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Timber Bollards

For protection and traffic control

Technical Design Guide issued by Forest and Wood Products Australia

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1 Introduction

Bollards can define space, control vehicles and people, and protect from unwelcome traffic. They also can be used for decorating and wayfinding.

As security awareness increases, bollards are being used to resist threats such as ram-raid burglaries, and even potential terrorist activity. External bollards provide one of the most weather-exposed uses of timber. They are rarely maintained and yet are expected to have long service lives.

The selection of appropriately durable timber species and grade are important – not only for the weather-exposed portion of bollards, but also that buried in-ground.

This guide details the considerations for better bollard design and specification so that common poor construction and inferior product substitution can be avoided.

Bollards are a permeable barrier used to control and guide pedestrians and vehicles. Their form and layout mediate the transition across both physical and perceptual boundaries. This control can be used to minimise conflict between different traffic types.

Bollards offer safety and refuge as a physical barrier, and provide visual clues to deliver a range of functions:

- **traffic flow** – visually define road and path boundaries
- **pedestrian contro**l – chains between bollards can create a form of balustrade
- **vehicle control** – can be closely spaced to restrict vehicle movement
- **impact protection** – act as security barriers to protect infrastructure from accidental and deliberate impact
- **guidance** – can include signage and wayfinding functions
- **decoration** – provide sculptural and memorial points of interest.

1.1 Bollard Types

Bollards have maritime beginnings as wharf-side posts for mooring ships, but are now common throughout the built environment. While hinged and machine-operated bollards are used for variable vehicle access, the focus of this guide is on fixed timber bollards that are:

- **surface mounted** – bolted to the ground plane *or*
- **embedded** – buried at one end to support the above-ground portion.

External bollards are fully exposed to weather variations. Their top edge is the most susceptible to degradation. When bollards are embedded in-ground the timber is also exposed to ground moisture.

The likelihood of maintenance for many bollards is low, and a 'set-and-forget' mindset demands an emphasis on good design and correct specification. This Guide sets out design parameters and core principles of bollard design. While the core function of bollards remains largely static, there is a trend for increasingly more complex designs that push the boundaries of both function and appearance.

1.2 Bollard Aesthetics

Beyond function requirements, bollard design needs to consider the following aesthetic considerations:

- **establishing context** – the bollard use categories described in this Guide steer aesthetic form
- **style** – while bollard uses vary, their design can reflect a project's individual design style
- **clear function** – detailing can be used to convey the intended bollard function (i.e. wayfinding, slowing traffic, protection, etc).

1.3 Bollard Use Categories

Using bollards in particular scenarios requires different bollard forms. If designed to protect a building from impact, a bollard may be quite squat in form. If used for wayfinding, a bollard may have a flat profile to be more visible and if it just denotes a pathway, it may be quite slender.

This Guide divides bollard use into three distinct classes that offer greater clarity in design and detailing:

- **park scenarios** – for open recreational spaces
- **urban scenarios** – used to define decision points and mark boundaries of abutting spaces
- **esplanade scenarios** – when bollards are seen in long vistas based on formality and repetition.

The design parameters for each installation type are outlined in the following sections. While variation of bollard function does not appear to be a strong design consideration in the outdoor furniture industry, allowing function to guide the bollard form offers major benefits in controlling both movement patterns and the sense of barrier and/or safety.

2 Parkland Environments

Park environments are predominately open and uncluttered. Park bollards are often experienced at a pedestrian scale, resulting in a more personal engagement between the pedestrian and the bollard. Bollards offer the following benefits to park environments:

- **add interest** – enliven an otherwise unobstructed expanse
- **pedestrian engagement** – encourage engagement with pedestrians and a sense of play
- **unobtrusive** – provide rail-less boundary fencing (typically these are less visually intrusive).

In the past, bollards have been used in parks as purely functional barriers. However, there are ways for bollards to be used in a way that is more engaging to park users.

Figure 2.1: Parks frequently use timber bollards to guide pedestrians and define borders.
Photograph: Dennis Clark Photography

The two main forms of bollards for park environments can be categorised as 'mass' and 'feature'.

2.1 Mass Bollards

Bollards are often used en masse to define the boundaries of a space, much like fencing without rails. The long runs of bollards that can traverse a park landscape provide the opportunity to design for their mass visual effect rather than just their individual impact. The potential is to use bollards as a more sculptural item. Mass bollards tend to be:

- **simple** – of plainer detail
- **thinner** – smaller cross-section
- **inexpensive** – contributed to by the points above.

The market for mass park bollards will always be price sensitive, with high levels of competition from low-grade timber substitutions. Designers can respond with careful specifications and by inspecting supplied timber to ensure it conforms to the required grade prior to installation.

2.2 Feature Bollards

Feature bollards are located at points of entry, street intersections or activity centres. They tend to be:

- **taller** – more bollard height than mass to increase visibility
- **thicker** – increased size and bulk also aids visibility
- **visually obvious** – act as demarcations for entry points or a change in conditions
- **detailed** – often have a more detailed design to increase their visual emphasis.

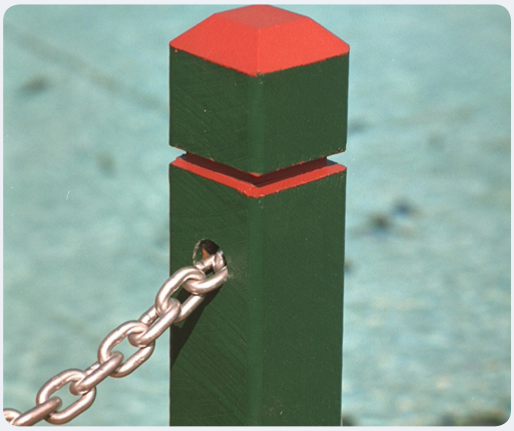
2.3 Bollard Design

Noting the simplicity of the park landscape, design trends generally focus on primarily simple forms. Detail is applied with banding or capping that acknowledge the dominate design form. Details can include:

- **circumferential banding** – for simple decoration
- **wave lines** – often used in riparian or coastal environments
- **other forms** – natural forms such as leaves or animals
- **places names** – reinforcing region or locale identity
- **signage and wayfinding** – direction arrows and symbols such as bikeways, etc.

Figure 2.2: When used for sculptural purposes, decorative timber bollards can use scale and design to create interest and leave a strong impression of place.
Photograph: Kevin Tostado; sourced under Creative Commons from wikipedia.com.

A: Path delineation –
Bollards give visual cues to direction.
Copyright Dennis Clark Photography



B: Vehicle control –
Functioning as physical barriers.

C: Mooring – Maritime use for mooring vessels.
Copyright Dennis Clark Photography

D: Decorative function – Simple and low-scale decorative function with longevity.

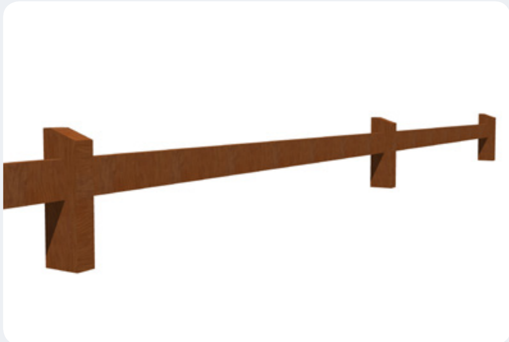
E: Impact protection – Protection for buildings and infrastructure.

F: Signage and wayfinding – Wider faces of rectangular profiles allow signage to be routed into the face or affixed.
Copyright Dennis Clark Photography

Figure 2.3: Bollards can be designed to perform a range of functions, including guidance, traffic control and protection.

A: Rope and chain – Linking bollards restricts vehicle movement and discourages pedestrian access with minimal visual intrusion.
Copyright Dennis Clark Photography

B: Balustrade – Infill cables and balustrading provide protection from falling.



C: Rails – Rails between low-height bollards provide a unobtrusive barrier to vehicles.

D: Enclosure – Bollards can be in groups and linked with rails to provide protection to trees or structures.

E: Face-fixed rails – Simple construction with lower potential to harbour moisture.

F: Recessed rails – Rebates for rails offer better support, though greater potential for decay.

Figure 2.4: A range of external furniture forms occur when bollards become fences that are likely to be in the same design language as adjacent bollards. Much of their construction will be similar to that outlined for bollards.

3 Urban Bollards

The use of bollards in urban environments can be quite distinct from those in park and coastal esplanade environments. In urban environments, bollards are primarily sited in key locations to define decision points and mark boundaries. Typical functions of bollards in urban locations include:

- **blocking streets** – particularly T-intersections at entries to malls or pedestrian ways
- **pedestrian protection** – at crossing areas and where pedestrians approach verges and potentially come in to conflict with vehicles
- **vegetation protection** – additional barrier fencing may be required in high-use pedestrian areas
- **building protection** – where structures are close to traffic zones (typical in older city areas where space is at a premium and not designed for modern traffic conditions).

3.1 Visual Impact and Legibility

Situations that require the long 'soldier' runs typical of park bollards rarely occur in urban environments. In the urban setting, ground-level vistas lose clear perspective lines due to fragmentation by both the activity of people and competing street furniture. Bollards in these locations require particular characteristics to enable them to compete for visual space in a cluttered environment and fulfil their intended role.

