ 12 in.	11	24	.01<p<.05	7.10	32.90
> 12 in.	0	32		3.90	18.20
Nosing Projection					
0 in.	14	27	p<.01	8.44	32.56
> 0 in.	0	27		5.56	21.44

* High risk stairs: 1, 5, 20. Low risk stairs: 11, 12, 22.

Values for characteristics of high and low risk stairs in the two columns at the left of the table are actual or observed values; those in the two columns at the right are expected values under the null hypothesis of homogeneity of values. The obtained level of significance or p-level is in the middle column.

TABLE 14 - CONTINUED

	HIGH RISK	LOW RISK		HIGH RISK	LOW RISK
Stair Surface					
Polished Terrazzo w/ Insert	12	30		8.65	33.35
			.01<p<.05		
Other	2	24		5.35	20.65
Ascent Lateral View					
Open 1 side	0	18		3.27	14.73
Open 1 side w/rich view	9	21	.01<p<.05	5.45	24.55
Open 2 sides w/rich view	3	15		3.27	14.73
Descent Lateral View					
Open 1 side	0	18		3.49	14.51
Open 1 side w/rich view	9	21	.01<p<.05	5.82	24.18
Open 2 sides w/rich view	4	15		3.69	15.31
Descent Frontal View					
Open Front	14	36		10.29	39.71
Closed Front	0	18	.01<p<.05	3.71	14.29

All other variables showed no heterogeneity.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The National Bureau of Standards has conducted research for the Consumer Product Safety Commission the objective of which is to recommend ways to reduce the frequency and severity of stair and landing accidents. One of the several approaches to identifying stair hazards is to videotape stair use in a variety of public settings. About 50 hours of videotape of stair use have been collected and it has been processed in various ways to provide information on typical human responses to stairs and landings. This report of an analysis of videotape of stair use focuses on the relationship between the occurrence of incidents, including falls, and the stair users' characteristics, user behavior, and environmental conditions. The analysis relies, in part, on a comparison of matched samples of incident and non-incident user groups. Based on the findings of the analysis, a literature review, and other research on stair use by the authors, 44 performance statements are proposed which, if applied to stair design, should substantially reduce the frequency and severity of stair accidents.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Architectural design; design considerations; dimensional relationships; environmental design; safety; stairs; user needs.

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