



Building dry stone walls

A guide for beginners



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May 2020

Photos:

All photos by B Munday except:

P 3

Pp 8 (top & middle right), 9 (top), 10 (bottom left)

Pp 7 (top), 11

P 9 (bottom)

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The first iteration of these guidelines drew on Richard Tufnell's *Building and Repairing Dry Stone Walls* (1982). This updated version also benefits from Richard's suggestions, and those of Geoff Duggan and Jon Moore.

Line drawings in this manual are from *Dry Stone Walls – Fundamentals, Construction, Significance*, edited by the Swiss Environmental Action Foundation. This excellent book was reviewed in DSWAA's journal *The Flag Stone* # 47, Jan 2020. Permission to reproduce these drawings is granted by their creator, Dani Pelagatti, and the Foundation under the Creative Commons Attribution-ShareAlike 4.0 International licence.

DSWAA at www.dswaa.org.au and <https://www.facebook.com/drystonewallsaustralia>

How to build a free-standing dry stone wall

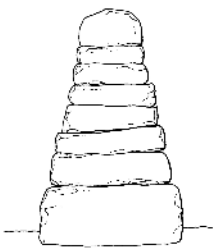


A single-skin wall

Single-skin walls are quickest to build, generally less demanding of regular-shaped stone and in their simplest form involve piling one stone upon another. But to endure they need care and skill.

Single-skin walls lack the visual finesse of double-skin walls, partly because the faces of the wall are uneven and one can invariably see light beaming through. And yet a sound single-skin requires every bit as much skill as a double—maybe more.

Single-skin walls taper from bottom to top for stability. A metre high wall probably needs to be about 750 mm wide at the base where the foundation stones sit on their flattest and fattest side (if they have one). Ideally these will be quite large stones and will need to be crow-barred into place.



The ends can be tricky which is why it is smart to finish at a post, wall or tree. If not so supported, the end stones need to be tied in through friction with their neighbouring stones on that level. This means that the end stones should have approximately the same thickness as those neighbours. Tapering the end also assists stability.

This manual deals only with double skin free-standing walls and retaining walls.

The Dry Stone Walls Association of Australia (DSWAA) believes that there is a waller in each of us. We aim to raise awareness of the heritage value of dry stone walls and also pass on the practical skills of the craft.

Dry stone walling is both challenging and satisfying. We hope that these pages, introducing the basics of walling, will help you improve not only your landscape but also your understanding of and respect for stone. Of course there is no substitute for hands-on experience and in some instances professional advice. The DSWAA can connect you with other amateur and professional wallers.



A domestic landscaping feature can display the fine finish that only time allows, whereas a wall marching perhaps kilometres across paddocks is more about grandeur than glitter, function than finesse.

Andy Goldsworthy's well at the Adelaide Botanic Gardens is all finesse.

A double-skin wall

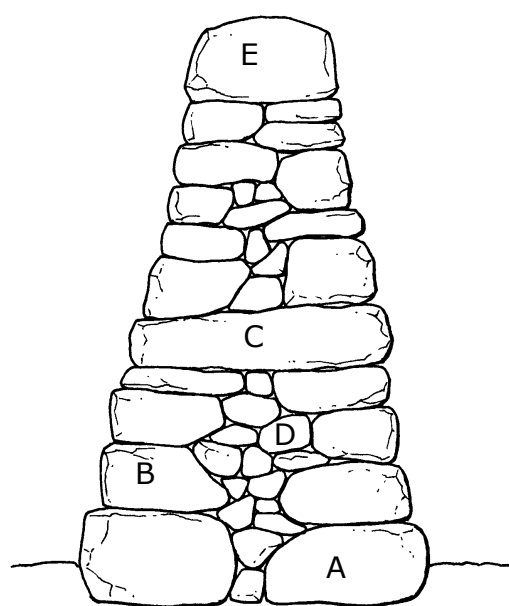
A double-skin wall is essentially two load-bearing facades leaning slightly in on each other, the structural integrity owing to the interlocking of the **building stones** along with '**through-stones**' at regular intervals. Voids are tightly packed with smaller stones and rubble known as '**hearting**', and with gaps under stones packed with '**pinners**'.

