The University of Sydney
Faculties of Health Sciences and Architecture
The Home Modification:
Information Clearinghouse Project

Evidence Based Research

Use of Reeded (Ribbed) Timber for Decks, Ramps and Paths

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Abstract

Objectives: To determine the occupational risk and safety factors surrounding the prescription of reeded decking ramps in the homes of persons with mobility impairment.

Design: Systematic review of electronic and other published literature.

Main outcome measures: Co-efficient of friction (COF) and relevant regulations. Safety interventions: minimise gradient, provide non-slip coatings or non-slip inserts, regular cleaning and maintenance schedules and provision of weather cover.

Results: No 'co-efficient of friction' (COF) study of timber surfaces has been published. Existing research does indicate that the required COF increases as the slope gradient increases. Slip resistance status of reeded decking is unclear, especially on steeper grades. Reeded decking has greater surface roughness and facilitates water run off relative to a sawn timber surface. However, with increased surface roughness the surface area for footwear to grip decreases.

Conclusions: Building Code of Australia (BCA) considers general slip-resistant design parameters although no minimum COF value is set. Specifically, the required COF for reeded decking is not known. Until the required COF of reeded timber ramps is definitive, there is a need for additional safety interventions.

Acknowledgements

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Problem Statement:

Is reeded timber suitable as a slip resistant surfacing of outdoor ramps used by clients with mobility problems?

Area of concern:

Use of appropriate materials and legal liability.

Background:

There is confusion amongst therapist and tradesmen regarding this question. Some confusion relates to the inconsistent use of terminology between manufacturers. Specifically, the term “reeded” and the term “anti-cupping scallop” appear to be ambiguous.

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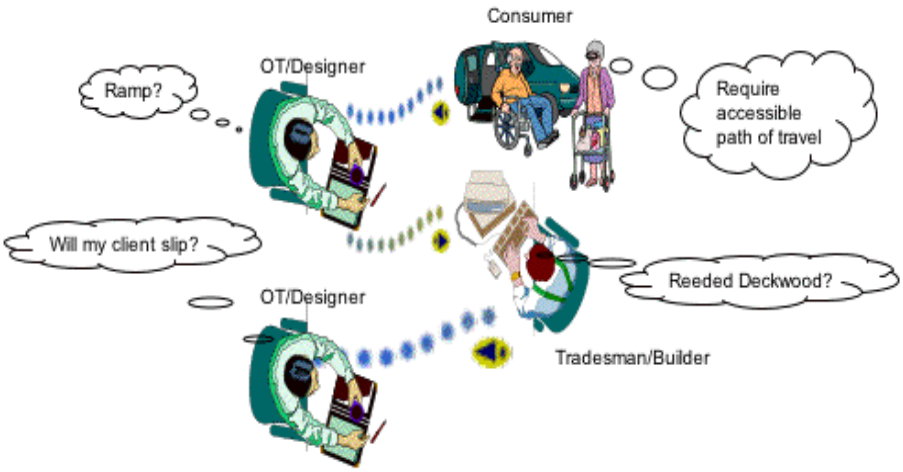
It may be that sawn top timber with anti-cupping scallops is being confused with reeded timber and consequently, the construction method may not comply with the manufactures' specifications. The grooved or scalloped side of sawn top timber should be fixed downwards to minimise warping. This is especially true if the climate is hot and dry, has periods of sustained rainfall or if water pools (James Pierce & Associates, 2000). However, the rule of thumb that appears to be in use by many tradesmen is grooved side up for external applications and grooved side down internally. Indeed some written guidelines state, "Grooved deck boards allow some surface water to be drained away from contact with the walking surface and generally give greater levels of slip resistance compared with flat sawn boards" (Building Research Association of New Zealand Incorporated, 1999). The grooves can also be used to house non-slip inserts that provide higher levels of slip resistance for higher risk situations (Trada Technology, 2001). However, "the grooves can encourage the accumulation of dirt and will not achieve the slip resistance required should mould build up on the surface (Building Research Association of New Zealand Incorporated, 2000)

The situation is further complicated when the degree of slope, type of mobility aid and type of footwear are factored in (Gao, Shahnavaz, & Holme'r, 2002; Redfern & McVay, 1993). For example, a grooved surface may have less area upon which a shoe may grip and hence the slip-resistive factor may decrease. To date the Co-efficient of friction (COF), the test of friction used to assess the slip resistance of ground surfaces, has not been formally tested on timber. In general a COF of 0.4 or higher is generally considered to be desirable for normal safety purposes (Bowman, 2000). Most ramp design guidelines recommend a higher COF, with 0.5 as minimum (Miller, 1990; Redfern & McVay, 1993).