Urban bollards need to maximise visibility to ensure they are readable elements in the landscape. Mass, size and strong graphical design will help pedestrians read a bollard's intended purpose.

3.2 Thresholds

Rigid structure and signifiers of urban language inform and regulates pedestrian behaviour along controlled footpaths. Pedestrian behaviour in urban environments is more chaotic when pedestrian traffic is unrestricted – such as a market square.

In this environment, bollards can act as a semi-permeable boundary to mediate between pedestrian-only zones and zones shared with vehicles. Pedestrian transition through this permeable boundary creates a sense of safety and welcomes the pedestrian without the conventional constraint of kerbed lanes used to control vehicle movement.

3.3 Bollard Design

More visually conspicuous bollards offer an increased sense of protection for both pedestrian and driver. This can be achieved through greater visual mass, size and a strong graphical impact. Design considerations for urban bollards include:

- **fixing method** – bollards may be surface-mounted to existing paving rather than penetrate it; fixing mechanisms need to be considered as part of the overall bollard design
- **durability** – edges and joints need suitable resilience to weathering without degradation
- **context** – the design language should reference the environs and the shape; the form and the materials should be of an urban scale and design detail
- **adequate passage** – allow suitable threshold between bollards for the intended level of pedestrian flow; thresholds might be deliberately reduced where additional pedestrian caution is required.

4 Esplanade Bollards

'Pedestrianisation' has been used as a mechanism to revitalise city centres, industrial landscapes and waterfronts. Malls, boulevards and river walks have become increasingly popular. Even though many of these spaces have been vehicular streets, esplanades tend to be strongly pedestrian in focus. Long vistas result in an aesthetic language that is based in formality and repetition.

Unlike the urban market place, pedestrian movement along esplanades is characterised by the linear flow of the promenade. These are generally open carriageways that may be shared by vehicles and pedestrians. Bollards can be used as merely a visual indicator of traffic flow or be spaced close enough together to physically restrict vehicle access.

Typical functions of bollards on esplanade environments include:

- **visual dominance** – usually there is little competing street furniture
- **pedestrian control** – providing general directional guidance, and then used at key junctions to draw pedestrians' attention to key conflict points
- **vehicular control** – providing barriers to low-speed vehicular traffic ways
- **protection** – for existing features such as planting areas or protecting pedestrians by denoting hazards.

4.1 Designer Requirements

Because esplanade bollards are close to people and often with little competition from other outdoor furniture, they can be viewed more as furniture than being primarily a barrier. As such, their form and finish can be designed to be more tactile, approachable and interactive with the pedestrians.

Critical design issues include:

- **path width**: The threshold width on esplanades is often narrower than other pedestrian paths due to their consistent lineal nature. Narrowing path width at points of conflict can focus pedestrian attention and control walking speed.
- **bollard design**: The tendency for longer runs of bollards along esplanades increases their visual legibility. The bollards can be of a finer scale and simpler detail.

5 Bollard Design

The use categories for bollards discussed in earlier sections give the parameters for function and some visual demands. Design of the bollard itself needs to knit these visual and functional demands together with detailing that allows timber to perform at its best.

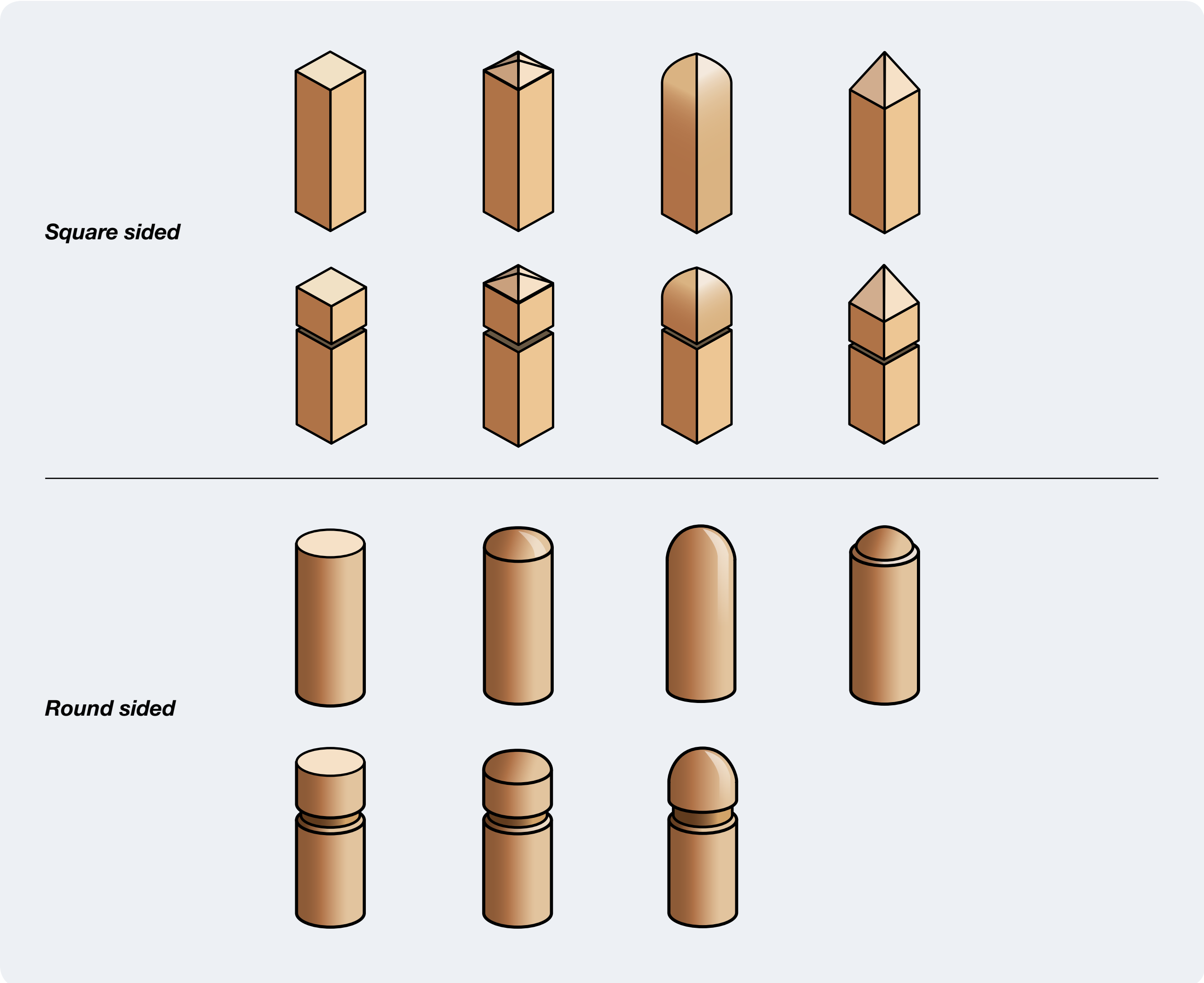


Figure 5.1: Uncapped bollards. The detail of bollard ends can be used to give a distinguishing style and, in many cases, minimise weathering.

5.1 Determining Size

Larger posts can be striking in appearance and have been seen in older buildings and wharfs, evoking a sense of tradition. However, large members need careful consideration of timber sourcing.

As with many materials used in the built environment, attention must be given to the effect on the natural environment from which the raw materials are drawn. As an example, the square post in Figure 5.2A has considerable width and is hewn from one piece of timber. The timber shown contains no heart (otherwise known as pith or corewood) and the growth rings suggest that it was cut from a log that was about two metres in diameter. A tree of sufficient size to provide such a log are no readily available.

A: Mass bollards –
Mass bollards from single large timber members risk environmental consequences.

B: Composite alternative –
Two wide members are fixed to a central steel fin, providing a mass appearance.

C: Composite alternative –
Fixing multiple smaller members in conjunction with stainless steel fins and capping provides a sophisticated alternative to single mass timber elements. Those pictured provide crash protection at an airport.

Figure 5.2: Large saw logs come with higher environmental cost. Specifying larger members free of heart can require cutting very large trees .

5.1.1 Heart vs Heartwood

The centre of a tree is called 'heart'; in sawn softwood it is commonly referred to as 'pith' or 'corewood'. Designers often confuse the term 'heartwood' with wood that contains 'heart' due to the similar sounding terms, though they describe two different parts of the tree. Heartwood, and sometimes termed 'truewood', is that portion between the heart and the sapwood (see Figure 5.3).

In hardwood, this inner pith is frequently at least is 50 mm either side of the centre. It is important to note that hardwood that contains 'heart' (pith) is particularly vulnerable to splitting and therefore degradation.

Sapwood, heartwood and the tree heart need to be considered differently in hardwood, cypress and pine. The chemical preservation needed to adequately protect timber from decay due to weathering is generally only absorbed by sapwood, leaving any exposed heart vulnerable to weathering.

- **Hardwood** – While some naturally durable hardwoods will have highly durable heartwood, the sapwood itself will quickly decay if not treated.
- **Softwoods generally** – Sawn pine must be incised to allow adequate penetration of chemical preservation of the heart, though once treated, the heart (pith) can be considered structural. Pine 'rounds' can be used where the pith is shielded by treated sapwood; the sapwood will decay very quickly if not treated.
- **Cypress specifically** – While cypress heartwood offers good natural durability, cypress sapwood doesn't absorb waterborne chemical treatment and so it can't be preserved at all.