In most (but not all) styles the bigger stones are at the base for stability. Along the length of the wall the two-on-one principle is used to bridge all joints as if building a brick wall. This is easier said than done when there is great variation in the length, width or thickness of stones.

Stone fences of the early settlers (c. 1850-80) were generally built where ample stone was readily available, clearing of the paddocks an obvious benefit. In those situations a team of four (usually including two children) could build about a chain (approximately 20 metres) of fence one-and-a-half metres high per day. For that they were paid about 'a pound a chain'.

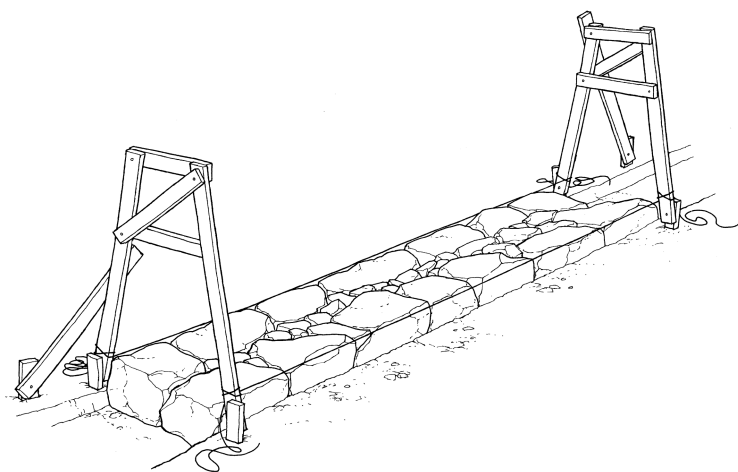
Stone walling on a grand scale was overtaken by post and wire in the eighteen-eighties when the Bessemer Process enabled wire to be economically drawn from steel.

Today when labour is not cheap, a metre-high dry stone wall with coping might cost \$300 per metre length plus materials. Clearly this is seldom an option other than for landscaping projects.



- A Foundation stone
- B Building (face) stone
- C Through stone
- D Hearting
- E Cope stone

Basic cross section of a double-skin wall



Foundation course with batter frames to define the wall. Upper surfaces should be as level as possible in preparation for the next course



Foundation course between string-lines. Stones mainly length into wall (bottom left could be better). Through stones would usually be higher in the wall but can be used here if available.

Retaining walls

At first glance a retaining wall would seem to be less challenging than a free-standing wall – only one face needs to be true as the other is always hidden, and it might seem that it will be supported by the material behind. Having to present only one fine face is indeed a simplification, but its function is not to lean on the earth behind but rather to hold it back. It must be structurally sound and well enough founded not to break apart, fall over or slip away under considerable lateral force.

A great virtue of dry stone retaining walls (compared with mortared walls) is their free-draining property, nonetheless heavy clay soils when thoroughly wet

can exert considerable lateral force on the wall unless this is relieved with stone packing. When a retaining wall is built to support a terrace it might experience additional forces due to traffic or structures loaded on the terrace.

Distortion or shifting of a retaining wall can be seasonally incremental, small movements occurring as the wall settles, soil wets and dries, tree roots heave, vehicle traffic increases, and so on. It may be years or even decades before the damage is recognised.

