Recommendations for improving the safety of stairs
Pauls, J. L.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20374154
Building Practice Note, 1982-06-01

ISSN 0701-5216

BUILDING PRACTICE NOTE

RECOMMENDATIONS FOR IMPROVING THE SAFETY OF STAIRS

by

J.L. Pauls

Division of Building Research, National Research Council of Canada

Ottawa, June 1982

RECOMMENDATIONS FOR IMPROVING THE SAFETY OF STAIRS

by

J.L. Pauls

These recommendations apply to the improvement of existing stairs and the construction of new ones. The recommendations are based largely on results of research conducted since 1967. Brief summaries of this research, included with suggestions for further reading, are provided at the end of this Note.

A general caution concerning improvements to existing stairs must be stressed right at the beginning. Avoid introducing new hazards to a stair while attempting to improve it either for safety or for general appearance. For example, new tread coverings must be carefully selected and properly installed. Even adding a handrail can create new safety problems if it is not securely fixed.

Six general principles for improving existing stairs have been prepared by a U.S. National Bureau of Standards research team and these are quoted directly from the team's report, "Guidelines for Stair Safety," (National Bureau of Standards Building Science Series 120, 1979):

"1. Upgrade the stairs most frequently used by the most vulnerable people first. Children under the age of 5 have twice as many stair accidents as their proportion of the population suggests they should. Accidents among older people, while less frequent, are much more likely to lead to serious injuries or even death. People with hearing problems, epilepsy, frequent dizzy spells, or similar medical problems are vulnerable to having these conditions aggravated by the effort required to use the stair. Persons who wear bifocals or hearing aids are particularly susceptible to subtle deceptions on stairs.

"2. Avoid piecemeal repairs and temporary patches on stairs. A flight of stairs is a single unit and any improvements that are made should contribute to the uniformity of the materials and dimensions of the whole assembly from landing to landing. One-shot improvements like tacking down a rubber mat on one tread where the carpet appears worn, cement infill for a broken concrete nosing, or a piece of framing lumber to replace a single hardwood tread are often worse than no improvements at all. A lot of accidents are caused by makeshift repairs that the householder thought would make the stairs more safe.

"3. Do not try to learn new skills while fixing stairs. Some improvements or repairs on stairs require expertise that most householders do not have. When it comes to stretching a carpet or replacing resiliant tile it may be more economical from a safety standpoint to have the work done professionally. Proper installation of most materials is far more critical on a stair than it is elsewhere in the home.

"4. There are upper, as well as lower limits to safe conditions on stairs. There is a relatively wide range of material and dimensional characteristics that can support safe behavior on stairs, yet treads can be too long and risers can be too low for safe passage. Treads that are so resistant to slipping that the foot will not move when it should or lights that are so intense that all visual information is washed out can be just as hazardous as icy stairs in the dark. Safe practices, if carried to extremes, can produce unsafe stairs.

"5. Compensate for all defects that cannot be corrected. While dimensional characteristics of a stair are seldom amenable to change, it is often possible to alert the user to steep or irregular stairs, low headroom or a missing landing with a strip of reflective tape, special lighting, or a warning sign. It may also be possible to add extra handrails or more slip-resistant tread materials where precarious situations cannot be avoided. The key to stair safety does not lie so much in the hazard itself as it does in the user's awareness of his vulnerability to the hazard. If someone sees a short tread or a high riser he can grab the handrail, step cautiously, and usually avoid an accident. On the other hand, if there is no handrail or the stairs are difficult to see, he may be less fortunate.

"6. Avoid repairs or renovations near the stairs that could create new hazards. A new exhaust fan over an exit stair could lead the user to turn his head and miss an otherwise visible hazard. A new window near the stairs can introduce shadows or patches of glare that confound the user's ability to see the nosing of a tread at certain times of the day. Repaving a driveway can shorten the bottom riser of an adjacent stair by the depth of the paving and thereby introduce a non-uniform bottom step. Safe stairs are as dependent on the conditions which surround them as they are on the materials and dimensions of the stair itself. Changes in the surroundings can negate otherwise safe conditions on a stair."