Table 5.1: Durability of timber for bollards.

Timber	Sapwood	Heartwood ('truewood')	Heart/pith
Hardwood	Not durable - can be treated	Sometimes durable - cannot be treated	Unstable - cannot be treated
Cypress	Not durable - cannot be treated	Durable - cannot be treated	Structural - durable, cannot be treated
Pine	Not durable - can be treated	Not durable - cannot be treated unless incised	Structural - not durable cannot be treated

When hardwood bollards contain heart it is important that it is shielded from weathering by capping the top of the bollard with a material that protects from moisture. Normally, a sloping top will suffice for pine and cypress. Thin aluminium plates are used to similar purpose to protect the top of steel electricity poles.

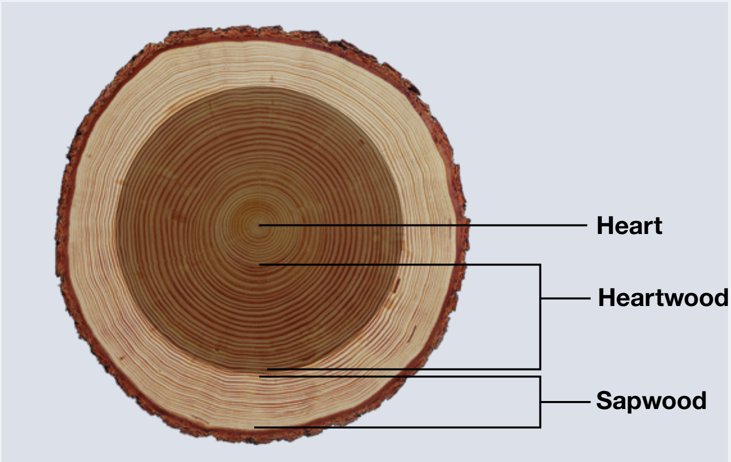


Figure 5.3: The very centre of a tree is where early growth took place and is known as the heart or pith. Wood that contains this 'heart' is quite different from the 'heartwood' that surrounds it. The heart is vulnerable to splitting, while the heartwood is the more durable wood.

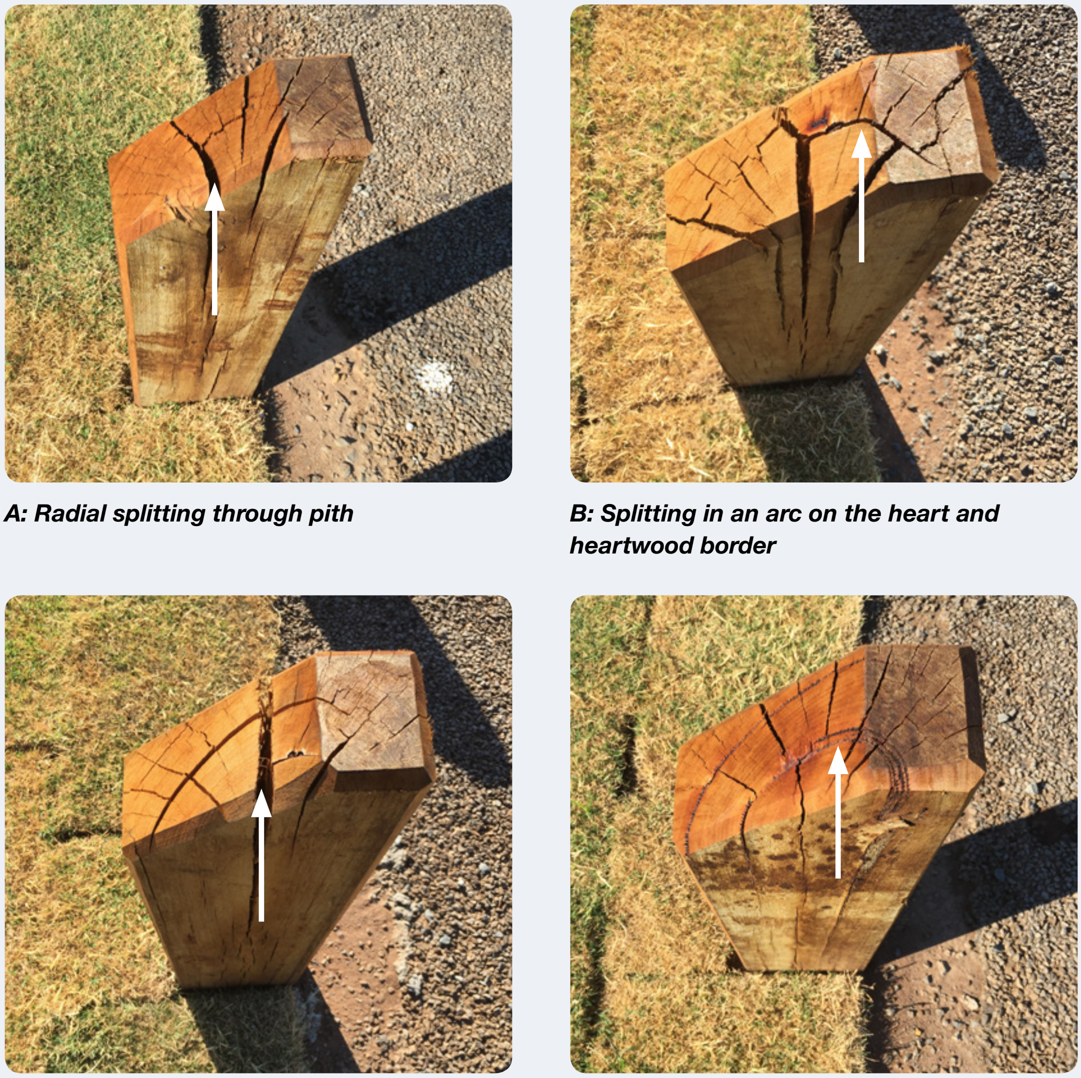
Development of forestry practices in Australia has led to more responsibly harvested timber being available but generally in smaller stem (saw log) sizes. The durability required for external timber calls for hardwood members up to 175 mm x 175 mm to be free of heart (pith). Designers can encourage better practice by specifying alternative members such as:

- **smaller sizes** – without heart (pith)
- **allowing heart** – pith centres are permissible in larger sizes where these are suitably protected with a top cap (pith should be shielded by being at the centre of the member)
- **uniform size** – consistent member sizing makes fitting of protective caps easier
- **improved detailing** – see discussion below on expansions joints
- **sustainable resource** – consider selection of member size with realistic availability of plantation timber.

5.1.2 Protecting Pith Centres

The Australian Standard *AS 2082: Timber - Hardwood - Visually stress-graded for structural purposes* now allows smaller members to contain heart (pith) in many common species in all sizes. Previously, the Standard only allowed heart in 175 mm x 175 mm and larger, though it is common for even bollards as large as 200 mm x 200 mm to split lengthways when they contain heart. This can result in unsightly, random tears that many asset owners object strongly to and which can considerably hasten deterioration due to weathering.

If the timber to be used contains heart, designers should consider using a sufficiently large size to encapsulate the pith and ensure this heart is more at the centre of the member. Splitting will not be avoided but can be controlled by expansion grooves.



A: Radial splitting through pith

B: Splitting in an arc on the heart and heartwood border

C: No connecting tissue

D: Gum vein with connective tissue

Figure 5.4: Exposed pith (heart) resulting in splitting. Timber heart should be excluded from the member or fully concealed. If present, exposed heart is likely to result in severe splitting leading to early degradation of the bollard.

5.1.3 Size Considerations

Uniform size

Dimensional tolerances for sawn timber mean that bollards ordered at a set size will potentially each have a slightly different dimension. The sawing tolerance of a standard rough-sawn 200 x 200 mm post used to be +8 mm and -3 mm. Although this has tightened to +/-3 mm, the author's experience is that the old standard more accurately reflected what will be supplied. This subtle inconsistency can make fitting premade protective end caps difficult. One solution is to specify dressed timber or consider smaller caps to allow for dimensional variation (refer Figure 5.7B for an example).

Appropriate width

Bollards used for impact protection need serious consideration of the nature and speed of any impact threat. Advice from a structural engineer is suggested. Beyond structural considerations, other size determinants are listed below.

Increasing a bollard's thickness will allow for considerable degradation from weathering to occur before affecting the bollard's performance.

Where the appearance of a larger bollard is desired, it is possible to gain bulk by forming a composite of smaller, and thus more readily available, members. Figure 5.7B shows an eloquent example of such designs.

Considerations for bollard size are:

- **function** – need for resisting vehicle impact, etc
- **visibility** – larger sizes are more visible (though using smaller members in series increases visibility)
- **proportion** – bollards used to support signage, safety reflectors, etc, may need to be wider
- **weathering** – greater width can give more protection to central pith and disguise warping that may occur from shrinkage.

See *Appendix A: Selection and Construction Notes* for more on particular-sized bollards.