A Foundation (footing) stone

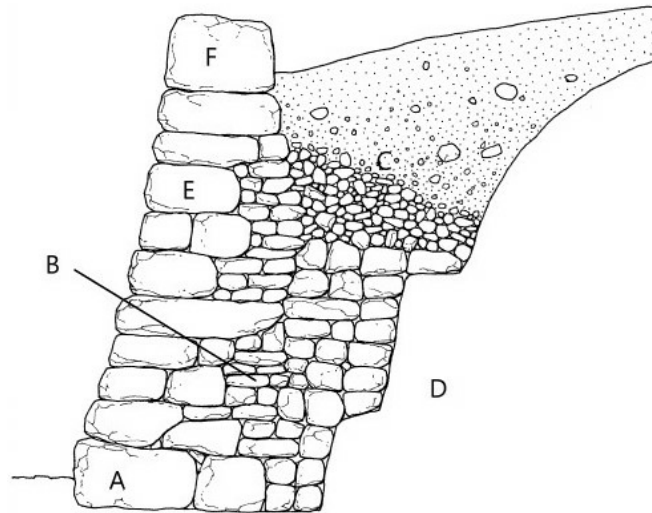
B Hearting

C Backfilling

D Native soil

E Building (face) stone

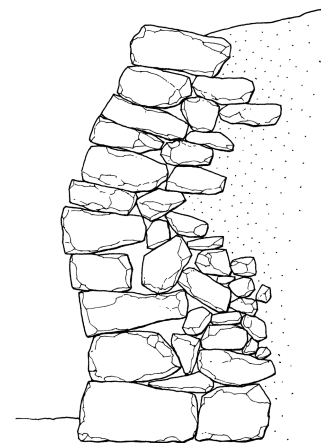
F Cap or cope stone



High retaining walls (with their inherent danger) can often be avoided by terracing whereby the function of one high wall is fulfilled by two or perhaps more smaller terrace walls.

Whilst dry stone walls generally do not require concrete footings, take care with retaining walls on new building sites where the building ground might be unconsolidated fill.

The general principles for building a retaining wall are very similar to those for a free-standing wall. The batter for a retaining wall is often less steep, but that depends on many factors not least being taste. The photo at left shows the batter frame for a retaining wall in progress.



Bellying of a retaining wall due to lateral forces exerted by soil

Basic principles

The basic techniques needed to build a strong good-looking wall can be condensed down to six important rules.

1. Cross all joints

Each stone should be sitting on two stones below it so that it is crossing a joint – or as they say in Cumberland 'Yan on twa and twa on yan'. What should not be done is to stack stones so that there are vertical joints running from one course to the next. Such joints are called **running joints**, zips or stack bonds. Walls with running joints are very weak, look poor and are liable to fail.

This dry stone retaining wall in front of the kiosk at Waterfall Gully (SA) shows the consequences of running joints, exacerbated in this case by ivy invading the cracks.



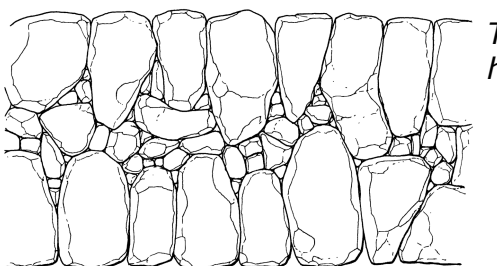
2. Set the length of the stone into the wall



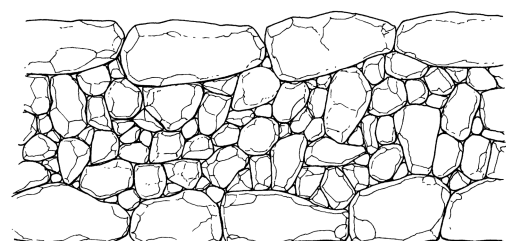
The strength of a wall is very dependent on friction holding the two facades together. This is achieved by laying the stones lengthwise into the wall, not along the wall. The force holding a stone firmly in the wall depends on the friction between that stone and all its neighbours, above, below and beside. Stones placed along the wall so that the long sides are visible create a much weaker wall and is called trace or face walling. Think of how firewood is stacked, each piece perpendicular to the overall direction of the stack, so all you see are the ends of the pieces. A stone wall should be built the same way. That said, practicality sometimes dictates that a face stone can intrude only 150 mm into the wall – we can live with that so long

as it is well covered above and below by stones that do penetrate well into the wall.

Through-stones (long stones, the ends of which show on both sides of the wall) are an extension of this rule, and should be placed every metre or so, halfway up the wall, to tie the wall faces together. Trace walling is one of the most common errors, and is a primary reason walls belly-out and eventually fall down.



Correct (plan view): stones length into the wall



Trace walling: Inadequate bonding of face stone



3. Heart the wall tightly

The wall should be sound, with gaps in the interior of the wall, behind the face stones, tightly packed with smaller stones (**hearting**). These voids should be filled with stones as large as possible (see left) then followed by smaller stones that are also used to pin the building stones so that there is absolutely no wobble. Never pin from the front of the wall as they inevitably fall out. Hearting stones are much better if flat or angular, as rounded stones act like ball bearings. Hearting stones should be packed individually - not randomly thrown in - as the wall is being built, making sure each course is completely hearted before beginning the next course (see left). Not properly hearting a wall allows stones to move independently of one another, resulting in a structurally weak wall that will not last.