RECOMMENDATIONS FOR EXISTING STAIRS AND NEW STAIRS

The basic criteria for stair safety are:

a) Make stair treads large enough so that footing is secure.
b) Provide graspable handrails.
c) Make sure the stairs can be seen.

The criteria are detailed in this order, with first priority given to geometry - a factor that is best dealt with early in the design and construction processses. Inadequacies in design are not easily corrected later.

1. Step geometry

A. Stair risers should be at least 125 mm (5 in.) high and no higher than 180 mm (7 in.). Treads should be at least 280 mm (11 in.), preferably 300 mm (12 in.) deep, measured horizontally between tread nosings. This results in a maximum pitch, or steepness, of 33°.* This recommendation applies to stairs used by elderly persons, young children and others with mobility impairments; thus there is good reason for applying this standard to domestic stairs as well as public stairs. Maximum tread dimensions have not been well studied, however research has shown that treads up to 350 mm (14 in.) function well. In special cases, such as aisle stairs, where pitch cannot be held below 33°, the provision of adequate treads should take precedence over keeping risers below 180 mm (7 in.).

B. Riser and tread dimensions should be uniform. If there is more than 5 mm (3/16 in.) nonuniformity between adjacent treads or between adjacent risers (as may occur at the top or bottom of a flight due to structural settling) apply measures such as described in 2 below to improve perception of the hazard, or adjust or rebuild the stairs - particularly when step dimensions differ by more than 25 mm (1 in.). When doing this, keep treads as consistent as possible in terms of surface characteristics. (See 2 below.) The problem of nonuniformities, due to uneven settling, at the bottom or top of a flight can be largely overcome by designing and constructing upper and lower landings that are structurally integral with the stair flight.

---

*The recommendation for moderate-pitch stairs is not new. Architectural history contains frequent references to good stair design, stressing the importance of adequate treads and moderate pitch. Modern research such as reported in the October 1974 issue of Scientific American, demonstrates how important adequate treads and suitable risers are to safety. Moreover, with increasing concern about improved accessibility of buildings for a wide range of disabled persons, including the elderly and others with moderate mobility impairments, many standards dealing with design for disabled persons have included the above recommendations.

C. Helical or spiral stairs, many curved stairs, and winders or wedge-shaped treads are used differently than stairs with parallel tread nosings, where a consistent tread is provided regardless of where a person walks on the stair. An important consideration in designing stairs with nonuniform treads is the tread depth at the "walking line" as it is called in some European stair literature. This is the centreline for foot placement and it normally occurs approximately 250-300 mm (10-12 in.) in from the handrail on the side of the stair having the largest treads. On heavily used stairs this line passes through the center of the wear or erosion marks.

One reasonable rule of thumb for curved stairs that might be used by large numbers of people (such as in evacuations) is to make the smaller inside radius not less than twice the width of the stair and to provide a minimum tread depth of 280 mm (11 in.) at the inner walking line. For example a stair having a width of 1200 mm (48 in.) between handrails and an inside radius of 2440 mm (96 in.) would have treads 250 mm (10 in.) deep at the inner radius and 375 mm (15 in.) at the outer radius. Tread depths between the inner and outer walking lines would be approximately 280-350 mm (11-14 in.), the range of tread depths described in 1A.

Helical or spiral stairs and stairs with winders, or wedge-shaped treads, are suitable only for low use or mostly unidirectional travel situations. Users should not have to compete for the preferred walking-line position on the outer side of the stair, where treads should ideally be sized as described in 1A, at least 280 mm (11 in.) deep, measured horizontally between nosings.

An additional consideration, where a descending person may meet someone ascending, is to select the direction of turn of the stair so that a person descending has the outside handrail on his or her right side. Under the commonly respected keep-to-the-right rule, the descending person would then have the safer tread depth. If the stairs are wide enough to permit such counterflow usage, they should also provide adequate treads, for ascent purposes, at the inner walking line, 250-300 mm (10-12 in.) from an inner handrail. Continuously graspable handrails at the inner side of such stairs are described below in section 4.

D. Aisle stairs pose special problems of design and use. Design infill steps between seating platforms so that all treads in the aisle are uniform. Do not have infill treads smaller than those at the seating platforms. Moreover, because many aisles have slopes that do not lend themselves to the recommended dimensions for risers and treads, it is especially important to provide handrails, as described in 4A below. For steep stairs, the goal of providing adequate treads should govern the choice of riser heights. With very shallow slopes, avoid very low risers (under 100 mm or 4 in.) and use ramps wherever possible.