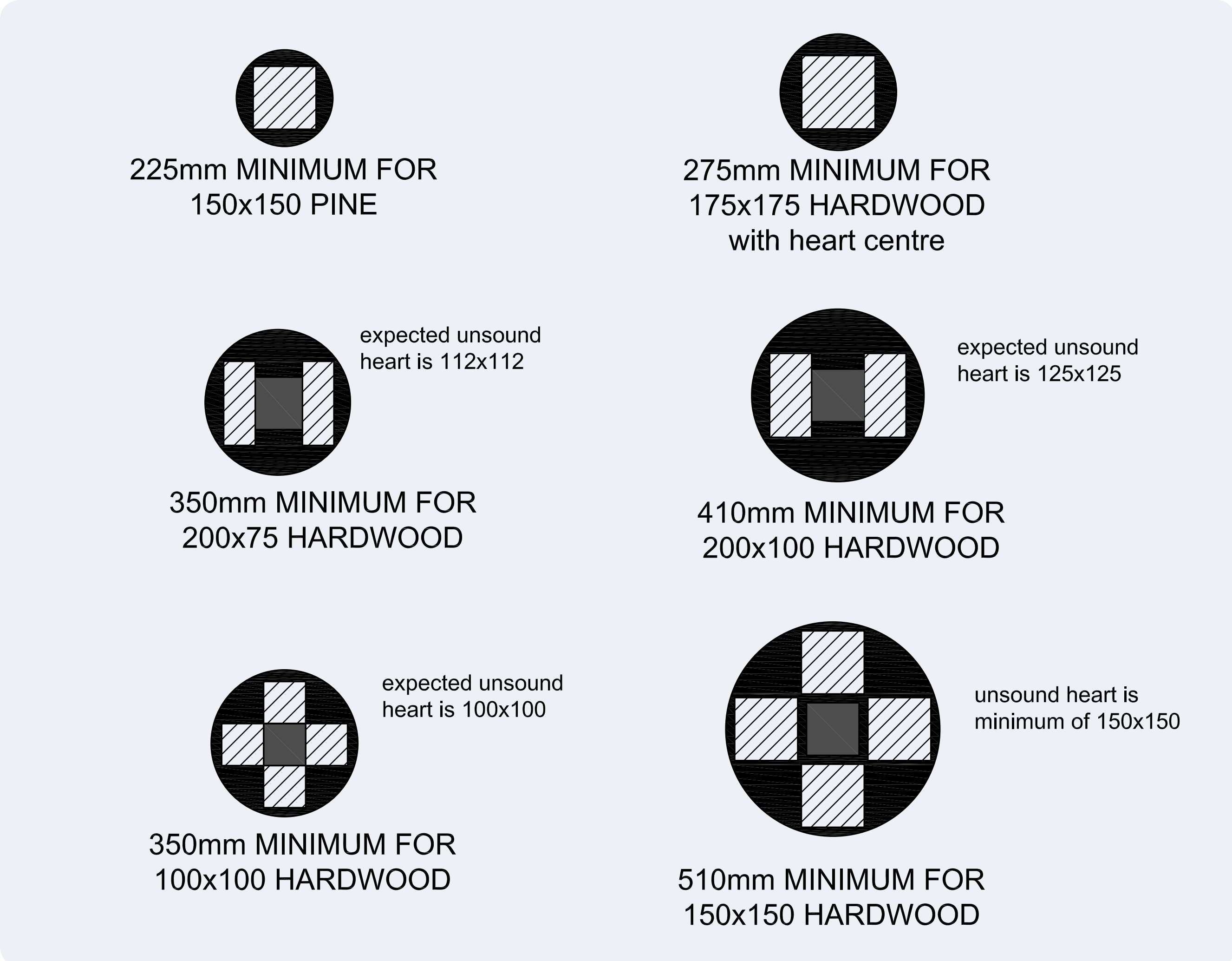


Figure 5.5: Wider bollards require wider saw logs. Using smaller sizes requires smaller sawlogs. This increases sourcing options, especially from more sustainable sources.

Bollard height

The length of bollard will depend on its in-ground length and desired height. For non-surface mounted bollards the in-ground depth would generally be 600 mm (see Section 6 Bollard Installation). The above-ground height will be controlled by a number of considerations:

- **protection** – if a bollard is merely to protect from vehicle collision it might only need to be low
- **safety** – the height needs to be sufficient to avoid trip hazards and conspicuous enough to be noticed amid the anticipated surrounding pedestrian/vehicular traffic
- **visibility** – consider the height of signage sight lines, undulation of ground surface and the needs of people who are visually impaired.

Some visually impaired people have only a narrow cone of vision that means they may not see a bollard they are approaching until they collide with it. The national transport standards document *Disability Standards for Accessible Public Transport* concerns itself with public transport and related infrastructure. This Standard prohibits the use of bollards in pedestrian spaces. The understanding of what is considered a pedestrian space can vary and the use of bollards within and at the borders of pedestrian spaces needs careful consideration. In some cases, bollards 1,200-1,500 mm high with very high luminance contrast have been used. Advice should be sought on the location and height of bollards in relation to disabled access and visibility.

5.2 Bollard Colour

Bollard design might involve the use of colours as part of aesthetic considerations or even to form sculptural feature bollards. Applied finishes such as penetrating oils and paints are added to protect the timber from weathering.

Apart from aesthetics, the choice of bollard design should consider safety concerns for visibility including those for vehicles and pedestrians. This includes the visually impaired. The previously mentioned Disability Standards for Accessible Public Transport 2002 says where 'poles and obstructions' might be considered obstacles they need to be made more apparent. This Standard says: "Obstacles that abut an access path must have a luminance contrast with a background of not less than 30%".

5.3 Bollard Detail

Timber will move over time as it seasons and some surface checking on the face of heart free members is likely. Extra consideration will need to be given to contain this movement in larger bollards with heart in the centre where splitting can occur (Figure 5.6BA). These larger bollards can be sawn longitudinally along the face (say 25 mm deep and 3 mm wide) and the edges of that cut arrissed as seen in Figure 5.6b. Bollards that are more exposed to close pedestrian traffic will benefit from pencil-rounded edges to avoid splinters. Bollard detail design considerations include:

- **expansion joints** – routed grooves can enhance aesthetics while providing a controlled and neat path for any surface cracking that occurs as the timber ages
- **pencil round** – rounding all edges increases safety (also consider rounding expansion grooves)
- **signage** – utilising at least one face to allow for engraving of wayfinding and signage symbols
- **end caps** – offer weather protection for timber containing heart, while enhancing aesthetics.

A: Uncontrolled splitting – Bollards that contain heart (pith) frequently split along their length.

B: Controlled movement – Using a router to provide a groove over a sawn line controls surface splitting and avoid splinters.

C: Deterioration at heart – Traditional steel banding to bollard ends does nothing to protect the post from weathering.

Figure 5.6: Avoidable failure in large hardwood bollards. Incorrect use of heart in timber bollards leads to splitting and deterioration.

Dressing considerations

Dressed horizontal timber surfaces deteriorate more rapidly than rough-sawn surfaces. In the case of bollards, however, the bulk of the exposed timber is vertical and so a rough-sawn finish is less valuable than it would with decking, for example. Durability aside, dressing offers benefits such as:

- **preservative treatment** – reveals timber grain after preservative treatment
- **machine worked** – allows for accurate indexing
- **multi-faceted cutting** – gives a more even alignment.

The decision to dress the timber used for bollards will be driven primarily by aesthetics. If the timber is to be treated with chemical preservatives before being dressed, the natural grain colour will be evident. If left rough-sawn, the colour of the treatment will be evident rather than the grain. If dressed then treated, the colour of the grain is visible

Creating bollards for signage or with complex shapes may require the timber to be processed in computer-controlled equipment such as CNC routers. In this case, the timber needs to be dressed to enable the machine to index accurately when working from two or more sides.

Multi-angled tops of bollards, such as pyramids, can be difficult to cut accurately on rough-sawn timber. The irregular size of a rough-sawn bollard makes getting a neat central diamond difficult. In this case, dressing 6 mm undersize rather than the normal 5 mm will assist accuracy by avoiding hit and miss on the dressing.

Rounded and arrissed edges

Providing a pencil rounded edge with a router provides a neat edge. It is more difficult to achieve a neat edge with a planer and splintering can occur on the two edges created when arrissing. If stainless is being used for a cap that the author recommends 316 grade to avoid tea staining.

5.3.1 Protecting Bollard Ends

Bollard caps act primarily as protection mechanisms of the underlying bollard structure and are essential for all timber bollards that contain heart. They also give the opportunity enhance the appearance of bollards.

Haptic design

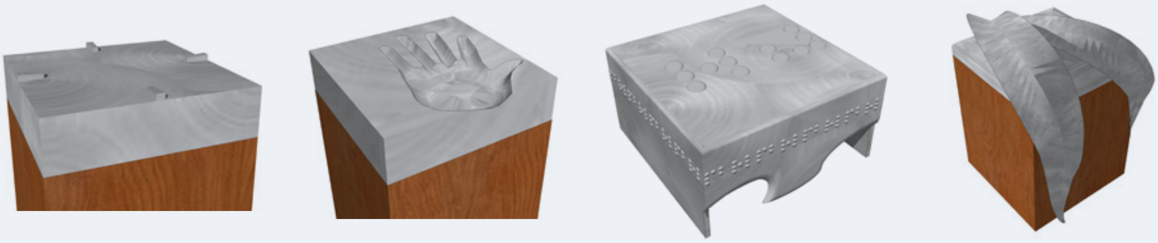
Although designed as barriers and to direct and protect, bollards also have a role as furniture. Social interactions in the environment tend to occur at points of transition. It is at these points that bollards are more likely to be touched by pedestrians, giving the opportunity for the bollard cap to communicate via touch. Bollard caps can be designed to generate a sensation in addition to enlivening the bollard's visual form. Through what is known as 'haptic' design, components designed to come in contact with people can be used to:

- **invite touch** – be visually identified by the use of contrasting material, form or texture
- **communicate** – braille can be used at key nexus to communicate to visually impaired people.