The COF of level surfaces vary from 0.3 (ice) to 0.8 (concrete), depending on the material (Miller, 1999). Studies indicate the degree of roughness of a ground surface, as found in textured and raised patterned surfaces is important. Rough surfaces have a higher COF (Gronqvist, Roine, Korhonen, & Rahikainen, 1990). This finding would in general support the use of reeded timber surfaces over sawn timber. However, the degree of slope or gradient also affects COF. There appears to be a linear relationship between increase in ramp angle and the increase in COF required to prevent a slip or trip (Redfern & McVay, 1993). Consequently, Redfern and McVay recommend that COF for ramps be greater than the 0.5 minimum previously recommended.

Lastly, environmental conditions (volume of water, possibility of frost etc.) and direction of the reeding when laid will also influence the degree of actual slip resistance in situ (on site). The grooves need to lie across the path of travel, and not in the direction of the path of travel (James Pierce & Associates, 2000). A number of authors recommend the provision of cover or canopy for a ramp (CSIRO, 1981; Miller, 1990) to protect the surface from the build up of organic matter and reduce maintenance when environmental problems exist.



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Legislations/Regulations Relevant to Slip-Resistant Walking Surfaces for Housing:

Building Code of Australia (BCA)

The BCA Part D1 Clause 1.3.3 (d) (Australian Building Codes Board, 1996) states that for paths of travel that are an extension of a building, application of the BCA requirement may be appropriate. The BCA requires all access routes to "have adequate slip-resistant walking surfaces under all conditions of normal use". Clause A2 of the code defines an access route as "a continuous route that permits people and goods to move between the apron or construction edge of the building to spaces within a building, and between spaces within a building". The acceptable solution D1/AS1 (28 Feb. 1998), in providing examples of areas meeting this definition, includes decks, patios and steps on the approach to the main entrance to housing and common areas of communal residential and multi-unit dwellings (Building Research Association of New Zealand Incorporated, 1998)

Australian Standards:

AS 2082-2000: Timber - Hardwood - Visually stress-graded for structural purposes

AS 2082 (Nos/1, 2, 3 and 4) specifies grade descriptions for structural grades of hardwood (Standards Australia, 2000). Appearance grades relate to structural members exposed to view. The grades consider adequacy of strength in addition to limitations on the visual characteristics. The appendices of this standard include stress grades, strength groups and methods to measure these characteristics.

AS 2796.1-1999: Timber - Hardwood - Sawn and milled products - Product specification

AS 2796.1 specifies product requirements for sawn and milled hardwood products (Standards Australia, 1999b). The scope includes moisture content, profiles, tolerances and grades, and requirements for glued laminating, finger jointing and end matching. This standard also provides guidance on information to supply when ordering.

AS 1684.1-1999 and AS 1684.1-1999/Amdt 1-2002: Residential timber-framed construction - Design criteria

AS 1684.1 sets out design methods, assumptions and other criteria used in the preparation of the span tables, uplift forces and racking pressures as contained within Parts 2, 3 and 4 of the AS 1684 series (Standards Australia, 1999a, 2002). It applies to the preparation of design data for residential, timber-framed construction for Class 1 and Class 10 building as defined by the Building Code of Australia. Loading and performance requirements are included.

AS 1720.1-1997: Timber structures - Design methods

AS 1720.1 sets out the limit state design methods to be used in the design or appraisal of structural elements comprised of timber or wood products and of structures comprised substantially of timber (Standards Australia, 1997a). Test methods are included for components or assemblies of unconventional design that are not readily amenable to detailed analysis. AS 1720.1 also includes guidelines on serviceability considerations and information on the assignment of capacity factors to timber products.

AS 1720.2-1990: Timber structures - Timber properties

AS 1720.2 provides a table of timber species and their general properties for the design of timber structures (Standards Australia, 1990). This standard also provides extensive explanatory clauses to the table.