E. Prevent water accumulation on solid treads by having a slight "wash" on the treads, that is, a slope of approximately one percent (one-eight inch per foot), to drain water away from the nosings, where adequate and consistent friction is most important. The water could, for example, be drained to the back of the tread and then to an open side by having the slope in two directions, or it could drain each sucessive tread by sloping them toward the nosings.

F. If projecting nosings are desired this should be done by providing a backslope on closed risers rather than a lip below the nosings; this can catch people's heels in descent or their toes in ascent, particularly persons with leg disabilities. Projecting nosings do not increase the effective tread depth much, if at all. There is no need to project nosings on stairs that have proper treads.

2. Tread surfaces

A. Remove tripping hazards such as worn carpets, loose mats, and projecting strips, including the mis-named "nonslip" abrasive strips that project above treads.

B. Provide surfaces that are uniformly slip-resistant. If kept dry, any combination of flooring material and finish that provides adequate slip resistance on level floors is suitable for stair treads, and there is no need to add abrasive strips. On treads subject to wetting, provide slip resistant surfaces such as broom-finished concrete or special epoxy coatings with abrasive additives.

C. Avoid using deep-pile or shag carpet and underlay material on stair treads.

D. On stairs having treads that are less than 280 mm (11 in.) deep, measured horizontally between nosings, and with nosing projections of less than 25 mm (1 in.), a possible hazard is introduced where risers are carpeted. A descending person may catch the back of his or her shoe on the riser carpet and stumble.

E. Fix all tread coverings securely to the stair. Carpeting should fit tightly around tread nosings. Care should be taken that the covering will not stretch or bulge through use.

F. Avoid using richly patterned materials that tend to mask the tread nosings. Surface materials with a distinct geometric, pictorial, floral, or randomized pattern may be visually more pronounced than the nosings of the treads themselves.

G. Provide treads or nosings that stand out visually against the whole stair environment (for example, by being lighter in value or of greater saturation than the surrounding elements).

H. If tread nosings are difficult for descending persons to see (due to uncontrollable lighting conditions or surface characteristics of treads) or if step dimensions are nonuniform, provide a contrasting marking stripe of uniform width (not more than 40 mm or 1.5 in.) on the leading horizontal surface of every tread. Its friction coefficient should not be less than that of the remainder of the tread and no tripping hazard should be created; i.e., it should be flush with the tread. Such marking stripes are especially important on aisle stairs.

I. Tread nosings should have a rounded edge with a radius between 6 mm (0.25 in.) and 13 mm (0.5 in.) to improve visibility (because of modeling that occurs with directional lighting) and to reduce the severity of injuries in falls against the nosings.

J. Do not install tread materials that erode quickly through use.

3. Lighting of stairs

A. Increase tread nosing visibility with directional lighting from a source or sources that do not leave the steps in front of a descending person in strong shadow. Avoid having a large variation in illumination from one part of a stair to another. Directional lighting is most effective when used with slightly rounded nosings described in 2I above.

B. Provide shielding around lamps and blinds on windows so that persons descending a stair are not presented with a glaring source of light.

C. A permanent, unswitched, low-wattage night light even with the nosing of the first tread below every landing may be installed on interior stairs that descend from sleeping areas.

D. To avoid having the stair entirely unlit, due to the failure of one bulb, use two bulbs in the same fixture or in separate fixtures serving a stair.

E. Light switches controlling stair illumination should be provided at all points where a person might enter or leave a flight of stairs. Large switches that can be activated by the elbow or the back of the wrist may be useful in areas where stair users have hands occupied. Illuminated light switches are useful.

4. Handrails

A. Provide securely fixed handrails, running continuously the full length of flights, on both sides of all stairs. On aisle stairs, where side handrails would prevent access to seating, install a center-aisle handrail. Such a center handrail can have breaks at every third to fifth row of seats to permit crossing from one side of the aisle to the other.

B. In situations where a stair is heavily used by crowds, the minimum spacing between handrail centers should be 1270 mm (50 in.) to permit people to pass each other without twisting to avoid collision.