A: Over-fitted – Simple push-on end cap requires accurate symmetrical post cutting and ideally discrete fixing.

B: Flush-faced – Rebating bollard ends allows caps to fit flush with column sides, giving a more complex but neater finish.

Figure 5.7: Using metal bollard caps protects timber end grain from weathering and enhances aesthetics though it requires considerable accuracy in bollard cutting and cap fabrication to ensure a good fit. Caps can be chemically bonded (though with limited success) in place or mechanically fixed from the side. The use of security or one-way screws can avoid vandalism. Photographs: Dennis Clark Photography



A: Basic protection – Caps fold over edge of bollard ends to shield from weathering.

B: Inviting touch – When used in heavily pedestrianised areas caps invite touch.

C: Braille text – Adding braille can transform a bollard into an information point.

D: Sculpture – Identity and interest can be given by the addition of sculptured forms.

Figure 5.8: Bollard caps protect and communicate. Providing caps to protect the most vulnerable top face of bollards from weathering also creates an opportunity for tactile and visual design.

5.4 Bollard Layout

When bollards are designed as part of a landscape they may function singularly but frequently have impact through their numbers. Beyond the multiple functions discussed in the Park, Urban and Esplanade use categories there are general factors to consider in their placement, including:

- **in series** – visual route markers should be spaced close enough so as to be clearly read en masse and generally positioned on a smooth line – aligned with that of adjacent path or boundary
- **individual** – located at key junctions and may be used to obstruct pathways in order to be more obvious
- **protection** – closely spaced to physically disallow vehicles or to discourage pedestrians
- **universal access** – given the evolving awareness of needs of people with a disability and corresponding standards and legislation, gaining specific design advice from an appropriately qualified disability consultant is advisable.

6 Bollard Installation

As discussed in the Introduction, there are several common ways of mounting bollards:

- **surface mounted** – bolted to the ground plane
- **embedded** – base buried in ground
- **kinetic** – rebounding, retractable and removable bollards

Setting timber posts in concrete could almost be classed as universal practice due to its simplicity but this is bad practice in the case of hardwood and cypress, where trapped moisture can decay bollard bases.

Retractable bollards are generally proprietary items and their installation requires specialist detailing from manufacturers.

6.1 Surface-mounted Bollards

Surface-mounted bollards are commonly fixed with steel plates bolted to a paved ground plane. Surface mounting avoids major penetration of paved surfaces, avoiding deterioration that would otherwise be exacerbated by moisture penetration.

As a bollard's length allows considerable leverage to be exerted, base fixing brackets need enduring strong construction. Welded steel plate brackets provide this strength and can be readily protected by hot-dipped galvanising. A 6 mm steel blade welded to a 12 mm base with four M16 stainless steel chemical anchors is adequate for most standard applications. Where a specific load must be resisted, seeking advice from a structural engineer is advisable. Considerations for surface-mounted bollards include:

- **shrinkage** – to allow shrinkage of bollard timber the base can be constructed slightly smaller (say 6%)
- **hole size** – laser cut holes to support brackets allows greater accuracy, which is especially important if holes are to align with CNC-produced timber
- **base-plate purchase** – fixing base plates a minimum of 125 mm from the edge of the concrete reduces risk of pavement cracking
- **safety** – using 'captive nuts' with rounded heads avoids the danger of protruding bolts to pedestrians passing by.

6.2 Timber without Concrete Footings

Timber bollards can be founded in earth without footings and this is often done to avoid timber decay from any moisture that may become trapped in a concrete footing. Considerations for founding bollards in earth include:

- **timber durability** – consider timber durability and any preservative treatment is adequate to achieve required in-ground durability rating
- **natural earth** – consider bedding in the earth foundation material if it is suitably free draining and provides sufficient resistance to overturning
- **crushed rock** – if the foundation material is not free draining, fine crushed rock such as crusher dust can be used
- **sinking depth** – bollard bases should be buried 600 mm in ground to avoid overturning (less than this can lead to failure as shown in Figure 6.1)

Figure 6.1: Bollards buried in ground should aim for 600 mm deep to avoid overturning.

6.3 Timber in Concrete Footings

Cypress and hardwood bollards inserted into concrete footings are initially more secure, but as the timber shrinks, the developing gap between the post and the concrete can harbour moisture. A common cause of decay for timber bollards with concrete footings is irrigation and/or rainwater seeping down the gap around the bollard and being held by capillary action against the side of the bollard. Any fertilisers present will nitrify irrigation water, which further promotes timber decay.

Using timber of suitable natural durability will not compensate for inappropriate installation. Great care is needed when specifying concrete bollard footings as hardwood and cypress degrade more quickly when encased. To date, the author is not aware of decay problems related to correctly treated pine set into normal concrete (containing sand in the blend) footings. Considerations for using concrete footings with timber bollards include:

- **durable species** – with an 'in-ground' durability rating of 1 or a high 2 (the author has had considerable success with spotted gum, strictly a 'durability 2 in-ground' timber in tropical and subtropical climates)
- **permeable concrete** – use of 'no fines' concrete for footings as it is made without sand and thus allows moisture to drain through it
- **moisture cap** – rather than bringing a concrete footing to ground level, a clay cap (minimum 100 mm depth) can be added to prevent infiltration of surface water into any gap between bollard and footing that may develop as the timber shrinks
- **wrap in-ground timber** – suitable plastic pole bandages applied to lower durability species such as jarrah will offer some protection from decay
- **inhibiting biodegradation** – some products include pellets of slow-release active ingredients that inhibit biodegradation, but caution is needed as bandages can create a detrimental microclimate that can exacerbate timber decay.

WoodSolutions Design Guide No 41 *Timber Garden Retaining Walls* makes recommendations for construction of concrete footings for retaining wall design. The recommendations are also suitable for bollard applications, say: "No fines concrete shall be 10 mm maximum aggregate size, 450 kg cement per cubic metre and a water cement ratio of 0.55. The concrete shall be ready mixed or hand mixed manufactured to the requirements of AS 1379. For no fines concrete the concrete shall be well agitated immediately before placing to ensure a complete coating of the aggregate. The concrete shall be discharged directly into the holes and tamped without delay. All concrete shall be placed within one hour of batching. The no fines concrete shall not be reworked as this destroys the bond."

This clay capping method is more important for structural applications due to potential danger of failure. For large, free-standing, in-ground timber structures - such as totem type poles – seek advice from a specialist timber engineer.

Failure through decay – Decay in this timber bollard has been hastened by the post base being set in concrete. The bollard is under 20 years old.

Figure 6.2: Providing a free-draining foundation for bollards limits the potential for moisture build-up and thus decay.

7 Timber Durability

Timber is a natural product that, if left to weather, will in time break down to organic matter. There are many different situations and applications in which timber can be used, and bollards that are both buried and weather exposed are one of the most demanding. Timber may deteriorate through the action of insects, fungi and marine-boring organisms. This deterioration can be prevented if conditions are made unsuitable for these destructive agents.

Timber preservation uses chemicals that improve the natural durability of the timber, while rendering the material unpalatable to insects, fungi and marine borers. Correct specification of timber with appropriate treatment provides timber bollards that are durable and which endure and age well.

7.1 Natural Durability

The natural durability of timber is classified according to the heartwood's resistance to deterioration. The sapwood of all timbers, softwoods and hardwoods, is always non-durable and will rapidly deteriorate if not protected.

Natural durability refers only to mature outer heartwood. Resistance is given by the presence of special tannins, oils, resins and extractives in the heartwood that repel or kill insects and decay.

Australian Standards defines timber durability of in-ground and above-ground use and for treatment levels. AS 5604 *Timber – Natural durability ratings* gives four classifications of natural durability with a rating of one being the highest. Refer Table 7.1.

Table 7.1: Probable life expectancy for natural durable timber

Durability Class	Probable in-ground life expectancy (years)	Probable above-ground life expectancy (years)
1	Greater than 25	Greater than 40
2	15 to 25	15 to 40
3	5 to 15	7 to 15
4	0 to 5	0 to 7

Adapted from AS 5604: Timber – Natural durability ratings.

7.1.1 Hardwood

Sapwood is the only portion of the hardwood that can be treated with chemical preservatives as it contains open passages that allow chemicals to travel into the timber's cellular fabric. As mentioned previously, treating timber with preservatives does lift the durability of sapwood, but it offers no chemical protection to the remaining timber.

Sawn hardwood bollards invariably contain only a small amount of sapwood. Figure 7.1A illustrates the amount of sapwood that can be treated in a typical batch of hardwood timber. If the timber was not treated and the sapwood was allowed to completely decay – the bollard would still be within recognised structural limits. The Australian Standard *AS 2082: Timber – Hardwood – Visually stress-graded for structural purposes* allows up to 20% of the cross section to be missing from most grades. Timber with this extent of decaying sapwood is unattractive. The treatment process on sawn timber bollards serves an important task of stabilising the sapwood but it does not preserve the critical heartwood portion either above or in the ground.