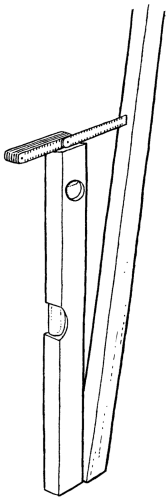
Photo at left shows good hearting.

4. Build within the plane of the wall

This means aligning the stones so that there is an even plane to the faces of the wall. A **batter frame** and string-lines are especially useful and in most instances essential for keeping an even plane to the wall.

The batter frame defines the profile of the wall; for free standing walls the slope is generally about one-in-ten, for retaining walls about two-in-ten, however these dimensions vary with the height of the wall, type of stone and style.

The string-line running between the insides of the batter frames is the 'sacred line' that must not be breached. The outermost 'bump' of each stone should not touch the string-line. The result is a wall that looks smooth and even when you stand back. This applies both in cross section and in each course as the photo on page 5 shows. If a stone protrudes and displaces the string-line it will affect the alignment of all the stones following and the wall will grow steadily wider. Many beginners (and some more experienced wallers) struggle to keep the batter correctly to the string. Two strings about 150 mm apart when aligned from above, make placing the face stones very much easier.



In the accompanying sketch the arm of the batter frame is set to the required angle from vertical. For example, a one-in-ten tilt would be achieved with a 10 cm fall from a 1 m spirit level.

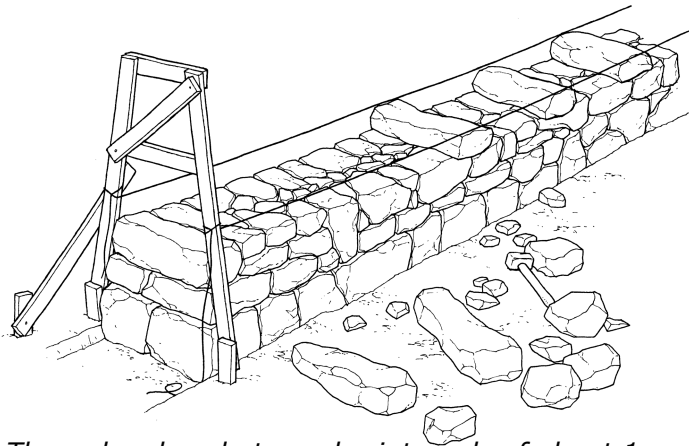


5. Keep courses level

When a wall is built in courses these should be level across and along the length of the wall. This is not always possible along the wall and on gentle slopes the courses can follow the contour of the land, but on more pronounced slopes they should be terraced. This is particularly so when using flat stones but applies to nearly all walls. Stones that are not level will tend to slide causing internal stress in the wall which will eventually fail as it shifts over time. While there are a few local styles and techniques that don't follow this rule (e.g. herringbone and feidin walls), it should generally be followed, particularly when you are learning to build. This rule is essential when building across sloping ground.

Some UK texts suggest laying stone with a slight tilt to shed water. Rarely an issue in Australia with less rainfall and milder frost, tilting slightly inward perpendicular to the batter generally favours stability.

6. Holding the wall together



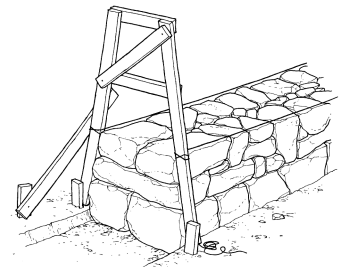
Throughs placed at regular intervals of about 1m

It is important to remember that a wall's real strength comes not from the batter, but from the interlocking of stones and in particular from the **through-stones**. 'Length into the wall' is a fundamental principle of good wall building that is exemplified in the use of through-stones (generally referred to as **throughs**) and in the building of the **cheek-end**. As the name suggests, throughs pass right through the wall from one side to the other and in some cases protrude a few centimetres. Their role is literally to tie the two facades together by friction. Regularly arranged and protruding they can also add aesthetic value, while traditionally their display reassured the wall owner that in fact sufficient throughs had indeed been laid.