AS/NZS 4491:1997: Timber - Glossary of terms in timber related Standards

AS/NZS 4491 provides definitions of terms used in timber related Australian and New Zealand Standards (Standards Australia, 1997b). It includes new products and reflects changes in a number of Standards currently published.

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AS 1428.1-2001: Design for access and mobility - General requirements for access - New building work

AS 1428.1 specifies the design requirements applicable to new building work to provide access for people with disabilities (Standards Australia, 2001). The Standard specifies requirements to permit general use of buildings and facilities by people with disabilities. This includes people with disabilities who are acting independently or with a companion or carer. The Standard is based on data resulting from empirical testing of persons aged between 18 and 60 years and therefore may not be appropriate when applied to persons outside this age range. AS 1428.1 states, that design of buildings purpose-built for people with disabilities should consider the special need of the occupants over and above the minimum requirements of the BCA and AS1428.1. The information provided relates to access-ways, circulation spaces, and consistent linkages that are suitable for use by people using wheelchairs, people with ambulatory disabilities and people with sensory disabilities.

The Building Code of Australia, Amendment 9, references AS1428.1 (as of 1 July 2001). In general, compliance with this Standard satisfies the requirements of the BCA in relation to the provision of access to buildings for people with disabilities. The BCA makes allowance for the use of any alternative method that can be shown to satisfy these requirements. AS1428.1 specifically excludes work to private residences. However, in the absence of more relevant guidelines, application of Clauses relating to external locations may be appropriate.

AS 1428.2-1992: Design for access and mobility - Enhanced and additional requirements - Buildings and facilities

AS 1428.2 sets out enhanced requirements for the design of buildings and facilities to enable access for people with disabilities (Standards Australia, 1992). This standard modifies the requirements of some clauses in relation to the AS1428.1. Other clauses reference Part 1. In addition, AS 1428.2 includes requirements for items not covered in Part 1.

AS/NZS 3661.2; 1994: Slip resistance of pedestrian surfaces - Guide to the reduction of slip hazards

AS/NZS 3661.2 gives guidance on the selection, installation, care and maintenance of flooring and other surfaces in domestic, public and commercial areas to reduce the slip hazard to pedestrians, including people with disabilities (Standards Australia, 1994). NOTE: The risk of persons slipping on pedestrian surfaces is impossible to remove completely. Slip-resistance characteristics of surfaces varies greatly depending on factors such as weather conditions, activities carried out in the building (e.g. there is a high risk of slipping where water and other liquids may be spilled), cleaning methods used on the surface, and the type of footwear that the person is wearing.

Disability Discrimination Act (DDA): Advisory note on access to premises

The DDA, Part 5, Clause 5.8.1, states that all ramps should be safe and convenient for all users (Human Rights and Equal Opportunity Commission, 1997). This document recommends compliance with AS 1428.2 for ramps (clause 5.3.5) and floor surfaces on a continuous accessible path of travel (clause 5.3.7). These are not regulatory but been prepared by the Commissioner to assist people understand their responsibilities and rights under the DDA.

Although under the DDA the definition of 'premises' includes existing buildings, these advisory notes are aimed at new (proposed) buildings. Appendix C of the advisory notes relates to existing buildings. The notes specifically relate to Class 1b and Class 3 through to Class 10 buildings. They do not address questions of access requirements for Class 1a buildings (a detached house, terrace or similar) or Class 2 buildings (a building containing 2 or more sole-occupancy units). However, legal opinion suggests that the common areas associated with Class 2 buildings may be subject to complaint if they are not accessible. Responsibility and consequent liability for the accessibility, the construction and/or management of an infrastructure element is likely to be responsible for its accessibility.

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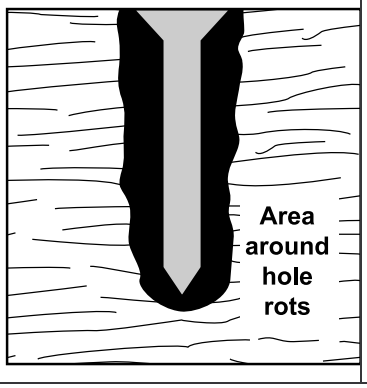
Customary Law/Published Guidelines

A search for published guidelines revealed the production of manufacturers' specifications (Gatton Sawmilling Co., 1998a, 1998b; James Pierce & Associates, 2000). The product manufacturer produces these documents to assist the consumer make more informed product decisions. The documents also serve to reduce liability of the manufacturer by listing the conditions for safest application of their product. The specifications relevant to reeded-decking installation follow:

