How far should a tread go?

Rod A Hunter

The size of stair treads may not be as safe as they appear: radii at their front and rear edges could reduce the tread depth to below that necessary for reliable foot support and contribute to the risk of falls.

The deemed-to-satisfy provisions of the Building Code of Australia (BCA) stipulate the required profile of steps and stairs (going and riser height, see Figure 4), but is silent about tread edge radii. Part 1 of Australian standard AS1428 'Design for access and mobility, General requirements for access – New building work' which can be for used for guidance on safe pedestrian movement and the 2001 version of which is called-up by the BCA , is also silent[i].

Attention to the effect of radii, especially for shallow treads, seems well warranted. In a report for the Australian Buildings Codes Board, Ozanne-Smith et al (2008) state that, internationally, falls are the 2nd largest cause of unintentional injury and death after road traffic injuries and that, in Australia, falls have contributed to approximately 340 deaths and 106,000 injuries over the three years from 2002 to 2005, incurring direct costs of $13 billion. Whilst the report indicates that only 6% of these incidents were associated with stairways, this proportion is still very significant, accounting for 2,126 injuries and deaths per year at a cost of approximately $30.6 million each year according to the report. The cost of lost productivity and other indirect costs are additional to these costs. The report notes that this is a problem that will continue to grow due to the ageing of the Australian population, and to the increase in housing density and multi-storey dwellings.

Figure 1: Fire escape stairway

Radiused upper-front edge of treads and junction of treads with risers

A radius, bevel or chamfer at the upper-front edge of treads[ii] (radiused tread edge) may be inherent to the method of their manufacture or fabrication and, regardless, minimises unsightly or hazardous wear effects. Radiused edges also help minimise injury from falls and the risk of walking aids or prostheses catching on treads; they may also assist in the discernment of treads (Pauls,1982). Radiused tread-riser junctions are exemplified by prefabricated metal formwork for concrete stairs (see Figures 1, 2 and 4) and, in effect, stair rods fixed at tread-riser junctions for carpeted stairs (see Figure 3).

Notwithstanding their advantages, radiused tread edges and junctions with risers have the adverse effect of reducing tread depth available for foot support (effective tread depth and effective going); if the radii are too great and the treads shallow, the risk of mis-steps is significantly increased. Shallower treads are typically found in fire escape stairs and residential stairs.

Figure 2 and 5 show stairs whose profiles comply with the BCA (190 mm riser and 250 mm going). In each case, the tread depth is 270 mm and the going is 250 mm. However, for the tread in Figure 2, the 20 mm radius of the forward edge and the 35 mm radius of the tread-riser junction reduce the effective tread depth to 215 mm and the effective going to 235 mm, as shown in Figure 4[iii.] In contrast, the radii of the stair in Figure 5 are only 5 mm and therefore reduce the effective tread depth by only 10 mm to 260 mm.

What should the radius of tread edges be?

The BCA and Part 1 of AS1428 are silent about tread edge radii, but the non-mandatory Part 2 of AS1428, 'Enhanced and additional requirements – Buildings and facilities' (1992) recommends a minimum tread edge radius of 10 mm and a maximum of 15 mm, although it does not refer to radiused junctions with risers. The 2009 version of Part 1 of AS1428, which will be invoked by the BCA when the proposed Access Code for Buildings is incorporated in the BCA, stipulates a maximum tread edge radius of 5 mm; but not a minimum radius or the radius of tread-riser junctions[iv].

Figure 2: Radiused tread edge and tread-riser junction

Figure 3: Stair rods

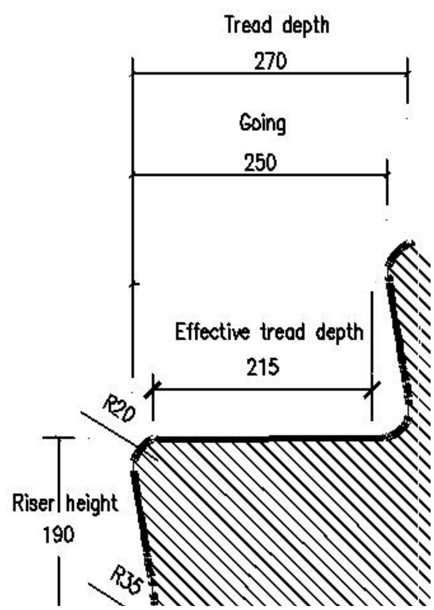

Figure 4: Profile dimensions of the stair in Figure 1.