Throughs are generally laid in the wall at about half height and spaced about a metre apart, however some high walls might have two courses of throughs. They should be carefully laid to make good contact with stones beneath and above and avoiding running joints. Depending on the rock pile it is not always easy to find sufficient throughs, so they should be assiduously put aside before walling commences and not broken up for building stone.



The end of the wall is referred to as the **cheek-end** and this deserves particular attention, requiring numerous through stones and ties back into the wall. More than a decorative element for the most visible part of the wall, it is reinforcement for the most vulnerable part. Set aside suitable stones of appropriate length with square corners and parallel faces, too valuable for general building.

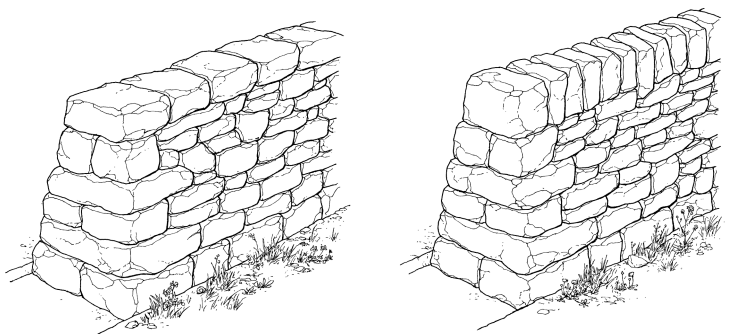


The cheek-end is often battered back, but not if the wall terminates at a post, pillar or other permanent vertical feature.

The top course of stones also contribute greatly to strength and stability. Horizontal **cap-stones** (*below*) are adequate in a domestic setting where walls are not subject to undue disturbance. From a landscaping perspective they also provide a platform for garden ornaments. Again, be on the lookout for suitable large flat stones and put them aside for the purpose. The top course of building stones needs to be uniformly flat to support capping stones neat and firm.



Courtyard with cap stones



Caps stones (l) and cope stones



Walls in paddocks with livestock should – must! – be topped with **cope-stones**. Like throughs, the 'copes' span the wall and tie together the facades. Standing on edge the weight of each stone bears down on a relatively small area and so applies considerable pressure – several times the pressure that would be exerted if the stone was laid flat. When placing the copes, make sure that they do indeed bear down on both sides of the wall, not pivoting on a mid-point, using pinners if necessary. For a neat finish work to a string-line between two equal-height stones about 5 metres apart.

Copes are sometimes set vertically but more often on a slight slope. More important is that any sign of movement should be eliminated with shims between the stones. It is no accident that the most enduring dry stone paddock walls have well placed coping stones.

As with throughs and cheek-ends, copes should be selected from the rock pile before building commences and set out in a row to ensure there are enough when building is complete.



These are just the basic rules for dry stone walling. There is much more to walling, particularly dealing with difficult sites and with difficult stone. There are also challenges in using tools for dressing stone; negotiating changes of slope and changes of direction; features such as steps, seats, stiles and even arches.

Understanding stone

A basic understanding of stone is important if you are to wall efficiently. Some stone is easy to work with, and other stone can be very challenging. Building a wall from paddock stone has its reward in the satisfaction of recognising stone with potential. This is a skill respected by farmers who also like to show that they can 'pick a good dog' or 'find good water'. Paddock stone, by virtue of its random shape and weathered surface, is more difficult to work with than quarry stone with its regular faces and which is often dimensioned (cut to size).

Wall stone can be divided into two basic categories: level bedded and irregular. Level bedded stones have more-or-less parallel top and bottom surfaces, and will often spilt into thinner stones. Slate and shale and sandstone are typically level-bedded stones. Some limestone and schist are also level bedded. Some wallers will also refer to level-bedded stone as regular stone.



Irregular stone accounts for all stone that is not level-bedded. It can be angular or rounded. Irregular stone does not have flat naturally parallel surfaces, and will not usually split. Granite and marble both break into irregular shapes as does some limestone. There is a range from stone that is clearly level bedded (e.g. slate), to stone that is clearly irregular (e.g. basalt). Most stone is somewhere in between. Irregular stone can also be cut, or spilt using feathers and wedges, and some quarries will cut stone to regular shapes. Some limestone (*left*) is relatively soft and can be fairly easily tooled to build tightly jointed walls.