Attributes	Deckwood sawn top Flatsawn Top  	Deckwood reeded (rippled) top Reeded Top 
Typical uses	▸ Bridge decking ▸ Loading docks ▸ Maintenance accessways ▸ Boardwalks ▸ Piers ▸ Park facilities	▸ Swimming pool surrounds ▸ Steep ramps ▸ Marina gangplank ▸ Pontoon decking
Maintenance Many companies guarantee the timber for 20 years or more. Regular maintenance is required to keep the structure in good condition. The routine may include cleaning away any surface dirt and re-application of a preservative treatment and/or finish to provide protection from weathering.	**Particular attention should include:** ▸ Ensuring that anti-cupping scallop is placed downwards ▸ Replacing damaged boards ▸ Tightening loose boards ▸ Retightening fasteners left proud by shrinkage ▸ refinishing	**Particular attention should include:** ▸ Ensuring that anti-cupping scallop is placed downwards ▸ Replacing damaged boards ▸ Tightening loose boards ▸ Retightening fasteners left proud by shrinkage ▸ refinishing
Durability **Water enters along nail hole**  	▸ Timber must be appearance grade ▸ Timber must be spaced 5 - 12 mm apart to let air circulate for expansion & contraction ▸ Growth rings must be concave downwards ▸ Requires roofing or painting ▸ Fixing from bottom improves durability but retightening and replacement of timber will be more difficult	▸ Timber must be spaced 5 - 12 mm apart to let air circulate for expansion & contraction ▸ Growth rings must be concave downwards ▸ Fixing from bottom improves durability but retightening and replacement of timber will be more difficult ▸ Water may pool in reeded surface increasing risk of rot and frost

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Dimensions	▸ The longer the length the greater the chance of defects ▸ Timber should be fixed with longest dimension running perpendicular to the main direction of travel ▸ Available widths 700 – 1450mm ▸ Timber widths greater than 1200mm reduce decking 'rattle' and produce smoother ride for wheelchairs	▸ The longer the length the greater the chance of defects ▸ Timber should be fixed with longest dimension running perpendicular to the main direction of travel ▸ Available widths 700 – 1450mm ▸ Timber widths greater than 1200mm reduce decking 'rattle' and produce smoother ride for wheelchairs
Spans	▸ Recommended maximum span varies (550 -1160mm) depending on decking size, house type and intended loading purpose	▸ 10% less than the sawn top timbers
Fixing	▸ Shall be greater than 100mm from ends ▸ Should be countersunk ▸ Should be staggered 15mm ▸ Timber wider than 70mm must be double fixed to joist	▸ Shall be greater than 100mm from ends ▸ Should be countersunk ▸ Should be staggered 15mm ▸ Timber wider than 70mm must be double fixed to joist
Loads	▸ Ultimate limit state 1.4G ▸ For uniformly distributed load in domestic applications limits vary on building/activity from 1.5 - 5kPa	▸ Ultimate limit state 1.4G ▸ For uniformly distributed load in domestic applications limits vary on building/activity from 1.5 – 5kPa
Known problems	▸ Stiletto heels ▸ Furniture legs less than 25mm ▸ Cracks may originate around fasteners	▸ Stiletto heels ▸ Furniture legs less than 25mm ▸ Cracks may originate around fasteners

Anecdotal evidence:

Concerns exist in areas where frost may form or dew may gather in the reeded top and become black ice. For instance, an OT in Victoria reported that this had contributed to a client's fall injuries. Nevertheless, DVA Victoria states that they have had no recorded complaints of slippage using reeded timber for outdoor ramps (personal communications from occupational therapist's participating in the Legal Aspects of Home Modification workshop OTVictoria, July 26th 2002).

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Evidence Based Practice Search Methodology:

Question refinement strategy

As per the systematic review protocol the research question was refined into an operational format that could be researched systematically by application of appropriate search criteria as illustrated in table 1 below.