Reference to the radius of tread edges in other countries varies. The British Building Regulations Parts K1 and M1 are silent, as is British standard BS8300:2001 'Design of buildings and their approaches to meet the needs of disabled people — Code of practice'. In contrast, the New Zealand Building Code 'Compliance Document Clause D1 – Access Routes', stipulates for stairs that are required to be usable by people with disabilities[v] a minimum radius or chamfer of 5 mm and a maximum of 10 mm. The American with Disabilities Act Accessibility Design Guidelines indicates a maximum radius for tread edges of 13 mm but does not indicate a minimum radius. The Research Council of Canada's Division of Building Research has recommended a minimum radius of 6 mm and a maximum of 13 mm (Pauls). The New York State Residential Building Code stipulates a maximum radius of 14 mm (9/16") or maximum bevel of 13 mm x 13 mm (½" x ½") but not a minimum dimension. There are no references to radiused tread-riser junctions. The New York City does not address any tread edge radii.

Interpolating between these recommendations and code provisions, a suitable radius for tread edges and tread-riser junctions appears to be between 5 mm and 7.5 mm[vi].

Minimum tread depth for foot support

For greater safety, treads should be deep enough to accommodate the length of the shod foot during ascent and descent, and when resting. Provision for resting is important for people with limited stamina or who are tend to experience imbalance.

Stair descent accounts for far more for injuries from falls on stairs than stair ascent (Ozanne-Smith et al; Templer, 1992). During descent, the ball of the foot typically makes contact with the tread first (Templer), followed by the heel. At the very least, tread depth should therefore accommodate the length of the foot from the ball of the foot to the heel. For shallower treads or when misjudgment occurs, the increased proportion of the foot projecting over the tread edge increases the probability of over stepping and a fall.


Figure 5: Metal risers in fire escape stair

A percentage of 70% of the foot has been suggested by Loo-Morrey et al (2004) as the minimum required for support of the metatarsal heads on treads. Roys (2006) observed that for goings of 250 mm, almost 50% of stair users had 70% or less of their foot on the tread (i.e. 30% or more overhanging the tread edge) whereas for a going of 300 mm, only 10% of users had such an overhang. In other words, people tend to take advantage of deeper treads. Templer suggests that treads should be large enough for shod feet to overhang by no more than 44 mm. He also suggests the need for an additional margin of 6 mm between the heel and the riser. However, an even greater margin than this may be required for variability of foot placement.

Loo-Morrey et al propose that from 300 mm to 350 mm is the necessary minimum safe going. A minimum dimension of 300 mm is also suggested in Adultdata (Peebles et al, 1999). Like Roys, Adultdata asserts that treads should be deep enough to support the whole of the shod foot, which, at the 95th percentile of the French male population reported in Adultdata, is 302 mm. Templer reports that for the United States male population the shoe length at the 95th percentile is 320 mm and at the 99th percentile it is 330 mm.

Code requirements in Australia and other countries

The British Building Regulations Parts K1 and M1 stipulate a range of minimum goings, namely:- for private buildings: 220 mm; for institutional and assembly buildings: 280 mm; for other buildings: 250 mm; for stairs that must comply with Part M1: 280 mm - 425 mm (except for accessible stairs in schools: 280 mm).

The New Zealand Building Code Compliance Document Clause D1 also stipulates a size range for treads: - for service stairways and minor private stairs: 220 mm; for secondary private stairs: 250 mm; for common stairways and main private stairs: 280 mm; for accessible stairs: 310 mm. If the maximum allowable nosing under the NZBC of 25 mm is deducted, this gives allowable goings of 195 mm, 225 mm, 255 mm and 285 mm respectively.

In the U.S., The New York City Building Code also has a range of minimum goings: - 279 mm for non-residential buildings, and 229 mm and 241 mm for residential buildings. The American with Disabilities Act Accessibility Design Guidelines stipulates goings of at least 280 mm.

In Australia, the non-mandatory Part 2 of AS1428 recommends that goings be no less than 275 mm. Part 1 of AS1428 on the other hand is silent, deferring to the BCA for this stipulation. The BCA stipulates only one size: a going of at least 250 mm regardless of building type or occupancy.

It is evident that code requirements in Australia and other countries are considerably less than recommendations resulting from research findings.

Case study

The effect on foot placement of shallow treads with large radii is exemplified by the fire escape stairway shown in Figures 1, 2 and 4. Figure 6 shows the typical placement of a foot upon the 270 mm tread. The shoe size is 8, its length is 296 mm and its overhang beyond the tread edge is 58 mm. However, the radiused edge of the tread means that the foot overhang beyond the effective tread edge is 78 mm, providing support for approximately 74% of the foot. The length of another stairway user's shoe was 324 mm which, for similar foot placement, resulted in an overhang beyond the effective tread edge of 106 mm, or support for approximately 67% of the shoe length.