C. The maximum spacing of handrails, particularly for stairs used by crowds, should be 1550 mm (61 in.) measured center to center, to permit all persons on the stair to be within reach of one handrail.

This spacing is based on handrails at least 910 mm (36 in.) high. If the handrail is lower, maximum spacing should be reduced by approximately twice the difference in height. For example, with handrails 810 mm (32 in.) high the centerline spacing should not exceed 1350 mm (53 in.).

D. Regarding the carrying capacity of stairs in evacuations, every additional increment of width (even a few millimetres, not only increments of 22 in. or 12 in.) adds to a stair's flow capacity. Stair design rules based on 22-in. units and 12-in. half-units (or quarter-units) of exit width fail to give proper credit to useful stair widths such as the 1400 mm, 55-in. width. In general the flow-carrying capacity of a stair is proportional to its effective width (approximately nominal width minus 300 mm or 12 in., or the spacing of handrail centerlines minus 175 mm or 7 in). For example, a stair with a nominal width of 1120 mm (44 in.) allows 120 persons to descend past a point in 3.2 minutes while a stair with a nominal width of 1400 mm (55 in.) carries 161 persons in similar conditions.

E. Handrail height should be between 815 mm (32 in.) and 910 mm (36 in.) measured vertically above tread nosings. Additional handrails for children should be installed 600 mm (24 in.) above tread nosings.

F. At a turn of a stair, inside handrails should be continuous. On helical stairs and stairs with winders (i.e., with wedge-shaped treads) it is particularly useful to have a continuously graspable handrail on the side where the treads are smallest and to locate this handrail so that users walk only on the portions of the treads that provide adequate footing (e.g., where treads are at least 280 mm or 11 in. deep). On common 30° winders the preferred walking line is approximately 520 mm (20.5 in.) out from the turning point and within easy reach of a handrail located at the inside of the turn. This handrail should be continuously graspable, i.e., it should not be broken by a newel post or by sharp bends at the winders where a person is making a critical transition between uniform and nonuniform treads and avoiding the undersized portion of winder treads.

G. At intersections of stair flights and landings do not break or bend handrails to ungraspable positions to adjust for differences in height requirements for guards and handrails. Continuity of handrail graspability is especially important at the approach to a flight of stairs and on the first few steps.

H. At landings the handrails that do not continue to the next flight should, if possible, continue horizontally at the required height for a minimum of 300 mm (12 in.) before being returned to the wall or landing. This provides a cue to the ends of the flight. It also reduces the need for people to search for the handrail just as they are trying to negotiate the first steps.

I. Handrails should be graspable along their entire length. The thumb and fingers should be able to curl around and under the handrail to achieve a secure locking grip even when muscular control is weakened. For adult-size hands this will require circular, oval or rectangular sections, with maximum dimensions in a horizontal orientation and less than 50 mm (2 in.), preferably 35 mm (1.5 in.). Smaller sections should be considered where stairs are used extensively by handicapped, elderly or very young persons.

J. Handrails should allow safe and comfortable handholds. Remove sharp projections such as splinters on wood railings and burrs on metal railings. In some outdoor settings, handrail surfaces can become so heated from exposure to the sun that they cannot be grasped. Use light coloured material for such rails to reduce solar heating effects.

K. In addition to ample clearance above a handrail there should be a clearance of at least 57 mm (2.25 in.) between a handrail and a wall. A greater clearance or a refinishing of the wall is suggested if it is rough enough to injure fingers brushed against it.

L. Details of structural supports for handrails should reduce the chance that a handhold is broken.

M. Handrails should stand out visually in the stair environment. The importance of perception of their location is second only to the perception of the stair treads.

5. Other important considerations

A. To avoid having objects left on stairs, and to reduce the number of journeys required up and down stairs, provide collection boxes or shelves to hold shoes, magazines, clothing, etc., at or near the bottom and top of stairs that connect major activity areas in dwellings. Locate these clear of the path of travel on the stairs.

B. If there is a door that swings within one tread depth of a riser, consider removing the door, reversing the direction of swing, or adding safety glazing (so that users on either side of the door are aware of each other). These recommendations must be considered along with fire safety regulations that apply to doors.