Problem	Intervention	Outcome	Comparison	Target population
Decks, ramps & paths	Reeded (ribbed) timber (Wood)	Increased Slip resistance (COF)	Sawn top timber (Wood)	Mobility impaired ambulant ((walking sticks, crutches, trolleys, walkers / pick up frames, traymobiles, foot drop / foot drag)
Outdoors (precipitation, weather / frost / water pooling), wet	Timber coating systems	Decrease trips / slips / falls	Timber coating systems	Mobility Impairment non ambulant (wheelchairs, scooters, amputees)

Table 1: Reeded (ribbed) inquiry researchable question parts

Deciding inclusion criteria

Any material fitting our systematic review protocol was included. Primary studies were sought in English covering the period 1953-2003. The time frame was capped at 50 years on the basis that technologies in housing construction and home modification practice have changed so substantially that material written prior to this will have limited or no relevance to current practice. Definitions of key search terms were agreed. A variety of search strategies was employed using keywords, synonyms, truncation and connectors.

Search terms

- timber
- wood
- ramp
- sip resistant
- disabled
- mobility
- coating
- aged
- safety
- fall
- reeded timber
- slip
- wet
- surface
- weather
- precipitation
- trip
- skid

Connectors:

AND, OR, ADJ (adjacent)

Truncation symbols:

*, $,?, # (dependant upon database searched)

Selection of databases

As the stated problem is technical and specific, a range of databases was considered to determine their relevance to the stated problem. The databases and search strategies are as follows:

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Exclusion criteria

The review did not include centre of gravity, gait, wheelchairs and scooters per se, nor did it include COF so these were only commented on within the material gathered in the wider search strategy. In addition, editorials, general and unoriginal, or whole of subject books and conference papers were excluded. Figure 1 illustrates the stages at which review criteria were applied and materials were excluded

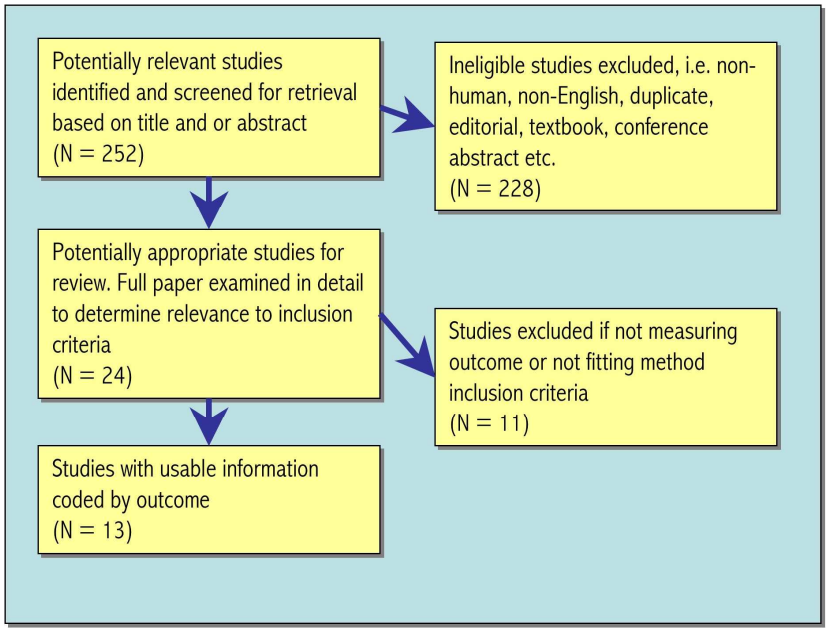

Figure 1: review process flow

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Outcomes of Search

The stated research problem is technical in nature relating primarily to the building and construction industry. The databases that produced relevant material included:

API: Architectural Publications Index; ARCH: Australian Architecture Database; BUILD: Australian Building Construction Engineering Database; Expanded Academic; OSHROM (occupational health and safety).

As indicated in discussion of method applied, 13 studies in total were systematically reviewed (see associated appendix for a summary of the main findings, process and issues and raw matrix analysis). The earliest study reviewed was 1991. The meta analysis following examines the results in terms of nationality, timber decking variables and methodologies employed.

Nationality

Inclusion criteria restricted the review to the English language so it is not surprising that nearly all the literature reviewed comes from English speaking countries Figure 2, below illustrates the breakdown of the material reviewed by the authors country of origin.