Walls built with level-bedded stone (*above left*) often look neater; irregular stone (*right*) tends to look more rustic. However the skill of the waller and style being built affect this as much as the stone. Walls built with larger stone favour the rustic look; smaller stones look tidier. While you want to build the best wall possible, don't try to force the stones into a character they are not.

Stone comes in all shapes and some can be trimmed (edges or points broken off) to improve their usability. Other difficult stones can be sporadically used throughout the wall, with better stones in between, without adversely affecting the look or structure of the wall. The very worst shaped stones often get smashed up into hearting. It is important to use all the stone in a consistent manner, not just the nice flat stones first then to be left with a bunch of awkward shapes at the top of the wall. This looks poor and often weakens the wall.

Breaking stones is a skill in itself. Each type of stone works differently, some break easily and some don't - layered stone such as slate or schist will often split nicely (*right*). Generally, breaking or shaping stones should be kept to a minimum; your objective is to build a wall, not carve stone. If you are going to work a stone, note that it is always easier to chip corners off a square stone than to make flat sides on a round one.



How a stone is supported often affects how it breaks as does the direction in which it is struck. Often the speed with which the hammer strikes the stone is more important than the apparent force when the hammer strikes the stone. The best way to learn how to break a stone as you want is to practise.

Note how each stone breaks when you hit it: If it does what you want remember that; if not, adjust your technique.

Finding Materials

Buying stone from a quarry or supplier is expensive. Typical costs for nice quarried ledge stone run from \$250 to as much as \$360 a tonne plus delivery. Remember a tonne of stone is not much when it comes to building a wall. Buying stone by the pallet is typically even more expensive unless you are dealing with a very small quantity. However, if you are looking for a very specific type of stone that is not available locally, buying palletised stone may be your best option.

For projects in rural areas stone can often be gathered from other places on the property. Pillaging



from stone fences on roadsides is unacceptable (and in some cases illegal), however there are often stone piles in paddocks. While there is a lot of labour involved to move the stone, the material could be free after asking the owner.

All types and shapes of stone can be used to build a wall and this informs the style and look of the wall. Many people think of thin flat stone as being 'good' and round or irregular stone as being 'bad'. In fact neither is true, they just lend themselves to different looks. Flat stones can be a pain to deal with because it takes so many to build a wall up to finished height and because minor blemishes stand out. Large rounder stones may give a more irregular finish

but can be much faster to build with. Smooth river stone is generally very difficult to work with and to create a strong wall.

Setting Up

Setting up is important to building a wall efficiently. Setting up for rebuilding an old wall involves stripping out the existing wall, and preparing for the foundation.

For a new wall it includes determining how much stone and what type, getting it to the site, and then preparing for the foundation.

Paradoxically a rebuild almost always requires importing additional stone to reach the original height: The Scottish Agricultural Survey of 1820 suggests "one cartload (three to four tons) for each twenty yard rebuild".

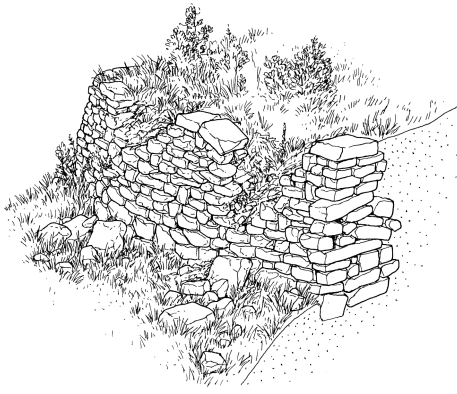
In each case it is important to organise the work site.

Rebuilding an old wall



Rebuilding an old wall typically happens in sections about 3-8 m. Each section will be completely rebuilt before moving on to the next section. Starting on the first section, setting up begins by clearing any brush or debris away on both sides of the wall. Ideally you want reasonably clear ground for about 3-4 m on both sides of the wall.