C. Remove any hazardous projections into the path of travel on the stair (i.e., projections up to 2000 mm (78 in. above the tread nosing).

D. If there is inadequate headroom anywhere on a flight of stairs (i.e., the tallest user has head contact when standing on his toes) remove the offending hazard or provide cues to its presence and location. Mark and cushion remaining projections to minimize the consequences of unavoidable contact.

E. If there are areas of glass on or near a flight of stairs, located so that a falling person could impact the glass, install safety glazing.

F. Access to stairs should be controlled by gates, where they might be used by children under four years of age.

G. Generally try to design stairs to reduce distractions. Design so that either there are no views to adjacent spaces from the flight or there is a continuous view, so that there are no visual surprises. If there are abrupt changes in the view seen by a person on a flight of stairs, then diminish the impact of such distractions by increasing the attention-getting qualities of the stair itself (e.g., by changing relative levels of lighting or by extending or reducing the opening so that this "orientation edge" is not distracting at some critical point on the flight).

H. The presence and location of stairs, especially single-riser and two-riser stairs, as well as flights of stairs with tiny risers (best avoided if possible), should be made obvious by providing handrails, increasing the relative lighting on the stairs, making the tread materials more obvious, using graphics on adjacent walls and if necessary by using warning signs.

I. Design stairs to have no more than 18 risers between landings. Where stairs are to be used extensively by elderly persons, provide more frequent landings, with continuous handrails and adequate standing space, for use as resting places.

J. All parts of the stair should be structurally sound and capable of carrying all loads in normal and accident conditions.

K. Avoid layouts that will produce conflicting patterns of pedestrian movement on or near stairs. For example, avoid stair plan configurations that encourage users to violate the "keep right" rule and to use routes that will bring those descending into conflict with those ascending.

L. Use signs indicating where stairs lead and what alternative means of travel are available to reduce the unnecessary use of stairs.

M. Do not include changes of level and stairs in designs unless they are strictly necessary. For example, moderate-slope ramps should be installed in place of stairs where possible.

SUGGESTIONS FOR FURTHER READING

Books on stair design, construction and repair can be found in large public libraries; however they seldom deal with stair safety in an explicit technical way. The majority are picture books of European origin, showing unusual and expensive stairs, often of the curved monumental type. Some provide drawings of details and other features that are of interest to designers and fabricators. A few older books deal with nearly-lost stair building craftsmanship by highly skilled carpenters.

The following suggestions do not include books that deal largely with unusual stairs, with an emphasis on aesthetic features. The first three documents discuss commonly constructed stairs in homes and public buildings. The remaining references, often the direct results of research, provide technical background for the recommendations given in this Note.

1. Construction of Typical Wood and Metal Stairs

J.D. Wilson and S.O. Werner. Simplified Stair Layout. Delmar Publishers, Albany, New York, 1973.

Directed to the skilled builder; the introductory section describes stair types and terms. The larger second section describes layout procedures and calculations for wood stairs.

Floors and Stairways. Time-Life Books, Alexandria, Virginia and Toronto, 1978.

Directed to the do-it-yourself homeowner, this well-produced, moderately-priced manual deals with the repair of common wood stairs as well as construction of functional basement stairs and assembly of prefabricated residential stairs and railings. A section on carpet installation provides guidance on proper fixing of carpets on stairs.

Metal Stairs Manual. National Association of Architectural Metal Manufacturers, Oak Park, Illinois, 1974. (A more recent edition may be available.)

Directed to architects and engineers, this includes general information, representative installations, construction details, structural design and data, and a glossary.

2. Findings and Recommendations of U.S. Studies of Stair Safety

Home safety guidelines for architects and builders. The Buffalo Organization for Social and Technological Innovation. National Bureau of Standards, Washington, D.C., GCR 78-156, 1978. (Order from National Technical Information Service (NTIS), Springfield, VA 22161.)

This has well-founded recommendations on stair design. It won an award from the periodical Progressive Architecture for its excellence as a well-presented product of research. Although it addresses home safety directly, it is a generally useful guide to stair design everywhere. The recommendations on stair design are based largely on research described at great length in the following three NBS reports. (Many of the recommendations in this Note came from this report.)