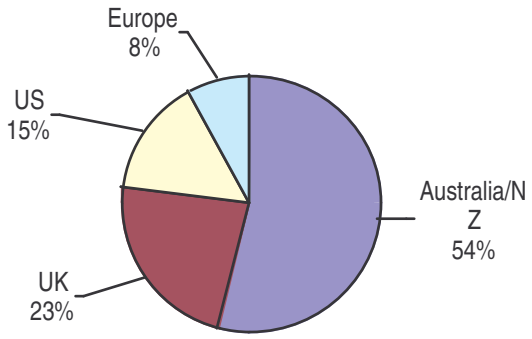

Figure 2: Piechart showing nationality

Analysis Outcomes

Of the studies reviewed, the variable that appears to be most frequently cited is normal ambulation. None of the references directly addressed the stated problem: Is reeded timber suitable as a slip resistant surfacing for outdoor ramps used by clients with mobility problems?

A number of references discussed slope (17%) as an issue, and alternative solutions for preventing slips and falls by applying specific coatings (17%). Cover and maintenance were also issues that were consistently raised (11%). Of greater significance is the absolute absence of research in regard to injuries of those using scooters and wheelchairs (0%). There was some general agreement that COF should be greater than 0.5 for sloped surfaces and that coatings, surface textures, compliance with standards at the design stage and attention to cover and regular maintenance were all important in reducing the legal and human sequelae attendant on poor decking outcomes.

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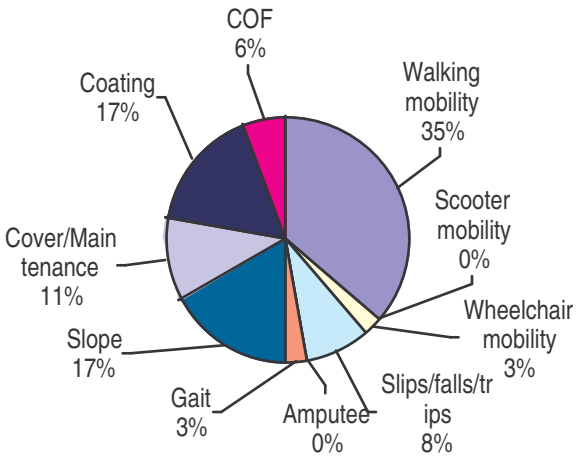

Figure 3: Piechart showing variables

Quality of evidence for attributing outcomes

In the review of the methods meeting our studies inclusion criteria, those methods that are most systematic and could be described as more classically experimentally driven (i.e. quasi experimental methods) account for 2 of the studies, (16% of those reviewed).

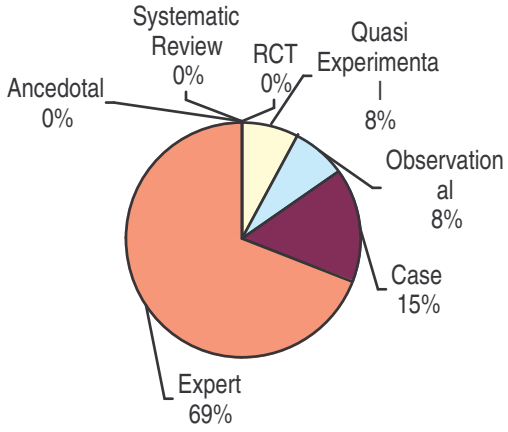

Figure 4: Piechart showing methods

Of particular interest is the fact that only one comparison study was located. No previous research appears to have been conducted in terms of examining the properties of timber surfaces in terms of COF or of non ambulant or disabled populations. No previous systematic reviews or random control studies were located. Consequently, evidence is primarily limited to case and expert methods, this means that at this point in time there is little hard evidence available to rely on and more research is urgently needed.

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Summary

To determine the critical features of reeded decking, we applied the International Classification of Function: Environmental Factors. Specifically, the Environmental Factors domains that externally influence functioning and disability (World Health Organisation, 2001) were considered in relation to the application of reeded decking in ramps or walkways used by people with a mobility impairment. The identified features are as follows:

Gradient

Law (BCA via AS1428) – for ramps with total length less than 1520mm, the steepest complying gradient is 1:8. Where the ramp length is greater than 1520mm then the gradient shall not be steeper than 1:14.

Intended Activity

Law (BCA) –the load limit is dependant on proposed activity e.g. limited pedestrian versus car traffic

Approach

Customary law – fix timber with the reeding perpendicular to the direction of travel, regardless of the gradient.