Once you have clear space, begin disassembling the wall; this is called stripping. Take the time to sort the stones as you strip out as this will speed up the rebuilding. Thicker stones to be used first will be near the wall, and thinner stones farther away. Through



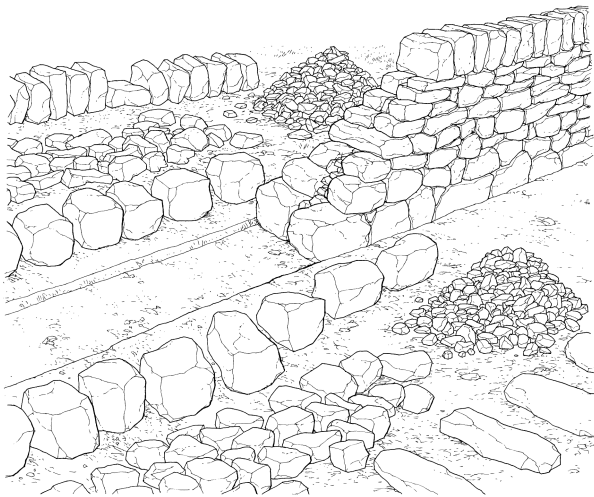
For a free-standing wall stones should be equally distributed on both sides of the wall. Remember to leave a path clear of stones about half a metre wide right along both sides of the wall. This gives you a place to stand. On retaining walls, typically all the stones should be stripped out to the downhill side. Excavated soil, hearting and cope-stones if they are going to be used can be placed on the uphill side.

Generally speaking all the stones should be removed, right down to bare dirt, when stripping out. Remove any roots or organic debris in the foundation and flatten and firmly compact the dirt. Stomping back and forth

several times with your boots is usually sufficient. If the wall is going up a slope, step the foundation so you have level shelves (*see right*). The foundation should typically be 50-100 mm below ground level on the lower side. If the footing stones are excessively large, they can be repositioned one at a time without fully removing them from the wall foundation. Once the stone is sorted and the foundation is prepared, you are ready to set up batter frames, string-lines and begin building.



Building a new wall



Building a new wall begins with preparing a foundation as described above. There should be sufficient access to have the stone delivered right next to where the wall will be built. If not, you will need to figure out a way to get it there. When stone is delivered in a dump truck it leaves a big pile, most stone hidden, sizes all mixed up, and hearting (if there is any) at the bottom.

Sort through the pile before you begin building, starting on one side of the wall and sorting into rows according to thickness, not overall size. As the pile gets sorted the rows get longer. Set this up so that the rows are parallel to the wall, with the thickest ones closest to the wall. Remember to set aside suitable stones for the copes (or caps), throughs and cheek-end.

If you are working from palletised stone (which is usually expensive), open all the pallets and sort through the stone before beginning to build. Some palletised stone is already graded by size in which case sorting is not needed. However, these pallets are often intended for veneer, and lack the large stones you need for through-stones and features.

Determining how much stone you need for a new wall is always a challenge. When buying stone by the tonne, the quarry should be able to tell you the weight of stone you will need. If your wall is an average of 600 mm thick and 1500 mm high, one metre length will represent about 0.9 cubic metres. This could require between 2 and 4 tonne of stone, with considerable variation due to the density of the stone, its regularity and how tightly the stone is stacked in the wall, so this figure is just a starting point.



Relatively high density schist wall (left) and low density granite wall

Tools

The basic tools used in wall building are not many and have remained unchanged for hundreds of years. For stripping out (taking apart an old wall), a shovel, pick and crow-bar are the main tools.

When building, the basic tools are a lump or trimming hammer (pictured), a sledge hammer, a batter frame, and string lines and supports.

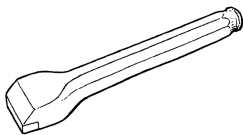


The lump hammer should be 1 to 1.5 kg although some wallers prefer a 2 kg weight. If you are just starting out and on budget, a brick hammer will work but it is too light to be efficient. Do not use carpentry hammers as they may chip when hitting hard stones.

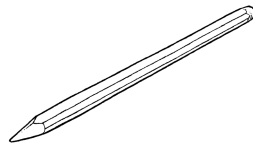
A long handled sledge hammer should weigh about 3-4 kg. Most commonly available sledge hammers have a head that is essentially round which works fine for smashing stones into hearting.

Many wallers also use chisels and points when more controlled shaping is needed. Chisels are great for splitting stones along their natural bedding (with the grain), and can be used for trimming and other breaking. However, while they give you more control, they take more time to use, so most skilled wallers only use them when precise control is needed. Points are like chisels that taper in from all sides to leave a point that can be used for removing high spots.