J.C. Archea, B.L. Collins and F.I. Stahl. Guidelines for stair safety. National Bureau of Standards, Washington, D.C., NBS BSS 120, 1979. (Order from U.S. Government Printing Office, Washington, D.C. 20402.)

Guidelines cover structural integrity and quality of stairs, physical attributes and appearance of stair surfaces, handrails, and the surrounding environment, and signs and symbols. Many recommendations are based on the premise (supported by research) that stair accidents are caused by human perceptual errors, frequently triggered by some flaw in the design or construction of stairs themselves. General directions of future research are suggested. (Many of the recommendations in this Note came from this report.)

J.A. Templer, G.M. Mullet and J.C. Archea. An analysis of the behavior of stair users. National Bureau of Standards, Washington, D.C., NBSIR 78-1554, 1978. (Order from National Technical Information Service (NTIS), Springfield, VA 22161.)

This will appeal mainly to researchers concerned with stair safety; however it does include 44 performance statements for improved stair design.

D.H. Carson, J.C. Archea, S.T. Margulis and F.E. Carson. Safety on stairs. National Bureau of Standards, Washington, D.C., NBS BSS 108, 1978. (Order from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

This is largely a description of a survey of safety-related conditions on residential stairs in Milwaukee, Wisconsin.

J.M. Fitch, J.A. Templer and P. Corcoran. The dimensions of stairs. Scientific American, Vol. 231, No. 4, October 1974, p. 82-90.

This article gives some of the highlights of J.A. Templer's Ph.D. dissertation on stair shape and human movement. The history of the 300-year old rule for stair riser-tread geometry is mentioned. Emphasis is given to a description of research findings and recommendations, namely for treads to be at least 280 mm (11 in.) deep and risers no more than 178 mm (7 in.) high.

J.K. Asher. Toward a safer design for stairs. Job Safety and Health, Vol. 5, No. 9, September 1977, p. 27-32.

This short review article deals with research on stair safety done by the U.S. National Bureau of Standards. It includes seven stair design guidelines proposed by researcher John Archea.

3. Findings and Recommendations of European Studies

L. Kvarnstrom. Stairs: compilation of sub-reports on stairs and use of stairs. Stockholm, Swedish Council for Building Research, Swedish Building Summaries, S2:1977.

This is a summary of T3:1977, a report in Swedish, which is a compilation of some 20 sub-reports describing a decade of extensive Swedish research and the resulting recommendations for designing safer stairs.

L. Svanstrom. Falls on stairs: an epidemiological accident study. Scandinavian Journal of Social Medicine, Vol. 2, 1974, p. 113-120.

An account is given of an epidemiological accident study of falls on stairs; this constitutes the sociomedical part of a broad investigation in Sweden (described in the preceding reference).

B. Poyner. Accidents on stairs and steps. The Tavistock Institute of Human Relations, London, 1980.

An in-depth study was done of 45 accidents reported to the Birmingham Accident Hospital during January-June 1979. The study included interviews, measurements and photography. The report has three parts: a classification of accidents in the survey, a list of physicial features of the stairs that may have contributed to the accidents, and a detailed analysis of each accident (often accompanied by drawings and photographs).

C. Whittington. Safety begins at home. New Scientist, November 10, 1977, p. 340-342.

This is a general description of British investigations into home accidents. Like the U.S. and Swedish studies, these show stairs to be the building feature involved in the largest number of injury-producing accidents; 12% of all home accidents involve stairs.

S. Burman and H. Genn (editors). Accidents in the Home. London: Croom Helm, 1977.

The papers in this book were given at a 1974 conference organized by the British Social Science Research Council's Centre for Socio-Legal Studies. The conference was called to discuss the social, economic and legal aspects of accidents in the home.

4. General References on Movement Facilities Including Stairs

J.J. Fruin. Pedestrian Planning and Design. New York, Metropolitan Association of Urban Designers and Environmental Planners, Inc., 1971.

This is the best text and general reference on designing pedestrian facilities. It is now out of print. A revised text, tentatively titled "Designing for Pedestrians," is in preparation by Dr. Fruin and a chapter on stairs is planned.

Health impacts of the use, evaluation and design of stairways in office buildings. Health Programs Branch, Health and Welfare Canada, Ottawa, April 1977.