Vague specifications for bollards that consist merely of a timber strength and treatment level are frequently seen. A request for example of "F14 treated to H5" will say nothing worthwhile for determining the durability of the timber. Treatment will not compensate for inappropriate specification and installation.

Species selection, grade and correct installation are far more critical for longevity than treatment alone. That said, treatment will prevent the sapwood decaying.

Table 7.2: In-ground durability for Australian species.

In-ground durability class	Description	Common Australian Species
Class 1	Timbers of the highest natural durability, may be expected to resist both decay and termite attack for at least 25 years and up to 50 years	Grey Box Grey Ironbark Red Ironbark Tallowwood White Mahogany Yellow Box
Class 2	Timbers of high natural durability, may be expected to have a life of about 15 to 25 years.	Jarrah Red Box River Red Gum Spotted Gum White Cypress Yellow Gum
Class 3	Timbers of moderate durability, may be expected to have a life of about 8 to 15 years.	Broad-leaved Peppermint Brush Box Southern Blue Gum Sydney Blue Gum Yellow Stringybark Western Red Cedar
Class 4	Timber of low durability, which may last about 1 to 8 years. These timbers have about the same durability as untreated sapwood, which is generally regarded as Class 4, irrespective of species.	Candle bark Douglas Fir (Oregon) Hoop pine Manna Gum Mountain Ash Radiata Pine Slash Pine

Adapted from AS 5604: Timber – Natural durability ratings, Table A1

7.1.2 Softwood Bollards

While correctly specified hardwoods can have greater durability than softwoods, it is possible to successfully use treated softwoods for bollards. Unlike hardwood, the chemical treatment of softwood is a must. Surface penetration of preservative treatment is a particular issue in softwoods, which is aided by incising. Additional to chemical treatment, timber durability can be optimised with the following considerations:

- **profile shape** – using round elements to avoid cutting through untreatable heart
- **incise timber** – softwoods should be incised to the correct depth prior to treatment
- **two-stage treatment** – steaming of timber prior to preservative treatment increases penetration.

Profile shape

Common softwood, such as pine, has very poor natural durability with an in-ground rating of 4.

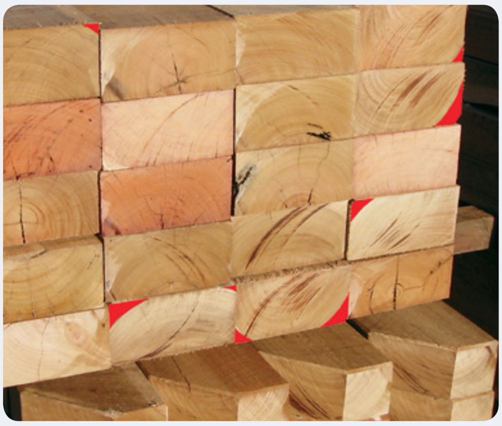
When round members are well treated, an outer unbroken band of sapwood can provide very effective envelope protection around the untreatable heart. Square-sawn members, on the other hand, particularly with a large portion of heart, can have large areas of the cross section untreated due to the limitations on treatment penetration of heartwood.

Incising

Scoring the face of softwoods aids preservative penetration, but the timber needs to be incised deeply enough. To achieve the in-ground H4 rating needed for large pine bollards, they require incising to a depth of 10 mm. Figure 7.1B shows an example of how too-shallow incising can limit the penetration of preservative into softwood.

Steaming

While steaming softwood prior to treatment can improve the preservative penetration, not all timber preservers do so. There is no substitute for incising and world-wide suppliers are increasingly seeing the cost of steaming and correct incising as a part of the cost of doing business. The ends of the packs can be easily inspected to confirm the level of preservative penetration. If more than 20% of the cross section of non-incised timber is untreated it should be rejected (the opposite to hardwood).



A: Extent of treatable sapwood in hardwood. Picture shows sapwood (highlighted in red) in untreated hardwood bollards. It is not possible to speak in a meaningful way of treating hardwood sapwood beyond H3.

B: Softwood with insufficient incising. Good penetration of softwood treatment is dependent on incising to the correct depth. An applied stain detects the level of penetration of the preservative treatment. This pine bollard was incised to about 3 mm rather than the 10 mm required resulting in a centre vulnerable to deterioration.

Figure 7.1: Providing a free-draining foundation for bollards limits the potential for moisture build-up and thus decay.

7.2 Specifying Preservatives and Hazard Levels

The treatment of timber with preservatives is concerned mainly with the protection of sapwood. The amount of preservative required is expressed as its Retention Level.

Australian Standard AS 1604: *Timber – Preservative-treated – Sawn and round* and often used in building structures. The standard provides strict guidelines for the amount of chemical preservative required in the sapwood of timber in order for the wood to perform as per its designated durability category. There are six categories with category six being the highest. Designers and constructors are best guided by AS 1604, which describes six main exposure and biological hazards as shown in Table 7.3.

In any particular charge (the term used to describe an individual batch of timber being treated) of treated timber there will be a range of preservative penetrations and retentions depending on the moisture content, sapwood to heartwood ratio, species, treatment schedule and inclusion of additives. Table 7.3 shows the treatment requirements considering the timber species natural durability.

Table 7.3: Exposure & biological hazard levels.

Hazard Level	Exposure & Biological Hazard	Typical Use
H1 – interior above-ground	Completely protected from weather and well ventilated. Beetles and borers only.	Susceptible framing, flooring, furniture, interior joinery
H2 – interior above-ground	Partially protected from wetting. To prevent termites and borers only.	Framing, flooring
H3 – exterior above-ground	Subject to periodic wetting. To prevent decay, termites and borers.	Weatherboard, fascia, window joinery, exterior framing and decking
H4 – exterior in-ground	Subject to severe wetting. To prevent severe decay termites and borers.	Fencing, greenhouses, above ground portions of pergolas and landscaping timbers
H5 – exterior in-ground	With or in fresh water. To prevent very severe decay, termites and borers.	Retaining walls, piling, house stumps, building poles, cooling tower fill
H6 – marine water exposure	To prevent marine borers.	Boat hulls, marine piles, jetty cross-bracing, landing steps

Taken from AS1604.1: Timber – Preservative-treated – sawn and round

8 Specification

Clear specifications can avoid undesirable outcomes. Providing greater clarity can require additional detail, which may not be warranted with quality manufacturers or contractors. However, in public tender scenarios, it is critical to ensure the desired outcome is delivered.

Consideration for the specification of timber bollards include:

- **species** – appropriately durable and commercially available species
- **treatment type** – timber preservative type
- **treatment method** – if pre-steaming or incising is required
- **treatment order** – timber may be processed then treated versus treated then processed
- **member size** – the size of member and format (round, square or rectangular) can have a direct effect on performance and ecology of sourcing
- **pith** – if heart is allowed, the required cover by durable shielding timber is import to avoid decay
- **composite construction** – detailing how multiple members are to be combined and fixed
- **timber finish** – dressed timber may be required for increased dimensional accuracy and different appearance as discussed above
- **control joints** – sawn grooves in faces can control splitting of heart in timber
- **edges** – a choice of arrissed or pencil-rounded edges will affect both splintering and weathering
- **fixings** – the fixing material and its finish impact its durability but also specification of sleeve nuts will provide better appearance than countersunk nuts for example (see Figure 8.1)
- **footing** – where natural earth is inappropriate, specifying a footing of no fines concrete will limit moisture retention (see notes about providing earth capping to footings above)
- **presentation** – achieving surfaces low in timber characteristics (knots and gum vein) and marks, including having any working annotations sanded off.

Figure 8.1 illustrates the different products that can be delivered under the same specification, if it does not contain sufficient detail.

Left: A: Well-supplied product – Note the use of 'captive nut' sleeved fixings, which avoid potential injury. This bollard is founded in a no-fines concrete footing to maximise drainage.

Right: B: Lower-price substitute – Manufacture marks give an unsightly finish and because the composite members were cut before assembly, the bollard has an uneven top face.

Figure 8.1: The illustrated composite bollards were built on the same project at different stages. The image A bollard has four spotted gum species members bolted together to gain a mass appearance.

9 Maintenance of Exterior Timber

While weathering primarily affects the appearance of timber, in the long term it can affect durability and performance. All timber will change when exposed to the sun and rain, irrespective of species, durability classification, or whether it is preservative treated or not.

Ultraviolet light and changing moisture exposure will cause timber to weather, resulting in a loss of natural colour over time. All timber will fade to a silver-grey and its surface will become rough, with the potential for cracks and spits to develop.

Weathering protection

Treating timber with preservatives to protect from decay and/or insects does not prevent timber from weathering. However, the application and regular maintenance of protective coatings will reduce weathering. Proper finishing also helps external timber fulfil its designed function. Protective finishes form a barrier between the weather and the timber, reducing water absorption on wetting, and slowing moisture loss on drying. To protect from UV light, finishes generally should contain a pigment (light colours preferred). The pigment reflects or absorbs the UV light, and shields the timber. Options for finishing timber bollards include:

- **natural unfinished** – consider if the species chosen weathers well and with an acceptable colour change
- **pigmented penetrating stain** – ensure that they have high UV blocking and water repellent ability
- **clear finish** – consider the potential high cost of maintenance for recoating and potential re-sanding over time
- **paint** – an oil-based primer followed by two coats of top coat generally offers the best result (ensure the paint chosen has Australian Paint Accreditation Scheme approval).