Load

Law (BCA) – spans need to be 10% more than sawn top timber. The specific load requirement is dependant on the building class, as defined by the BCA.

Gaps

Customary law - timber must be spaced 5 - 12 mm apart in order to let air circulate.

Extrapolating from AS1428, the maximum gaps on a path of travel should be 13mm with the elongated opening perpendicular to the direction of travel. Larger gaps are potentially hazardous to people using tipped mobility aids such as canes and walking sticks that may become trapped.

Cover

Customary law – Provide roofing cover in areas of high rainfall or frost.

Weather

Law (BCA via AS1428) - slip resistance must be ensured under all conditions of normal use.

Defects

Customary law – Timber length should be less than 1450 mm as the likelihood of defects increases with length. Defects may result in holes and warping which in turn increase the risk of tripping.

Abutments

Regulation (AS 1428.1) – Transition between abutting surfaces on paths of travel should be level (building tolerance is ±5mm). All decking should be checked regularly to ensure that weathering does not produce changes in level exceeding ±5mm.

Finish

Regulation (AS 3661.2) – Given that slip resistance finishes i.e. non-slip coating can deliver better safety it is advisable that they be used.

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Findings:

- Timber ramps in areas of heavy rainfall or frost should be covered or coated with non-slip products. There are a range of coating systems suitable for timber decks i.e. slip resistant coating systems for decking (Safe-T-Plus Australia, 2001)
- Timber decking and ramps undergo regular maintenance inspections
- Clients who rely on mobility aids such as canes, or walking sticks should consider other options such as steel mesh or brushed concrete products in preference to reeded timber.

Information Strategies:

- Develop a technical fact sheet on timber identification and installation for use by Home Modification and Maintenance Service Providers, builders and construction industry sub-contractors.
- Develop a plain English fact sheet on advantages and limitation of timber decking for consumers so they can make choices that are more informed.

Research Strategies:

- indicated. We suggest that the lack of research regarding the testing of timber surfaces be raised with relevant organisations able to The reeded-decking review was based on a systematic review of published material, relevant Australian regulations, and customary practice. The review revealed that there has been no testing relating to the slip resistance characteristics of reeded decking. A study regarding the slip resistance of timber surfaces that considers reeded-decking characteristics and the need of people with mobility impairment is relate findings to other national research agendas. Such organisations include Australian Building Codes Board, CSIRO Building and Construction Division, and the National Disability Caucus.

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Appendix 1: Search strategy

Databases	Strategy	Results	Inclusion
Ageline (Ageing in psychological, health-related, social, and economic contexts)	ramp* AND surfac*	4	2
Ageline (Ageing in psychological, health-related, social, and economic contexts)	ramp* AND safe*	10	1
API: Architectural Publications Index	timber AND coating*	8	5
API: Architectural Publications Index	wood AND coating	8	2
API: Architectural Publications Index	floor* AND slip*	9	2
API: Architectural Publications Index	surface* AND slip*	3	1
Arch: Australian Architecture Database	slip*	21	0
Arch: Australian Architecture Database	(timber OR wood*) AND slip*	1	0
Avery Index to Architectural Periodicals:	slip? OR (slip resist?)	1	0
BUILD: Australian Building Construction and Engineering Database	(timber and wood and ramp and surface and slip and (aged or mobility)*	3	0
CAB Abstracts (agriculture, agronomy, crop protection, dairy science, and environmental degradation)	(timber OR wood) ADJ4 (slip OR (slip resist$)) connector ADJ was used to retrieve relevant material	32	1
Cinahl (nursing and allied health)	(coat# or surfac# or precipit# or weather or wet or frost or safe#)	7	1
Cinahl (nursing and allied health)	AND (timber or wood)	0	0