This reports research by Robert J. Beck and Associates under contract to Health and Welfare Canada, along with additional studies by Pauls and Johnson of the National Research Council of Canada, on office workers' use and evaluation of stairways in government office buildings in Ottawa. The results are directed in part toward the development of policy, programs and technical information which may be employed to promote health in life style.

Findings of surveys in three office buildings (5, 8, and 21 storeys high) included the following: 8% of the population did not use the office building stairs at all; over half used them from 2 to 6 times daily; 30% used them 7 or more times daily. The 21-storey building averaged 4 stair uses per day per person.

5. References on Evacuation Using Stairs

F.I. Stahl and J.C. Archea. An assessment of the technical literature on emergency egress from buildings. National Bureau of Standards, Washington, D.C., NBSIR 77-1313, 1977. (Order from National Technical Information Service (NTIS), Springfield, VA 22161.)

This is not so much a review of literature as a review of the research basis for egress standards. The research basis is very fragmentary.

J.L. Pauls. Management and movement of building occupants in emergencies. Proceedings of the Second Conference on Designing to Survive Severe Hazards, IIT Research Institute, Chicago, Nov. 1977, p. 103-130. (Reprinted as NRCC 16845, available from the Division of Building Research, National Research Council of Canada, Ottawa, K1A 0R6; Cost: $0.50)

This review paper includes descriptions of Canadian studies of the movement of people in buildings and evacuation procedures for high-rise office buildings.

J.L. Pauls. Building evacuation: research findings and recommendations. Chapter 13 of Fires and Human Behaviour, edited by D. Canter. London and New York, John Wiley & Sons, Ltd., 1980, p. 251-275.

The derivation of the "effective-width" model for crowd flow on stairs is described in detail. This model could replace the traditional unit-width model for determining the total width of stairs that must carry crowds of people within certain time limits in egress situations.

J.L. Pauls. Building design for egress. Journal of Architectural Education, Vol. 33, No. 4, Summer 1980, p. 38-42.

This paper gives general background to the design of egress facilities and describes how the "effective-width" model is applied, along with other criteria, to determine appropriate widths of stairs used for egress.

6. Canadian Studies of Aisle Stairs

W.R. Rhodes, B. Barkow, D.A. Wallis. Studies of stair ecology in public assembly facilities: handrails, speed, density, flow, distribution, and foot placement. Report prepared for the Division of Building Research, National Research Council of Canada, Ottawa, Contract No. 079-072, May 1980.

Sample sizes were small in this preliminary analysis of some of the records from the study, by a DBR/NRCC team, of aisle stair use in the new Commonwealth Stadium in Edmonton during the 1978 Commonwealth Games. An aisle stair having handrails, with descent as the egress direction, had significantly higher egress flow than an aisle without handrails, with ascent as the egress direction. Methodological issues, including choice of coding variables and analysis of visual records, are discussed. (Subsequent work on microcomputer-aided coding of visual records was done by Rhodes and Barkow under DBR/NRCC Contract No. 080-027. Their report is

titled, "A visual data record analysis system," dated April 1981.)

J.L. Pauls. The stair event: some lessons for design. Proceedings of Conference on People and the Man-Made Environment, University of Sydney, Australia, May 1980, p. 99-109.

This paper is intended for use in conjunction with the documentary film, "The Stair Event," (referenced below). The background to the study and the methods used are described briefly. Preliminary findings and recommendations, similar to those presented in the film, make up the major portion of the paper.

J.L. Pauls (producer). The Stair Event. Division of Building Research, National Research Council of Canada, Ottawa, 1979.

This 18-minute, 16 mm, colour film describes the study carried out by a six-person research team at the 1978 Commonwealth Games in Edmonton. The "event" is the notable performance of spectators on long aisle stairs in the new Commonwealth Stadium. The film makes the general point that the "stair event" really occurs everywhere and it deserves close attention. There is much that can be done, using current technology, to make stair use safer and more comfortable. The film is intended for a wide range of technical and nontechnical audiences. It is probably the only film dealing with stair use and design.

Information about loan and purchase is available from the Publications Section, Division of Building Research, National Research Council, Ottawa, Canada.