9.1 Penetrating Oils

A correctly detailed bollard of the correct species and quality does not need to be oiled to ensure longevity, but designers may wish to apply a penetrating oil to improve the initial aesthetics. The only oil that offers a preservation function is Copper Naphthenate (CN). However, it has the potential to stain clothes and skin on touch.

The prime benefits of using penetrating oil are that it repels water and blocks ultra-violet radiation. UV blockers are expensive and some products can include very little of them, and some offer very little water repellence. It is important that any penetrating oil includes these properties or it will not offer the protection sought.

Some confuse penetrating oil with film finishes as, when the oils are first applied, it does have some level of gloss finish but this is frequently short-lived, especially on unseasoned timber. A lack of an apparent surface gloss does not mean that an oil is not present and/or not working. A test of the efficacy of an oil treatment is to apply water to the surface. Once the surface stops repelling moisture it is time to reapply.

If reapplication is required, the timber does not need to be sanded. A simple wash will remove dust and application of a fungicidal, if needed, will kill any mould present – following which the oil can be re-applied. This simplicity and relatively low cost makes maintenance a possibility.

Unseasoned hardwood will not allow the oil to penetrate deeply so for best results apply a coat when the bollards are installed and then again prior to handover. The timber can be left to weather to a typical silver grey colour over time.

A good quality oil should contain ingredients such as:

- **suitable oil/resin** – often resins are modified to have characteristics that address the limitations of natural oils, including mould growth in linseed oil and lanolin
- **UV absorbers** – offer protection to timber substrate and resin/oil system
- **water repellents** – can vary significantly in type and quality; it is best to have repellents that are not prone to mould (issues with linseed oil and lanolin)
- **mould and algae inhibitors** – will not remove or prevent mould from pre-infected timber
- **solvent** – provide the carrier that helps the oil's ingredients penetrate the timber.

Solvent system

There are many types of solvent systems. Many penetrating oil formulations contain petroleum-based solvents of varying flash points (degree of flammability) and levels of aromatics as well as those that have surfactants to allow water to be incorporated.

The best penetrating oils contain a petroleum-based solvent system as these are more able to penetrate timber and less prone to facilitate movement of tannins contained in the timber to the surface. A product that incorporates a solvent with a high flashpoint and low aromatics would be preferable. A high flashpoint (>60.5°C) will mean the product will not be considered flammable, reducing risks for transport, storage and use. A low aromatic solvent will reduce odour and potential health risk often associated with using solvents. While these features do not necessarily add to the quality of a product, they do provide benefits that make oil-based, penetrating oils more amenable to use and hence get the best result in timber.

Figure 9.1: Timber durability is enhanced by applying appropriate paint and oil systems.
The bollard shown is protected with a penetrating oil that repels water and blocks ultra-violet radiation.

10 Learning from Case Studies

10.1 Park Perimeter Bollarding: Gatton Region

- **Function**: Bollards and low height barriers used to define the parks perimeter
- **Material**: Spotted gum and blackbutt hardwood species
- **Key learning**: Durable species selection needs to be paired with supply of timber with no heart

Figure 10.1: Original timber barriers at Lake Apex, Gatton, Queensland. The exposed hardwood shows some weathering but is still functioning after 30 years exposure, some areas experienced extended areas of submersion.

The Lake Apex Park in Gatton is a council park that was enclosed by a hardwood post and rail fencing when the park was first developed in 1984. The author was involved in providing the timber for this project and, as a local, has seen how it has endured. After more than 30 years, the hardwood bollards and fencing endure. Based on the performance, it appears the barriers could have had a 50-year service life but were replaced with fresh timber bollards in a redevelopment of the park in 2018.

In the interim, recycled plastic bollards have been added adjacent in the park. Recently, new hardwood bollards were installed in nearby parkland, which provide a useful comparison to the original hardwood construction. The original hardwood rails and posts installed were a mixture of spotted gum and blackbutt species.

Although the original hardwood has endured and performed well, there are still lessons to be gained on improved supply and construction methods.

Portions of the fences were submerged repeatedly in the adjacent lake for long periods as the lake levels fluctuated, which led to more sever deterioration and were replaced after approximately 30 years.

Performance of rails

Of the visible weathering, the greatest deterioration is on the horizontal rails, as would be expected. The deterioration became apparent on the top face of the 200 mm x 50 mm rails after about 15 years of exposure to the warm and humid South East Queensland climate. The deterioration detracts from the appearance of the rails but does not affect their function. Suggested improvement:

- **Current**: rough-sawn rails with arrissed edges
- **Improvement**: dress the top of the rail with a moisture shedding top with a 6 mm rounding to the edges.

In-ground performance

Even at this stage, decay at the ground line is only slight. This has been helped by the posts being installed with a natural earth as opposed to a concrete footing that could harbour moisture. Suggested improvement:

- **Current**: 200x100 mm posts buried to about 600 mm in natural earth footing
- **Improvement**: good performance – none required.

Termite resistance

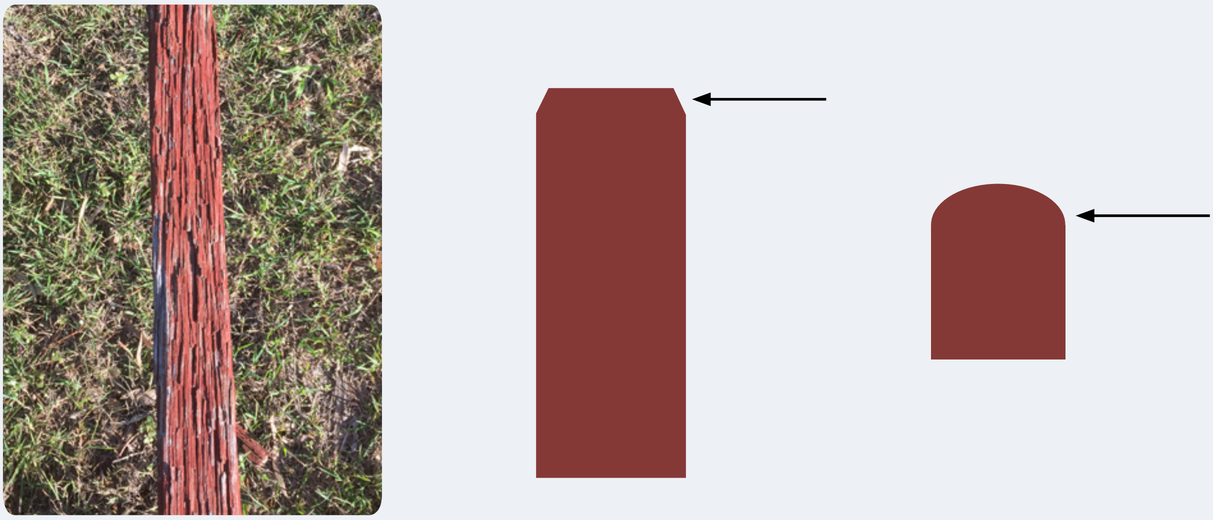
Because termite-resistant species were used, termite attack has been slight. Only two posts (i.e. less than 1% of the total) appear to have any termite damage. Suggested improvement:

- **Current**: naturally termite-resistant timber
- **Improvement**: good performance – none required.

Maintenance

The fencing was given a coat of protective stain in recent years, and a couple of rails have been replaced due to vehicle impact. Apart from that nothing has been done, nor needed to be done.

- **Current**: no finish was applied when installed, and one known application since
- **Improvement**: good performance – none required.



A: Top rail weathering – Some degradation apparent in more than 30 years of weathering.

B: Built top rail profile – A flat-topped member with arrissed edges was installed.

C: Improved profile – Providing water-shedding profile to top surfaces considerably enhances durability.

Figure 10.2: Although these hardwood rails have endured, water-shedding top edges would have further increased their life.

Plastic bollard comparison

A decade ago the local authority installed a recycled plastic bollard a few metres from the 1984 timber installation (figure 10.3B). Despite the poor weathering of this bollard, in 2015 a large number of plastic bollards were installed. Vehicle strikes have seen more than a dozen of the plastic balustrades sheered to the ground (Figure 10.3A). Figure 10.3 illustrates the comparative sturdiness of the three decade- old hardwood barriers, which have survived vehicle collisions.

When the council was queried about the choice of plastic as material for the new bollards, the author was told: “For several reasons, the use of timber bollards is diminishing over time, namely high maintenance costs, cracking timber, splinters, bollard weight and termite/borer attack protection. Recycled plastic bollards have a longer maintenance-free lifespan, are much lighter, don’t splinter and because they are made from recycled plastic they reduce our environmental burden.”

Maintenance demand was also linked to perceived need to oil spotted gum bollards that were less than two years old. In the author’s experience such maintenance was completely unnecessary.

Hardwood specification

In a nearby car-park hardwood bollards have been used as part of a new installation. These are 200 mm x 100 mm in section, a common dimension. Although the species used appears to be spotted gum and ironbark, a lack of grading has seen timber supplied that has been cut indiscriminately, with no concern to avoid the more vulnerable heart (pith). The result has been severe splitting in the majority of these new bollards. This splitting exposes the heart to weathering and hastens the decay of the timber. Some are so split that they create the potential to trap fingers.