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Current contents via Ovid (science, social sciences, arts and humanities)	Safe$ AND (ramp OR ramps)	63	0
Expanded Academic Index ASAP (humanities, social sciences, environment, science & technology; mostly full text)	(timber OR wood*) AND ramp*	46	0
Expanded Academic Index ASAP (humanities, social sciences, environment, science & technology; mostly full text)	ramp* AND (slip resist*)	3	0
Expanded Academic Index ASAP (humanities, social sciences, environment, science & technology; mostly full text)	ramp* AND surface* AND slip*	25	1
Medline via Ovid (allied health, health care, medical, biological, physical sciences)	(ramp OR ramps) adj (wet OR water OR weather OR frost)	1	0
Oshrom – HSELINE, MHIDAS, RILOSH, CISDOC, NIOSHTIC	(timber or wood) AND (slip* or (slip resist*))	34	4
Oshrom – HSELINE, MHIDAS, RILOSH, CISDOC, NIOSHTIC	ramp* AND (slip* OR (slip resist*)AND coating*AND surface AND wet	7	1
University of Sydney Theses (University of Sydney theses)	flooring* and thesis	2	1
Web of Science (science, social science, arts and humanities)	ramp* AND slip* AND resist*	13	0
Web of Science (science, social science, arts and humanities)	ramp* AND falls	48	0
Web of Science (science, social science, arts and humanities)	ramp* AND surface* AND safe*	10	2
Results		252	24

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Appendix 2: Reeded (ribbed) timber analysis matrix

°Reference	Nationality	Main Findings	Process & issues	Activity			Person			Environment				Methods						
				Walking mobility	Scooter mobility	Wheelchair mobility	Slips/falls/trips	Amputee	Gait	Slope	Cover/Maintenance	Coating	COF	Systematic Review	RCT	Quasi Experimental	Observational	Case	Expert	Ancedotal
(Boussaguet, 2000)	Europe	Comparison of actual solutions indicates that non slip coatings of resin domes and band finishes reduce timber slipperiness in wet conditions	Very small comparison sample of three finishes, Unclear if tested in situ with people with mobility impairment	1			1			1								1		
(Bowman, 1999)	Australia	Present information on the selection of pedestrian surface materials, it discusses slope and issues with testing.	No timber COF or considerations for non ambulant mobility mentioned	1						1			1			1				
(BRANZ, 2000a)	Australia/NZ	No specific requirement to provide slip-resistant surfaces to decks that are not used as access routes (nominal width 900 mm) to private houses. However compliance with codes requires special slip resistance consideration.	No references or evidence of a basis in research	1								1							1	
(BRANZ, 2000b)	Australia/NZ	Access routes across decking are required to have a minimum slip resistance of 0.4 when wet.	No references or evidence of a basis in research	1								1							1	
(BRANZ, 1999a)	Australia/NZ	Describes solutions for maintaining a slip resistance surface on decks.	No references or evidence of a basis in research	1							1	1							1	

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(BRANZ, 1999b)	Australia/NZ	Reeding (ribbing) is a serious attempt to increase slip resistance. It is recommended for access routes but requires regular maintenance	No references or evidence of a basis in research	1								1							1	
(BRANZ, 1998)	Australia/NZ	Links BCA to timber decking in private homes, communal residential & multi-unit dwellings in terms of slip resistance compliance	No references or evidence of a basis in research	1								1							1	
(Pierce & Associates	Australia	Designed to assist timber selection, covers specification and engineering data recommends reeded (ribbed) timber deckwood profiles for outdoor areas	References are only to standards no evidence of independently commissioned research	1			1				1								1	
(Redfern & McVay, 1993)	US	Ramps are particularly hazardous in regard to slips & falls due to higher sheer forces. The horizontal & vertical foot forces exerted during normal gait indicate that current guidelines of COF at 0.5 are too low.	Biomechanical analysis of six healthy young subjects using a force platform with slope ranging from 0-20°. Each trial is repeated 3 times at each change of angle.	1						1			1				1			
(Rosen, 1983a)	US	Ramps are hazardous and falls can result in death and disablement.	Legal case examples of fall accidents on ramps illustrated with case notes and photographs of environmental cases.	1						1								1		
(Rosen, 1983a)	US	Ramp standards and audit criteria are presented.	References are only to standards no evidence of independently commissioned research	1			1			1									1	
(Trada technology,	UK	Recommends grooved decking and suggests that grooves (reeding/ribbing) be used to house non-slip inserts for higher levels of slip resistance	No references or evidence of a basis in research	1							1	1							1	

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(Travers, 1991)	UK	Ramps are essential for older persons & persons with mobility handicaps. Surfaces need to be non-slip and grades of ramps should not exceed 5°.	Narrative literature review no evidence of a basis in research	1		1			1	1									1			
Results				13	0	1	3	0	1	6	4	6	2	0	0	1	1	2	9	0		

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