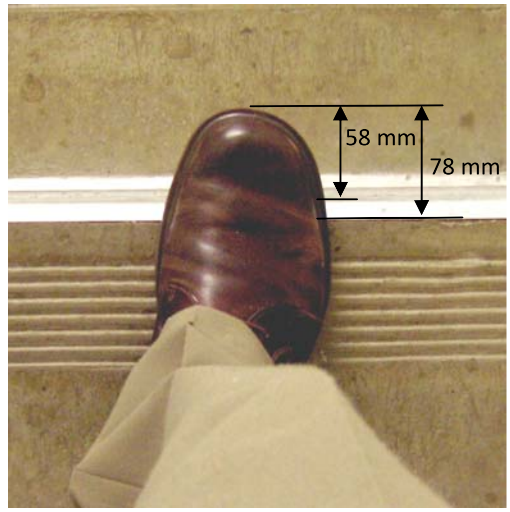

Figure 6: Overhang of foot past tread edge (58 mm) and flat part of tread (78 m)

For the person with the 324 mm shoe, and on the basis that foot placement tends occur so that the heel ends up being just in front of the riser, support for 70% of the foot plus a 6 mm margin would require a going of 288 mm, not 250 mm. Alternatively, if Templer's 44 mm maximum overhang recommendation is applied, the going dimension would need to be 286 mm overall. This is close to the recommendations for the minimum tread sizes cited above.

The previously cited studies do not indicate the radius of front and rear tread edges. Nevertheless, the considerable difference in tread depth recommendations from these studies and the tread depth of this stair, suggests that this stair's tread depth is at the threshold of safety. Moreover, with time it might come under the threshold. Scott (2005) and Templer refer to the upward trend in anthropometric dimensions with each successive generation and the increasing need therefore to increase treads depths.

Conclusion

Shallow treads tend to be more hazardous than deeper treads; and shallow treads with large radii at their front edge and at their junction with risers tend to be even more hazardous the radii reduce the effective going and tread depth for foot support.

Australia's mandatory requirement for tread depths is generally less than those of other countries. It is also considerably less than the recommendations of numerous research reports which, generally, propose treads of at approximately 300 mm. It is for this reason that Ozanne-Smith et al have proposed to the Australian Building Codes Board that the BCA requirements for goings sizes be increased.

Allowances by other countries for shallower treads in residences, and Australia's exclusion of the provisions of Part 1 of AS1428 from fire escapes seem anomalous. Residences account for the majority of stair injuries (Ozanne-Smith et al), and fire escape stairs have to cater for people under duress.

Evidence suggests that tread depths for all buildings, stair types, and occupants should be increased and, it is suggested here, tread edge radii should be designed or modified to be small in order to maximise effective tread depth. There is also merit effective going and effective tread depth being included in the BCA's deemed-to-satisfy provisions.

References

Loo-Morrey, M., Hallas, K., & Thorpe, S. (2004). Minimum going requirements and friction demands during stair descent. In P. McCabe (Ed.), *Contemporary Ergonomics 2004* (pp. 8 - 12). CRC Press, USA.

Ozanne-Smith, J.; Guy, J.; Kelly, M.; Clapperton, A. (2008). *The relationship between slips, trips and falls and the design and construction of buildings, Report No. 281.* Monash University , Accident Research Centre. Clayton, Australia: Monash University Accident Research Centre.

Pauls, J.L. (1982). *Recommendations for improving the safety of stairs.* National Research Council of Canada, Division of Building Research. Ottowa: National Research Council of Canada.

Peebles, L., Norris, B. (1999). *Adultdata: The Handbook of Adult Anthropometric and Strength Measurements – Data for Design Safety.* Dept. of Trade and Industry.UK.

Roys, M. (2006). Steps and Stairs. In R. Haslam, & D. Stubbs (Eds.), *Understanding and Preventing Falls* (pp. 52-68). Boca Raton, Florida, USA: CRC Press Taylor & Francis Group.

Scott, A. (2005). *Falls on Stairways – Literature Review.* Health and Safety Laboratory. Harpur Hill, Buxton, Derbyshire: Health and Safety Laboratory, UK.

Templer, J. (1992). *The Staircase: Studies of Hazards, Falls, and Safer Design.* Massachusetts, USA: MIT Press.

End Notes

[i] This standard has been developed with respect to people with disabilities; however, for stairways and many other features it logically follows that facilitating safe access for people with disabilities also facilitates safe access for all users.

[ii] The term “upper-front edge” is used rather than “nosing” because “nosing” refers to the overhang of a tread forward of the riser below.

[iii] A tread-riser junction with a radius might not be problematical if the radius is small and the radiused junction is used with an inclined riser. Furthermore, during descent the natural angle of legs means that heels tend to strike each tread slightly forward of the edge of the tread above and therefore, especially where there are inclined risers, heels might not touch the radius. The diminished dimensions calculated here might also not be quite as critical for well-worn shoes that have developed slightly convex soles and heels.

[iv] Even when the Access Code for Buildings is incorporated in the BCA, if it is incorporated in its present form, the 5 mm requirement of AS1428 Part 1 will not be obligatory under the BCA for fire-escape stairways.

[v] Under the New Zealand Building Code, at least one pedestrian access route (footpath, corridor), and therefore stairs on them, must be suitable for people with disabilities. For other routes, tread edges of stairs are therefore free from the NZBC requirement.

[vi] Optimising available foot support area is not the only benefit of small radii: they also facilitate more accurate discernment of tread edges.