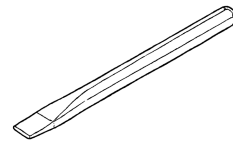
Some hammers and chisels have carbide edges, useful when working with hard stones like granite, however these are expensive and require special grinding wheels to sharpen them, so only worth the investment if you are doing a lot of work with hard stone.



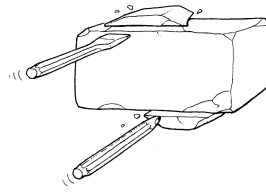
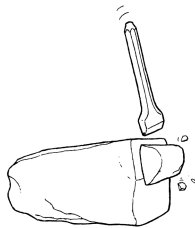
*Pitching chisel
with tungsten
carbide insert*



Pointed chisel



Flat chisel



Batter frames (*right and page 4*) are not exactly tools, but they define the cross-section of the wall. For longer walls the frame should straddle the wall with string lines running from the inner edge of the frame. The frames should be set vertical with a plum bob or spirit level and spaced anything from 5 to 10 metres apart depending on the terrain and how many people are working on the wall. String-lines when taught provide a guide to build to, but they sag if the batter frames are too far apart.



A couple of good videos on wall building:

- www.theguardian.com/money/audioslideshow/2009/aug/07/dry-stone-walling-richard-ingles
- www.youtube.com/watch?V=F0lpjWGclPo

Safety

Dry stone walling does include some elements of risk. By using safety gear, proper techniques, and being safety conscious, you can dramatically reduce the chance of injury.

Safety gear

Appropriate clothing and safety gear are important when walling. Steel-toed boots are important, as it does not take a very large rock to seriously crush a toe.

While some professional wallers prefer to work with bare hands, most wear gloves. Cloth covered gloves with the palm and fingers coated in rubber provide the best combination of protection and dexterity. Different weights are available for different temperatures. Leather gloves provide more protection, but limit dexterity and even the toughest leather gloves only last for about 50 hours when working with stone. Don't be tempted to use expensive builders' gloves as they only last about one day before wearing out.

Eye protection is very important if you are doing any reshaping or cutting, and really should be worn continuously. Invest in a comfortable pair of safety glasses so you are not tempted to take them off. If you are using power tools (drills, saws, etc.) wear ear and eye protection along with anything else instructed by the manufacturer. Breathing stone dust, particularly the fine dust from running dry power saws should be avoided. While limestone-based dust is not directly harmful, silica dust is. Granite, sandstone and related stones are very high in silica so it is important to avoid exposure. If you have to dry-cut stone wear a dust mask.

Practice

- Keep workspace clear of loose stones right along the base of the wall, typically at least half a metre.
- Don't try to lift stones that are too heavy for you and lift with your legs, not your back. If you take your time, you can safely move very heavy stones using levers and ramps.
- Make sure any stone you are putting your hand under is secure. A light stone falling just a few centimetres can seriously crush fingers.
- Try to avoid holding a stone with one hand while pounding on it with a hammer. The vibrations up your wrist can eventually cause problems. Instead prop the stone under your boot, or in such a way that you don't have to hold it at all.
- If working with others make sure you have clear signals and a plan before you lift a heavy stone together. If machinery (tractor, excavator, etc.) is used, agree on hand signals with the operator before you start. When working around lifting equipment, make sure the operator removes his or her hands from the controls before you approach the bucket. Keep well clear of PTO.
- Watch your hands. When you are stripping out or loading stones, keep your eyes on your hands, not on the next stone you are going to move.
- Cap metal stakes or rebar to protect people from being stabbed if they fall on the end.
- Hi-vis socks are helpful if working with others.

Awareness

If you start to think that what you are doing might be unsafe, it probably is. Stop and find a different way to do it. Plan ahead, if you are moving a heavy stone; clear a path before you pick it up. Don't rush or try to 'get away with it this time'; that is when people get hurt.



The wall

Compared with mortared walls, dry stone walls are more resilient to impact and to reactive soils. However they are more vulnerable to vandalism, so that cope-stones and cap-stones are often mortared in public spaces.

Dry stone retaining walls drain well but can be invaded by weeds if not backed with well-packed rubble. Sandy soil might need to be held back with geotextile fabric.

Nearby trees can cause damage from falling limbs, near-to-surface roots moving in high winds or waterlogged soil, and trunks simply expanding.