Figure 5.4 shows typical images of what are largely defective bollards installed in this parkland.

When supplied for use as landscaping sleepers, similar-sized members are often cut in an indiscriminate manner that exposes the vulnerable timber heart. Exposed heart is unsuitable for structural applications and quality control is needed to preclude it. Correct timber selection for durable performance requires not only correct specification of timber species, and how heart is to be avoided when cut, but also inspection of product after grading. Even when the specification is correct there is a danger that lower-priced material will be substituted.

A: Sheared bollard – This new recycled plastic bollard was sheared at the ground by vehicle impact.

B: Reinstated – The damaged bollard is about 10 years old and is shown reinstated with the aid of a steel picket.

C: Hardwood barrier – The 30-year-old hardwood barrier is shown here intact despite having rendered considerable damage to the vehicle.

Figure 10.3: Comparison of plastic to hardwood bollard. The occurrence of vehicle collisions illustrates hardwood endurance.

11 Glossary

Common industry terminology and abbreviations:

CUAZ: Copper and Azole is a timber preservative.

ACQ: Alkaline Copper Quaternary is a timber preservative.

CCA: Copper Chrome Arsenic is a timber preservative

dressed: Off-the saw timber that has been planed to provide smooth, even faces.

extractives: The constitute liquids which seep from green timber.

ex: 'Ex' sizes are the original cut size from which shrinkage, and dressing reduce in size.

heart: The centre of a tree is called 'heart', and in sawn softwood it is commonly referred to as 'pith' or corewood. Hardwood that contains 'heart' (pith) is particularly vulnerable to splitting.

heartwood: That portion of a tree between the sap and the heart.

pith: see 'heart'

rough-sawn: Timber left with a rough face, as it has been initially sawn.

rounds: Timber that has not been sawn, can either be natural or parallel sided.

sapwood: The outer growing zone of the tree.

12 References

Australian Standards

The following Standards have some coverage that affects the timber used to construct bollards or the nature of the design and placement of bollards:

Timber

AS 1604 Timber – Preservative-treated – Sawn and round

AS 2082 Timber—Hardwood—Visually stress- graded for structural purposes

AS 5604 Timber – Natural durability ratings

Concrete

AS 1379 Specification and supply of concrete

13 Appendix A: Timber Selection and Construction Notes for Bollards

<table>
<tr><th colspan="5">Species and Preservative</th></tr>
<tr><th colspan="5">Hardwood</th></tr>
<tr><td colspan="5">The best species performance can be achieved by using the readily available timbers traditionally known as ‘Royal species’. These include spotted gum, ironbark, tallowwood, etc. In some drier climates other in-ground durability class 1 and 2 timbers species, e.g. blackbutt, may provide adequate durability.</td></tr>
<tr><th>Nominal Size (mm)</th><th>Containing Heart?</th><th>Comment</th><th>Construction</th><th>Preservative</th></tr>
<tr><td>Smallest size <100 mm</td><td rowspan="5">No Heart</td><td>• An increasing trend to reduce size to 75 mm to save cost might save as little as $15 on a typical bollard length but not installation cost.
• Using smaller members could see a 25% reduction in service life.</td><td rowspan="5">• Free of heart.
• Grade is Structural Grade 2 for all species.
• Note on grading: Inspect each piece to ensure defect is placed in ground.
• Mark base with lumber crayon before processing and make available for inspection prior to processing.</td><td rowspan="5">• Sapwood treated to H3 with ACQ or Copper azole.
• CCA not acceptable</td></tr>
<tr><td>100 mm x 100 mm</td><td>• The standard size for bollards used for many years.</td></tr>
<tr><td>125 mm x 125 mm</td><td>• Easier to source, and fewer quality consequences than 150 mm.</td></tr>
<tr><td>150 mm x 150 mm</td><td>• A historically common size.
• Not recommended, as it can be hard to supply in suitable quality.
• As ‘free of heart’ material is much more expensive than ‘heart in’, be aware that ‘heart in’ is frequently substituted.
• Consider reducing to 125 mm for a more achievable size without loss of function.</td></tr>
<tr><td>200 mm x 100 mm</td><td>• Easily substituted with landscaping sleepers that may have low quality, low durability and quickly deteriorate.</td></tr>
<tr><td rowspan="2">175 mm</td><td>Contains Heart</td><td>• AS 2082 allows many common species to contain heart but this should not be done until the size is greater than 175x175 mm.
• More prone to splitting lengthways which can expose the heart and leads to deterioration.
• Consider increasing the specification to 200 mm.</td><td>• Sound heart in the centre.
• Structural Grade 2 required for all species.
• Cut expansion joints to at least two faces, (more is better) within one week of milling.
• Inspect each piece to ensure any defect is placed in-ground.
• Mark base with lumber crayon before processing and make available for inspection prior to processing.</td><td>• Sapwood treated to H3 with ACQ or Copper azole.
• CCA treatment is not acceptable.
• Note sapwood content will be small.</td></tr>
<tr><td>No Heart</td><td colspan="3">Not available without heart</td></tr>
</table>

Nominal Size (mm)	Containing Heart?	Comment	Construction	Preservative
200 mm	Contains Heart	• Much more dimensionally stable members. • Contains proportionally less heart and are less prone to splitting.	• Sound heart in the centre. • Grade is Structural Grade 2 for all species. • Expansion joints to at least two faces, more is better, ideally all within one week of milling. • Inspect each piece to ensure defect is placed in ground. • Mark base with lumber crayon before processing and make available for inspection prior to processing.	• Sapwood treated to H3 with ACQ or Copper azole. • CCA treatment is not acceptable. • Note sapwood content will be small.
	No Heart	Not available without heart		
>200 mm	Contains Heart	• Much more dimensionally stable members. • Contains proportionally less heart and are less prone to splitting.	• Sound heart in the centre. • Grade is Structural Grade 2 for all species. • Expansion joints to at least two faces, more is better, ideally all within one week of milling. • Inspect each piece to ensure defect is placed in ground. • Mark base with lumber crayon before processing and make available for inspection prior to processing.	• Sapwood treated to H3 with ACQ or Copper azole. • CCA treatment is not acceptable. • Note sapwood content will be small.
	No Heart	Not available without heart		
>300 mm	Either	Impractical to supply. Consider composite members.		
Natural Hardwood Rounds	Contains Heart	• Reasonably readily available and, when turned, striking in appearance	• Durability 1 in-ground timber with a small sapwood boundary, e.g. red ironbark. • Overgrowth of injury and 'dryside' not permitted above ground. • Place any irregular shape in the ground. • When grading natural rounds in their natural state the defects that are seen in the sawn are generally not evident but may be hidden behind a bump or irregularity on the surface. These should not be removed.	• Sapwood treated to H3. • All in Ground Durability 1 and 2 species are automatically H5 if there is less than the usual 20% sapwood. • If specifying H5, CCA will be supplied unless stated otherwise.
Cypress				
Sawn - all sizes and species	This product may be unsuitable for use as bollards as the sapwood cannot be treated. If used sapwood content, which can be considerable must be limited to a maximum of 20% of the cross section.			
Natural Cypress Rounds	Contains Heart	• If the sapwood is removed in a rounding machine similar to pine, it would be eminently suitable. • Install as above.	• Maximum amount of sapwood not to exceed 20%. • Structural grade 2. • Inspect each piece to ensure defect is placed in ground. • Mark base with lumber crayon before processing and make available for inspection prior to processing.	• Sawn and natural rounds of cypress can contain large amounts of sapwood. • The sapwood of cypress is resistant to treatment and should not be ordered treated.

Nominal Size (mm)	Containing Heart?	Comment	Construction	Preservative
Pine				
Sawn - all sizes and species	Either	• A significant quantity of treated pine does not meet the required standard. Inspection for heartwood compliance if not incised is critical	• Incised to a depth of 10 mm or maximum amount of sapwood not to exceed 20%. • Structural grade 2. • Inspect each piece to ensure the depth of incisions is 10 mm or heartwood does not exceed 10%. • Ensure the defect is placed in ground. • Mark base with lumber crayon before processing and make available for inspection prior to processing.	• Sapwood treated to H4 with ACQ or Copper azole. • CCA treatment is not acceptable. • Incising is very important.
Pine Rounds	Contains Heart	• It would be rare to find natural rounds available on the landscaping market in any quantity.	• The product is now machined to give a true diameter and form along its length and is pre-graded. • Install as you would sawn pine.	• Sapwood treated to H4 with ACQ or Copper azole. • CCA treatment is not acceptable. • Incising is not an option.
Mounting and Footings				
Surface Mounted		• Galvanised or stainless steel. • Note stainless fasteners into the concrete give less trouble.	• Provide fixings 125 mm from paving edge.	
Earth		• Set in natural earth if suitable. • An alternative is fine crushed rock.	• Consider use of a pole bandage to assist lower durability species.	
Concrete	No-fines	• Use where possible to avoid potential moisture holding in footing.	• Consider whether it really is needed.	
	Normal	• Consider its use only with pine.	• Where possible, provide a 100 mm thick earth cap to top of footing to limit ground water entering any gap around between the footing and bollard base.	

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